Minerals yearbook: Metals and minerals (except fuels) 1965. Year 1965, Volume I 1966

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Minerals Yearbook 1965

Volume I of Four Volumes

METALS AND MINERALS (EXCEPT FUELS)

Prepared by staff of the

BUREAU OF MINES

UNITED STATES DEPARTMENT OF THE INTERIOR • Stewart L. Udall, Secretary

BUREAU OF MINES • Walter R. Hibbard, Jr., Director

Created in 1849, the Department of the Interior—a Department of Conservation—is concerned with the management, conservation, and development of the Nation's water, fish, wildlife, mineral, forest, and park and recreational resources. It also has major responsibilities for Indian and Territorial affairs.

As the Nation's principal conservation agency, the Department works to assure that nonrenewable resources are developed and used wisely, that park and recreational resources are conserved for the future, and that renewable resources make their full contribution to the progress, prosperity, and security of the United States—now and in the future.

U.S. GOVERNMENT PRINTING OFFICE
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Foreword

This issue marks the 100th year since the first publication by the Federal Government of a report on the U.S. mineral industries and the 84th year in which the Minerals Yearbook or its predecessors have been issued on an annual basis. The general content of the four-volume edition follows:

Volume I, Metals and Minerals (Except Fuels), contains chapters on metal and nonmetal mineral commodities except mineral fuels. In addition, it includes a chapter reviewing these mineral industries, a statistical summary, and chapters on mining and metallurgical technology, employment and injuries, and technologic trends.

Volume II, Mineral Fuels, contains a chapter on each mineral fuel and on such related products as helium, carbon black, peat, coke and coal chemicals, and natural gas liquids. Also included are data on employment and injuries in the fuel industries and a mineral-fuels review summarizing recent economic and technologic developments.

Volume III, Area Reports: Domestic, contains chapters covering each of the 50 States, the U.S. island possessions in the Pacific Ocean, the Commonwealth of Puerto Rico, the U.S. island possessions in the Caribbean Sea, and the Canal Zone. Volume III also has a statistical summary chapter, identical with that in Volume I, and a chapter on employment and injuries.

Volume IV, Area Reports: International, contains 105 chapters presenting the latest available mineral statistics for more than 130 foreign countries and areas. A separate chapter reviews minerals in the world economy.

The 1965 Minerals Yearbook has been redesigned to achieve a more compact volume and to maximize economy and efficiency in its publication. We believe that the short lines of the text improve readability despite use of the smaller type.

The Bureau of Mines' continuous effort to enhance the Yearbook's value to its wide readership can be aided by constructive comments and suggestions of its users. Such comment is particularly invited during the formative years of the new International review volume.

WALTER R. HIBBARD, JR., *Director*.

Acknowledgments

The Staff of the Division of Minerals prepared this volume except for the three review chapters and that on Employment and Injuries. The preparation and the coordination of chapters with those in other volumes was under the general direction of Paul Yopes, Assistant to the Chief, Division of Minerals. The manuscripts upon which the volume was based were reviewed by a staff under the direction of Kathleen J. D'Amico to insure statistical consistency among the tables, figures, and text between this volume and other volumes, and between this volume and those for former years.

The statistical data of the U.S. mineral industry presented have been collected and compiled by the staff of the Division of Statistics under the direction of Paul W. Icke, Acting Chief, assisted by Albert D. McMahon, Chief, Section of Nonferrous Metals, and James E. Larkin, Acting Chief, Section of Ferrous Metals-Nonmetals; U.S. foreign trade tables were compiled from Bureau of Census data under the direction of Elsie D. Jackson.

World production and foreign trade tables were compiled under the direction of Berenice B. Mitchell, Supervisory Statistical Officer, Division of International Activities, from many sources including data from the Foreign Service, U.S. Department of State.

Figures in the Minerals Yearbook are based largely upon information supplied by mineral producers, processors, and users, and acknowledgment is hereby made of this indispensable cooperation given by industry. Information obtained from individuals through confidential surveys has been grouped to provide statistical aggregates. Data on individual producers are presented only if available from published or other nonconfidential sources, or when permission of the individuals concerned has been granted.

The Bureau of Mines has been assisted in collecting mine-production data and the supporting information appearing in the Minerals Yearbook by more than 40 cooperating State agencies. These organizations are listed in the acknowledgment section of Volume III.

CHARLES W. MERRILL,
Chief, Division of Minerals.

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Review of the Mineral Industries

(Metals and Nonmetals Except Fuels)

By Edward E. Johnson [2] and Phillip N. Yasnowsky [2]

Contents

The U.S. economy boomed in 1965, completing its fifth consecutive year of expansion. Although the advance was somewhat irregular, previous records for production, sales, employment, and income were topped. During the first few months of 1965, as the economy recovered from the depressing effects of the automobile strikes of late 1964, increases were unusually large. The gains moderated in early spring, but were stimulated at midyear by sharply rising capital outlays, excise tax cuts, increased Social Security payments, and accelerated Viet-Nam defense expenditures.

Gross national product (GNP) in current dollars rose $49.5 billion or 7.8 percent, to a total of $681.2 billion. In constant dollars (effects of price changes eliminated), GNP increased 5.9 percent, a rate considerably higher than the historical postwar annual average growth of 3.5 percent. Demand increased in most final markets and was especially strong for business fixed investment and consumption expenditures. With the exception of construction, most of the increases in GNP were real, since prices increased less than 2 percent.

The value of total new structures was a record $52.7 billion, 8 percent higher than in 1964; however, this increase almost entirely reflected increased construction cost rather than increased output. Most of this increased cost was not for raw materials inputs, since the price of nonmetallics, which are used principally by the construction industry, did not increase. The major component of construction — residential building—was the only major component of private domestic investment that did not show a real increase. The 28-billion current dollar investment for residential structures changed little from 1964, but the constant dollar expenditures were 2 percent lower in 1965.

Expanding economic activity in 1965 led to both increased employment and reduction of unemployment. The unemployment rate tended downward throughout the year, falling from a high of 5.0 percent in February to 4.1 percent in December. At yearend, labor shortages in some occupations and industries were common.

The domestic nonfuel mining industry continued to expand in 1965. The Bureau

[1] Some fuels are covered in this chapter but only where specifically indicated and in general where mining-industry data were not available for both nonfuels and fuels components.
[2] Economist.

of Mines index of production increased 3.5 percent, with the largest gains made in monetary and base metals and in chemical nonmetals.

The net supply of most minerals and metals increased, because U.S. production and imports increased. Domestic consumption rose, with molybdenum, manganese ore, bismuth, aluminum, and zinc showing the major gains. With the exception of a few metals, stocks generally declined.

Total nonfuel mining employment increased as a result of a substantial increase in metal mining employment. There was a substantial rise in average annual earnings and in wages and salaries. Wages and salaries in the metal and quarrying and nonmetallic mining industries increased 8 and 9 percent, respectively. The large influx of new workers into the metal mining industry contributed to the decline in labor productivity.

The index of average mine value increased slightly in 1965. The nonferrous metals index increased 10 percent because of higher copper, lead, zinc, and mercury prices. The chemicals index increased, since prices of numerous chemicals were generally higher, especially for phosphate rock and potash. Higher wages and lower productivity caused the indexes of relative cost and metal mining to increase.

National income originating in the mining industry increased 8 percent in 1965. Although total profits were higher, higher costs have begun to reduce the ratio of profits to sales.

Total expenditures on new plants and equipment for the mining industry increased substantially in 1965. The expenditures for new plants and equipment in the primary nonferrous metals industry increased 42 percent. Because of higher sales and profits, the mining industry was able to finance more of their operations from internally generated funds.

U.S. foreign investment increased, while world demand continued strong. U.S. foreign investment policy was guided by the U.S. Government's program of voluntary restraint designed to improve the U.S. balance of payments deficit. Higher incomes from foreign affiliates, greater use of internal funds, and greater percentage of funds obtained abroad helped strengthen the U.S. balance of payments position.

In an attempt to insure a continuously advancing mineral industry, Bureau of Mines obligations of funds for fiscal 1966 were increased 11 percent. The Bureau's research is directed at developing the capability to solve production and consumption problems before they become critical. In 1965, the Bureau of Mines research made significant contributions in upgrading low-grade phosphorous-bearing shales and in developing an economic process to upgrade nonmagnetic taconites by using recovered steel from junked auto bodies.

There were several large disposals of stockpile material in 1965. Releases from the Atomic Energy Commission (AEC) inventory and the establishment of stockpile objectives for silver were first made in 1965. Stockpile releases were used as a means to increase supply and restrain prices. Large amounts of copper, zinc, nickel, and mercury were released. The Office of Minerals Exploration continued to encourage exploration to locate new domestic sources of essential materials by providing financial assistance. Government assistance programs continued to be dominated by gold and silver.

The world economy, stimulated by U.S. demand, continued to expand, but at a slower rate than in previous years. World consumption of aluminum, copper, lead, and zinc increased. The world stocks of aluminum and tin declined; copper, lead, and zinc stocks increased.

Stimulated by the strong demand from the industrial nations for more raw materials, world trade increased. Trade patterns began to shift in response to new sources of supply, erratic import supply, reduction of trade barriers, and administratively higher export prices.

DOMESTIC PRODUCTION

Value of Mineral Production.—The 4.5-percent increase in the value of U.S. mineral production (metals, nonmetals, and fuels) in current dollars established a record high and continued the upward trend which started in 1959. In 1965, metals showed the greatest increase, 9.3 percent, largely the result of higher prices and greater sales. Gains made by nonmetals and fuels were 6.3 percent and 3.1 percent, respectively.

Value of Mineral Production in 1957-59 Constant Dollars.—The value of mineral production in constant dollars increased 3.8 percent, slightly lower than the current-dollar equivalents. This indicated a slight increase in the price of all minerals. The largest price increases occurred in metals where the constant dollar value increased 5.2 percent, whereas nonmetals and fuels showed little evidence of price increases in 1965.

1965 continued to be a good year for domestic production. As the economy continued to expand, the greater need for basic raw materials resulted in the record production of many mineral commodities. The Bureau of Mines index of physical volume showed an increase of 3.5 percent in 1965, establishing a new high. The metals index rose 3.2 percent, featured by a 7.9-percent increase of the base metals index, a 14.1-percent increase of the monetary index, and a 14.3-percent decline of the other nonferrous metals index. The base metals increase resulted from higher production of copper, lead, and zinc; the decline of the other nonferrous metals index was mostly due to lower outputs of uranium, platinum, ilmenite, and zirconium.

The production of nonmetals increased 5.7 percent, with major gains in chemicals. As a result of substantial production increases for most chemicals, the nonmetals chemical index increased 13.2 percent.

Volume of Mineral Production.—The Bureau of Mines index of physical volume of mineral production has been reweighted using 1957–59 average prices as weights rather than 1947–49 average prices. The new relative weights of the index as compared with the old weights are—

	Percent of total	
	1947–49	*1957–59*
Metals	9.57	9.01
Ferrous	3.95	4.46
Nonferrous	5.62	4.55
Base	4.43	3.04
Monetary	.90	.52
Other	.29	.99
Nonmetals	10.78	20.87
Construction	7.24	16.29
Chemicals	2.81	3.56
Other	.73	1.02
Fuels	79.65	70.12
Total minerals	100.00	100.00

The greatest shift in the relative weights was between nonmetals and fuels. The relative weight of nonmetals increased as a result of extended coverage, relative price changes, and greater production.

The Federal Reserve Board (FRB) mining indexes showed similar upward trends. Before the Bureau of Mines index was revised, the total FRB mining index moved similarly to the total Bureau index of mining; but there were often rather large discrepancies between the movements of the nonmetals sections of the indexes. The FRB index of nonmetals had a tendency to change at a faster rate than the Bureau of Mines nonmetals index. The 1957–59 weight revision, which increased the relative weight of nonmetals in the Bureau of Mines nonmetals index, greatly reduced this disparity.

The FRB index of basic mineral manufacturing indicated the following gains in 1965: 6.5 percent for primary metals; 5.6 percent for iron and steel; 10.0 percent for nonferrous metals and products; and 6.0 percent for clay, glass, and stone products. Total industrial production in 1965 increased 8.3 percent and reached another alltime high.

Table 1.—Value of mineral production in the United States by mineral group [1]
(Millions)

Mineral groups [2]	1961	1962	1963	1964 [r]	1965	Change in 1965 from 1964 (percent)
Metals and nonmetals except fuels:						
Nonmetals	$3,946	$4,117	$4,318	$4,623	$4,916	+6.3
Metals	1,927	1,937	2,002	2,261	2,472	+9.3
Total	5,873	6,054	6,320	6,884	7,388	+7.3
Mineral fuels	12,357	12,784	13,295	13,623	14,045	+3.1
Grand total	18,230	18,838	19,615	20,507	21,433	+4.5

[r] Revised.
[1] Includes Alaska and Hawaii.
[2] For details see table 2 in the chapter "Statistical Summary" of this volume.

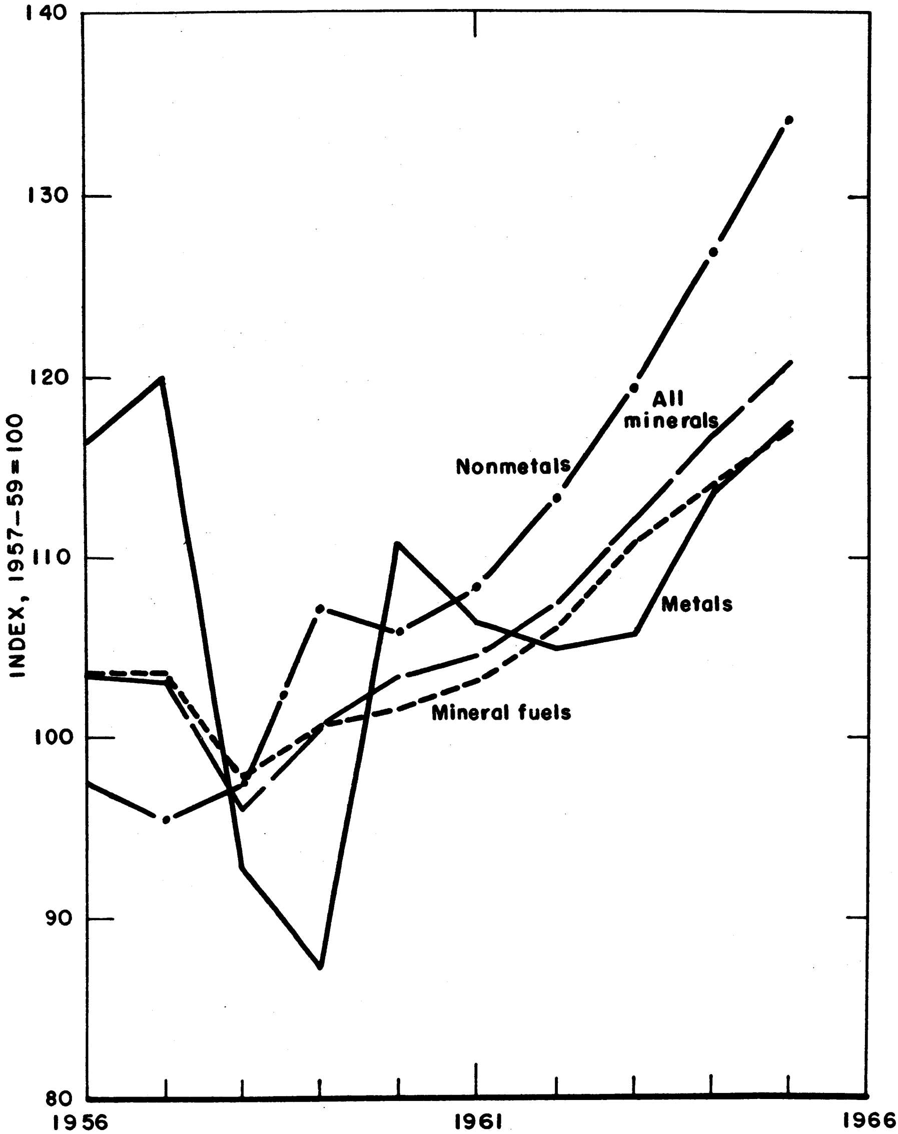

Figure 1.—Indexes of physical volume of mineral production in the United States, by groups.

Table 2.—Value of mineral production in the United States, by mineral group, 1957–59 constant dollars [1]

(Millions)

Year	Nonmetals (except fuels)	Metals	Nonfuel total	Mineral fuels	Total minerals
1961	$3,930	$1,875	$5,805	$12,296	$18,101
1962	4,129	1,870	5,999	r 12,632	r 18,631
1963	4,366	r 1,877	r 6,243	13,189	r 19,432
1964 r	4,665	1,973	6,638	13,596	20,234
1965	4,966	2,076	7,042	13,961	21,003

r Revised.

[1] Values were deflated by the index of implicit unit value.

Table 3.—Indexes of the physical volume of mineral production in the United States, by groups and subgroups [1]

(1957–59=100)

Year	All minerals	Metals: Total	Metals: Ferrous	Metals: Nonferrous: Total	Metals: Nonferrous: Base	Metals: Nonferrous: Monetary	Metals: Nonferrous: Other	Nonmetals: Total	Nonmetals: Construction	Nonmetals: Chemical	Nonmetals: Other	Fuels
1956	103.4	116.3	126.0	106.8	115.9	108.6	77.5	97.5	95.3	104.2	108.5	103.5
1957	103.3	120.0	132.8	107.5	113.7	106.8	88.6	95.4	94.2	99.7	100.1	103.5
1958	96.0	92.8	87.3	98.2	99.5	100.7	93.0	97.5	98.1	95.5	93.9	96.0
1959	100.7	87.2	79.9	94.3	86.8	92.6	118.4	107.1	107.6	104.8	106.0	100.5
1960	103.3	110.8	109.0	112.5	107.5	94.6	137.2	105.8	105.4	107.6	106.0	101.6
1961	104.5	106.4	96.2	116.3	114.3	94.0	134.2	108.3	108.2	110.5	103.4	103.1
1962	107.4	105.0	90.4	119.3	120.9	95.7	126.8	113.3	113.6	114.2	105.8	106.0
1963	112.2	105.7	95.8	115.5	120.8	90.8	112.2	119.4	119.6	120.5	111.6	110.8
1964	116.7	113.9	108.3	119.4	125.8	92.0	114.3	126.9	126.2	132.1	119.0	114.0
1965	120.8	117.5	110.8	124.0	135.8	105.0	97.9	134.2	131.2	149.6	127.9	117.3

[1] Reweighted using 1957–59 weights. For description of index see Bureau of Mines Minerals Yearbook 1956, v. 1, pp. 2–5.

Table 4.—Federal Reserve Board index of production, mining and selected mineral related industries

(1957–59=100)

Year	Mining	Coal, oil, and gas	Metal, stone, and earth minerals	Metal mining	Stone and earth minerals	Primary metals	Iron and steel	Nonferrous metals and products	Clay, glass, and stone products	Total industrial production
1961	102.6	100.9	110.5	111.9	109.4	98.9	96.5	107.5	106.3	109.8
1962	105.0	100.8	110.9	112.6	109.7	104.6	100.6	119.1	111.1	118.3
1963	107.9	107.0	112.2	112.3	112.1	113.3	109.6	126.7	117.5	124.3
1964	111.3	109.8	118.1	117.4	118.7	129.1	126.5	138.3	126.0	132.3
1965 p	114.4	112.2	124.8	122.6	126.5	137.5	133.6	152.1	133.5	143.3

p Preliminary.

Source: Federal Reserve System, Industrial Production 1957–59 Base, 1962, 172 pp. Federal Reserve System, Federal Reserve Bulletin, February 1964, pp. 224–225; February 1965, pp. 301–311; February 1966, p. 259; April 1966, p. 589.

Table 5.—Federal Reserve Board monthly indexes of mining production, seasonally adjusted

(1957–59=100)

Month	Mining[1]			Metal, stone, and earth materials			Metal mining			Stone and earth materials		
	1964	1965	Change from 1964 (percent)	1964	1965	Change from 1964 (percent)	1964	1965	Change from 1964 (percent)	1964	1965	Change from 1964 (percent)
January	108.8	111.8	+2.8	114.7	123.3	+ 7.5	116.4	126.7	+ 8.8	113.5	120.8	+ 6.4
February	108.9	111.8	+2.7	116.4	123.1	+ 5.8	118.8	123.4	+ 3.9	114.7	122.9	+ 7.1
March	108.8	112.5	+3.4	117.0	124,3	+ 6.2	119.8	124.6	+ 4.0	115.0	124.1	+ 7.9
April	109.9	113.0	+2.8	118.5	121.4	+ 2.4	124.2	125.8	+ 1.3	114.3	118.2	+ 3.4
May	111.3	114.0	+2.4	117.9	122.9	+ 4.2	119.4	121.6	+ 1.8	116.8	123.9	+ 6.1
June	111.4	115.3	+3.5	119.2	124.9	+ 4.8	119.2	123.7	+ 3.8	119.2	125.8	+ 5.5
July	111.7	116.0	+3.8	114.9	126.9	+10.4	107.8	126.4	+17.3	120.2	127.3	+ 5.9
August	112.1	117.0	+4.4	117.6	129.6	+10.2	112.1	130.2	+16.1	121.7	129.1	+ 6.1
September	112.2	112.6	+ .4	116.0	125.3	+ 8.0	111.1	122.4	+10.2	119.6	127.4	+ 6.5
October	112.0	115.8	+3.4	117.9	121.7	+ 3.2	115.4	116.5	+ 1.0	119.7	125.5	+ 4.8
November	112.8	116.0	+2.8	125.1	125.1	---	126.6	114.2	− 9.8	123.9	133.2	+ 7.5
December	112.5	117.9	+4.8	122.7	130.7	+ 6.5	121.8	120.6	− 1.0	123.4	138.2	+12.0
Annual average	111.3	p 114.4	+2.8	118.1	p 124.8	+ 5.7	117.4	p 122.6	+ 4.4	118.7	p 126.5	+ 6.6

p Preliminary.
[1] Including fuels.

Source: Federal Reserve System, Industrial Production Indexes, Federal Reserve Bulletin, March 1965, p. 477; June 1965, p. 875; September 1965, p. 1327; November 1965, p. 1597; February 1966, p. 257; March 1966, p. 401; May 1966, p. 713.

NET SUPPLY

The net supply of most minerals and metals increased in 1965. As a result of the general rise in U.S. production and imports, only tungsten ore, cadmium, mercury, ilmenite, uranium concentrate, asbestos, gypsum, and talc showed declines of net supply.

With a few exceptions, there were no radical changes in the relative shares of the components of supply from 1964 to 1965. Reliance upon foreign sources for mercury and uranium declined considerably; there was a substantial increase in domestic shipments of uranium and in secondary production of mercury. The secondary production included 29,753 flasks which were disposed of from the AEC inventory by the General Services Administration. Moderate changes were evident in copper, nickel, tungsten, and potash.

Canada and Mexico continued to be the major sources of mineral imports. However, the United States remained heavily dependent upon South America for copper, tin, and tungsten. Imports of mercury, magnesia, natural abrasives, and talc came mainly from Europe, and Oceania continued to be the principal foreign supplier of thorium, titanium, zirconium, and uranium. Asia supplied the major share of mica and Africa furnished almost half of the imports of chrome and antimony.

CONSUMPTION

Patterns.—Domestic consumption of most minerals and mineral products rose above the 1964 totals; some exceptions were iron ore, titanium concentrates, uranium, and asbestos. Substantial gains were made by some commodities in each of the three major sections. Because 1965 was a year of rapid economic expansion, many of the percentage increases between 1964 and 1965 were higher than the projected average annual growth rate.

For the ferrous metals group the largest rises were a 21-percent increase in molybdenum and a 28-percent increase in manganese ore. Iron ore consumption declined, but consumption for the remainder of the ferrous group made notable gains.

Consumption of nonferrous metals increased substantially; however, that of titanium concentrates and uranium declined. The largest percentage increases were for bismuth, aluminum, and zinc which increased 36, 16, and 13 percent, respectively.

The consumption of each nonmetal shown in table 8 increased more than 4 percent with the exception of asbestos and cement. The consumption of asbestos declined 2 percent, while the consumption of cement increased slightly more than 1 percent. Notable increases in the consumption of nonmetals were as follows: Phosphate rock, 18 percent; salt, 9 percent; crushed stone, 8 percent; and potash, 7 percent.

Estimated 1975 Consumption.—The projections for U.S. consumption of major mineral products in 1975 were made by using a postwar period trend analysis between commodity consumption and associated economic and related factors such as population, labor force, and construction activity.

The projected consumption figures for 1975 must not be regarded as predictions and will change when assumptions about future economic activities change. In 1965, the estimates for projected 1975 consumption of sulfur and copper were increased because the current consumption patterns for these industries indicated that a revision was necessary.

Shipments and Orders.—In 1965, shipments of all primary metals increased. Net new orders for the primary metals and blast furnace industries declined, while new orders for all other primary metals industries increased. Unfilled orders at yearend for primary metals and blast furnaces declined, but unfilled orders for other primary metals increased.

Table 6.—Net supply of principal minerals in the United States and components of gross supply [1]

Commodity	Net supply: Thousand short tons unless otherwise stated 1964	Net supply: Thousand short tons unless otherwise stated 1965	Net supply: Change from 1964 (percent)	Components as a percent of gross supply (gross supply = 100): Primary shipments [2] 1964	Primary shipments [2] 1965	Secondary production [3] 1964	Secondary production [3] 1965	Imports [4] 1964	Imports [4] 1965	Exports as a percent of gross supply 1964	Exports as a percent of gross supply 1965
Ferrous ores, scrap, and metal:											
Iron (equivalent) [5]	118,585	125,927	+6	46	44	[6] 30	[6] 31	24	25	4	4
Manganese (content)	997	1,244	+25	4	4	--	--	[7] 96	[7] 96	1	2
Chromite (Cr_2O_3 content)	643	682	+6	--	--	--	--	100	100	([8])	([8])
Cobalt (content) ... thousand pounds	[9] 12,591	[9] 15,495	+23	W	W	[10] 1	[10] 1	99	99	([8])	([8])
Molybdenum (content) ... do	37,705	52,053	+38	100	100	--	--	([8])	([8])	42	33
Nickel (content)	r 163	192	+18	r 10	9	r 11	6	r 79	85	([11])	([11])
Tungsten ore and concentrate (W content) ... short tons	r 6,079	5,831	−4	r 72	65	--	--	r 28	35	1	([8])
Other metallic ores, scrap, and metals:											
Copper (content)	r 1,666	1,705	+2	r 63	66	r 24	25	r 13	9	r 16	17
Lead (content)	r 1,161	1,220	+5	r 24	25	46	47	29	29	1	1
Zinc (recoverable content)	r 1,015	1,185	+17	r 55	51	r 7	7	r 38	42	3	([8])
Aluminum (equivalent) [12]	2,809	3,182	+13	10	10	4	5	86	86	10	8
Tin (content) ... long tons	r 48,336	57,546	+19	W	--	27	25	73	75	5	4
Antimony (recoverable content) [13] ... short tons	r 40,211	40,901	+2	4	4	54	59	[7] 42	[7] 36	2	([8])
Beryl ore (BeO content) ... do	597	857	+44	W	W	--	--	100	100	([8])	([8])
Cadmium (content) [14] ... do	r 5,745	5,095	−11	34	32	([15])	([15])	66	68	r 1	1
Magnesium (content) ... do	r 77,556	79,693	+3	r [16] 85	[16] 83	r 13	14	2	3	r 17	18
Mercury ... 76-pound flasks	r 78,884	73,975	−6	18	24	30	56	52	20	r 8	9
Platinum-group metals ... thousand troy ounces	r 897	1,208	+35	r 4	3	r [17] 12	[17] 8	r 84	89	r 14	8
Titanium concentrate:											
Ilmenite and slag (TiO_2 content)	r 645	606	−6	r 82	82	--	--	r 18	18	--	--
Rutile (TiO_2 content)	112	142	+27	9	W	--	--	91	100	2	1
Uranium concentrate (U_3O_8 content) ... short tons	17,144	13,092	−24	69	80	--	--	31	20	--	--
Nonmetals:											
Asbestos	r 813	795	−2	12	14	--	--	88	86	[18] 3	[18] 5
Barite, crude	r 1,430	1,564	+9	58	54	--	--	42	46	--	--
Bromine (bromine content) ... million pounds	238	275	+16	([11])	([11])	([11])	([11])	([11])	([11])	([11])	([11])
Clays	r 52,236	54,348	+4	100	--	--	--	([8])	([8])	2	2
Fluorspar, finished	r 901	1,048	+16	r 24	23	--	--	r 76	77	([8])	1
Gypsum, crude	r 16,701	15,918	−5	63	63	--	--	37	37	([8])	([8])
Mica (except scrap) ... thousand pounds	10,834	13,998	+29	2	5	--	--	98	95	5	5
Phosphate rock (P_2O_5 content) ... thousand long tons	5,123	6,028	+18	99	99	--	--	1	1	26	26
Potash (K_2O equivalent)	r 3,164	3,391	+7	80	73	--	--	20	27	16	16
Salt (common)	r 33,290	36,409	+9	93	94	--	--	7	6	2	2
Sulfur, all forms (content) [19] ... thousand long tons	r 7,086	7,964	+12	r 82	85	--	--	r 18	15	r 21	25
Talc and allied minerals	824	789	−4	97	98	--	--	3	2	8	8
Crushed and broken stone	r 721,563	776,431	+8	100	100	--	--	([8])	([8])	([8])	([8])
Sand and gravel	r 868,692	908,743	+5	100	100	--	--	([8])	([8])	([8])	([8])

r Revised. W Withheld to avoid disclosing individual company confidential data. Figure is not included in net and gross supply.

[1] Net supply is sum of primary shipments, secondary production, and imports minus exports. Gross supply is total before subtraction of exports.

[2] Primary shipments are mine shipments or mine sales (including consumption by producers) plus byproducts production. Shipments more nearly represent quantities marketed by domestic industry and as such are more comparable to imports. Use of shipment data rather than production data also permits uniform treatment among more commodities.

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[3] From old scrap only.
[4] Imports for consumption except where otherwise indicated; scrap is excluded wherever possible in both imports and exports, but all other sources of minerals through refined or roughly comparable stage are included except when commodity description indicates earlier stage. Exports of foreign merchandise (re-exports), if any, are included when imports are general.
[5] Iron ore reduced to estimated pig iron equivalent; reported weights used for all other items of supply.
[6] Receipts of purchased scrap.
[7] General imports; corresponding exports are of both domestic and foreign merchandise.
[8] Less than ½ unit.
[9] Sum of secondary production and imports only.
[10] Consumption of purchased scrap.
[11] Mostly imports or exports not classified separately or consisting of manufactured products or scrap; therefore, impossible to determine net mineral content of commodity.
[12] Calculated from the percentage of bauxite mine production (rather than shipments): bauxite imports, and alumina imports used in producing aluminum metal, and converted to aluminum equivalent. Some duplication occurs because of small quantities of loose scrap imported, which is also reflected in secondary production. To avoid a duplicate adjustment for nonmetallic use, exports of bauxite to Canada were excluded from exports.
[13] Based on recovery from all forms as byproducts from domestic and foreign sources.
[14] Primary shipments are calculated as a percentage of total primary production of metal, because part of the domestic primary output is recovered from foreign raw material sources. The quantities recovered from imported raw materials plus imports of cadmium metal are accounted for under imports. Exports exclude flue dust, dross, and residues.
[15] Secondary statistics are included in the primary statistics to avoid disclosing company data.
[16] Primary production of metal.
[17] Recovery from old and new scrap.
[18] Reexports included.
[19] Includes sulfur content of pyrites production.

Table 7.—Percentage distribution of imports of principal minerals consumed in the United States, by area of origin in 1965

SITC code	Commodity	North America	South America	Europe	Asia	Africa	Oceania	Soviet bloc[1]
2713000	Phosphates, crude and apatite	87	--	--	13	--	--	--
2732100	Gypsum	99	--	1	--	--	--	--
2743000	Sulfur	100	--	(2)	(2)	--	--	--
2752400	Natural abrasives	1	(2)	94	2	3	(2)	--
2762220, 2762240	Graphite, natural	35	--	28	14	23	--	--
2762520, 2762540	Magnesia, refractory, caustic-calcined, and crude	2	--	83	14	(2)	1	--
2763000	Salt	93	--	2	--	5	--	--
2764010, 2764020, 2764030, 2764040, 2764050, 2764060	Asbestos	86	(2)	1	--	13	(2)	(2)
2765210, 2765230, 2765250	Mica, including scrap	(2)	26	1	67	6	--	--
2765420	Fluorspar	75	--	22	3	(2)	--	--
2768300	Barite, crude	49	20	22	1	8	--	--
2768500	Talc	7	--	79	14	--	--	(2)
2810000	Iron ore and concentrates	60	35	(2)	(2)	5	(2)	--
2820000	Iron and steel scrap	82	--	14	1	3	(2)	--
2831110	Copper	6	84	--	1	8	1	--
2833020, 2833040	Bauxite	77	23	--	--	--	--	--
2834000	Lead ores and concentrates	35	28	--	(2)	18	19	--
2835000	Zinc ores and concentrates	73	19	(2)	(2)	7	1	--
2836000	Tin ores and concentrates	--	100	--	--	--	--	--
2837020, 2837040	Manganese ores and concentrates	3	49	(2)	6	42	--	--
2839120, 2839140, 2839160	Chrome ores	--	--	--	34	47	--	19
2839200	Tungsten ores and concentrates	19	52	1	10	8	10	--
2839310	Tantalum, molybdenum, and vanadium ores and concentrates	9	25	10	8	47	1	--
2839320, 2839330	Titanium ores	17	--	--	--	--	83	--
2839340	Zirconium ores	2	--	(2)	--	--	98	--
2839810	Antimony ores and needles	15	36	(2)	4	45	--	--
2839820	Beryllium ores and concentrates	--	18	4	26	33	19	--
2839830	Columbium ores and concentrates	48	--	3	--	49	--	--
2840200	Copper waste and scrap	38	57	1	2	1	1	--
2840300	Nickel waste and scrap	56	(2)	43	1	--	(2)	--
2840400	Aluminum waste and scrap	41	(2)	21	25	(2)	1	12
2840500	Magnesium waste and scrap	53	--	40	4	2	1	--
2840600	Lead waste and scrap	97	(2)	(2)	2	--	1	--
2840700	Zinc waste and scrap	100	--	--	--	--	--	--
2840900	Tin waste and scrap	100	--	(2)	(2)	--	--	--
2850000	Platinum group metals, ores, concentrates, and waste	47	1	25	(2)	13	14	--
2860000	Uranium and thorium ores and concentrates	--	3	--	35	3	59	--
5132500	Mercury, including waste and scrap	7	5	88	(2)	--	--	--
5136530, 5136550	Alumina	26	15	2	30	27	--	--

[1] U.S.S.R., Bulgaria, East Germany, Albania, Czechoslovakia, Hungary, Poland, Rumania, China, North Korea, North Viet-Nam.
[2] Less than ½ unit.

STOCKS

Indexes of Stocks.[3]—The Bureau of Mines index of yearend primary producers stocks declined more than 3 percent in 1965. The 13-percent decrease in the nonmetals index more than offset the 12-percent gain in the metals index. The index of stocks of iron ore increased 18 percent, however other ferrous and nonferrous stock indexes declined in response to the generally declining stocks of tungsten, mercury, bauxite, and titanium concentrates. The decline in the nonmetals index was caused by the 23-percent decline of sulfur stocks.

[3] Johnson, Edward E. Index Numbers for the Mineral Industries. BuMines Inf. Circ. 8275, 1965, 85 pp.

Table 8.—U.S. consumption of major mineral products, 1964, 1965, and projections for 1975

Commodity	1964	1965	Average annual growth rate 1947–64 (percent)	1975 projection	Projected average annual growth rate 1964–75 (percent)
Ferrous:					
Iron ore ... thousand long tons	132,328	125,861	+0.6	164,000	+2.0
Pig iron ... thousand short tons	86,382	88,945	+1.2	104,800	+1.8
Steel ingot [1] ... do	127,000	131,000	+1.2	158,000	+2.0
Ferrous scrap ... do	84,626	90,359	+.7	105,300	+2.0
Chromite ores (gross weight):					
Metallurgical grade ... do	832	907	+4.0	1,750	+7.0
Refractory grade ... do	430	457	+.6	570	+2.6
Chemical grade ... do	[r] 189	217	+1.7	235	+2.1
Manganese ore (35 percent or more Mn) ... do	2,242	2,866	+1.4	3,090	+3.0
Molybdenum (contained Mo) ... thousand pounds	56,409	68,112	+5.0	87,800	+4.1
Tungsten (W content) ... do	12,311	13,868	+3.3	16,870	+2.9
Nonferrous:					
Aluminum [2] ... thousand short tons	3,216	3,736	+7.3	5,980	+5.8
Bauxite, dry equivalent ... thousand long tons	12,546	13,534	+9.8	27,550	+7.4
Antimony, primary ... short tons	15,839	16,919	−1.9	27,850	+5.3
Bismuth ... thousand pounds	2,160	2,932	[3] +1.5	2,440	+1.1
Copper, primary and old ... thousand short tons	[r] 1,969	2,039	+.1	[r] 2,300	[r] +1.5
Lead, primary and secondary ... do	[r] 1,202	1,241	−.2	1,610	+2.7
Zinc, all classes ... do	1,536	1,742	+.9	2,150	+3.1
Mercury ... 76-pound flasks	82,608	76,454	+3.3	104,000	+2.1
Platinum-group metals ... thousand troy ounces	1,140	1,187	+6.9	2,570	+7.7
Silver, industry and the arts ... do	[r] 123,000	137,000	[4] +.4	155,000	+2.0
Titanium, ilmenite including Ti slag (est. TiO_2 content) ... short tons	602,921	588,485	+5.1	1,220,500	+6.6
Uranium (U_3O_8 content) [1] ... do	11,847	10,442	[5] +8.5	[6] 8,900–14,000	−2.6 to +1.6
Nonmetals:					
Asbestos [2] ... thousand short tons	813	795	+.7	870	+.6
Cement [1] ... million barrels	377	382	+3.8	660	+5.2
Clays [2] ... thousand short tons	[r] 52,947	55,092	+2.1	65,740	+2.1
Lime [7] ... do	[r] 16,089	16,794	+5.2	27,360	+4.9
Phosphate rock [2] ... thousand long tons	16,546	19,523	+4.7	27,200	+4.6
Potash (K_2O content) [2] ... thousand short tons	[r] 3,164	3,891	+6.3	6,250	+6.4
Salt [2] ... do	[r] 33,290	36,409	+4.4	53,950	+4.5
Sand and gravel [7] ... million short tons	868	908	[8] +4.3	1,800	+6.8
Stone, crushed ... do	723	778	+3.3	1,500	+6.9
Sulfur, all forms [2] ... thousand long tons	[r] 7,260	7,959	+2.7	[r] 12,500	[r] +5.3

[r] Revised.
[1] Production.
[2] Apparent consumption.
[3] Growth rate 1951–1964.
[4] Growth rate 1947–1963.
[5] Growth rate 1956–1964.
[6] Faulkner and McVey, U.S. Atomic Energy Commission. Fuel Resources and Availability for Civilian Nuclear Power for 1964–2000, table 4. See 1963 Review Chapter.
[7] Sold or used.
[8] Growth rate 1954–1964.

Table 9.—Shipments, net new orders and yearend unfilled orders for selected mineral processing industries

(Millions)

Year and month	Shipments [1]			Net new orders [1]			Unfilled orders at end of period		
	Primary metals	Blast furnaces	All other primary metals [2]	Primary metals	Blast furnaces	All other primary metals [2]	Primary metals	Blast furnaces	All other primary metals [2]
1961	$31,659	$17,381	$14,278	$33,107	$18,816	$14,291	$5,129	$3,501	$1,628
1962	34,016	18,264	15,752	32,619	16,790	15,829	3,761	2,057	1,704
1963	35,325	19,033	16,292	35,508	19,104	16,404	3,930	2,120	1,810
1964	38,832	21,236	17,596	r 41,308	r 23,303	r 18,005	6,559	4,311	2,248
1965	41,910	22,916	18,994	41,017	21,378	19,639	5,646	2,730	2,916
1965:									
January	3,455	1,976	1,479	3,739	2,232	1,507	6,656	4,387	2,269
February	3,456	1,979	1,477	3,802	2,291	1,511	7,073	4,759	2,314
March	3,629	2,086	1,543	3,593	2,018	1,575	7,058	4,720	2,338
April	3,796	2,245	1,551	3,456	1,876	1,580	6,683	4,351	2,332
May	3,435	1,835	1,600	3,286	1,632	1,654	6,569	4,148	2,421
June	3,389	1,820	1,569	3,454	1,816	1,638	6,637	4,144	2,493
July	3,782	2,170	1,612	3,493	1,851	1,642	6,348	3,825	2,523
August	3,708	2,105	1,603	3,119	1,465	1,654	5,760	3,185	2,575
September	3,237	1,652	1,585	2,908	1,276	1,632	5,431	2,809	2,622
October	3,204	1,608	1,596	3,148	1,451	1,697	5,375	2,653	2,722
November	3,335	1,681	1,654	3,392	1,635	1,757	5,432	2,606	2,826
December	3,470	1,730	1,740	3,684	1,854	1,830	5,646	2,730	2,916

r Revised.
[1] Monthly figures are seasonally adjusted and do not add to totals.
[2] All other primary metals can be obtained by subtracting blast furnaces from primary metals.

Sources: U.S. Department of Commerce, Bureau of the Census. Manufacturers' Shipments, Inventories, and Orders: 1947–1963. Revised, series M 3–1, October 1963, pp. 31–37, 44–48. U.S. Department of Commerce, Office of Business Economics. Survey of Current Business. V. 45, No. 3, March 1965, pp. S–5, S–6; v. 46, No. 3, March 1966. pp. S–5, S–6.

The index of yearend stocks held by mineral manufacturers, consumers, and dealers did not change from 1964.

The nonmetals segment of the index declined 11 percent, largely because of the substantial decline in cement and importer stocks of fluorspar.

Value of Inventories.—The value of seasonally adjusted inventories held by firms in the primary metals industry was 4 percent higher than in December 1964. The blast furnace and steel mill inventories decreased 1 percent, while the value of other primary metals inventories increased 11 percent. Inventories of stone, clay, and glass products increased more than 2 percent.

Table 10.—Index of stocks of mineral manufacturers, consumers, and dealers at yearend

(1957–59=100)

Yearend	Total metals and nonmetals [1]	Metals: Total	Metals: Iron	Metals: Other ferrous	Metals: Base nonferrous	Metals: Other nonferrous	Nonmetals
1961	103	102	99	98	98	126	120
1962	100	99	98	90	101	104	128
1963	95	93	91	85	97	r 96	r 128
1964	r 89	r 87	85	72	88	r 97	r 130
1965	89	88	84	72	92	96	116

[1] Excludes fuels.
r Revised.

Table 11.—Index of stocks of crude minerals at mines or in hands of primary producers at yearend

(1957–59=100)

Yearend	Metals and nonmetals [1]	Metals: Total	Metals: Iron ore	Metals: Other ferrous	Metals: Nonferrous	Nonmetals
1961	121	134	r 147	63	r 168	115
1962	124	147	r 165	73	149	113
1963	r 122	r 141	r 157	69	r 153	113
1964	r 114	r 133	r 153	44	r 147	r 105
1965	110	149	180	41	128	91

r Revised.
[1] Excludes fuels.

Table 12.—Seasonally adjusted book value of inventories for selected mineral processing industries

(Millions)

End of year or month	Stone, clay, and glass products	Primary metals: Blast furnaces, steel mills	Primary metals: Other primary metals	Primary metals: Total
1961: December	$1,468	$3,691	$2,286	$5,977
1962: December	1,492	3,528	2,345	5,873
1963: December	1,544	3,533	2,385	5,918
1964: December	1,587	3,707	2,404	6,111
1965:				
December	1,626	3,678	2,671	6,349
January	1,595	3,744	2,417	6,161
February	1,595	3,717	2,436	6,153
March	1,593	3,618	2,453	6,071
April	1,606	3,427	2,473	5,900
May	1,620	3,531	2,465	5,996
June	1,623	3,597	2,477	6,074
July	1,600	3,631	2,532	6,163
August	1,618	3,576	2,566	6,142
September	1,614	3,633	2,591	6,224
October	1,640	3,669	2,606	6,275
November	1,634	3,658	2,603	6,261

Sources: U.S. Department of Commerce, Bureau of the Census. Manufacturers' Shipments, Inventories, and orders: 1947–1963. Revised, series M 3-1, October 1963, pp. 62–67. U.S. Department of Commerce, Office of Business Economics. Survey of Current Business. V. 45, No. 3, March 1965, p. S–5; v. 46, No. 3, March 1966, p. S–5.

LABOR AND PRODUCTIVITY

Employment.—Strong demand for nonfuel minerals in 1965 resulted in mining firms substantially increasing employment in order to increase output. The gains made in nonfuel mining, however, were offset by employment losses in the mineral fuels industries so that total mining employment for the year declined slightly. Percentage changes in average total employment are shown below:

	Percent
All industries	+3.9
Mining (including fuels)	—.1
Metals and nonfuel minerals	+3.6
Metal mining	+4.9
Nonmetal mining and quarrying	+2.7
Coal mining	—3.5
Crude petroleum and natural gas	—2.4
Minerals manufacturing [1]	+4.3

[1] Based upon categories listed under mineral manufacturing in table 13.

Employment in selected mineral manufacturing groups increased 4.3 percent, slightly more than the average for all industries. Of the selected mineral manufacturing industries, only hydraulic cement employed fewer workers in 1965 than in 1964. This decline was the result of advancing technology wherein new or replacement plants require less labor for the same or increased productivity.

Hours and Earnings.—Average weekly hours of production workers in the nonfuel mining industry rose slightly in 1965, and hourly and weekly earnings increased 3.4 and 4.7 percent, respectively. As a result of increased hours, the percentage increase for weekly earnings was higher than that for hourly earnings. Similar trends were experienced in the mineral manufacturing industries except for the declines in weekly hours worked by cement, blast furnace, and steel and rolling mill employees.

Labor Turnover Rates.—Accession rates for metal mining, generally lower than those for all manufacturing, remained stable in 1965. However, there was a very slight increase in accession in copper ore mining. Separation rates in all metal mining increased slightly with the largest increase in iron ore mining. The layoff rate for all metal mining was unchanged at 0.7 layoffs per 100 employees. Accession, separation, and layoff rates for 1965 for the mineral manufacturing industries were mixed. The most significant changes were in the layoff rates for blast furnaces and steel and rolling mills which increased 160 percent and the nonferrous smelting and refining layoff rate which declined over 50 percent. In manufacturing, accession rates were slightly higher, separation rates remained constant, and layoff rates declined.

Wages and Salaries.—Wages and salaries in the mining industry, including fuels, continued the upward trend begun in 1961. However, the 4.8-percent increase in 1965 was below the 7.4- and 7.8-percent gains reported for all industries and manufacturing, respectively. Wages and salaries in the metal mining industry increased 8 percent, from $568 to $613 million. This was surpassed by the quarrying and nonmetallic mining industry which increased 9 percent, from $720 to $785 million.

Average annual earnings of full-time employees in mining rose 4 percent and remained slightly higher than earnings in all industries and manufacturing.

Productivity.—The most recent productivity indexes available are those for 1964. These indexes indicate substantial productivity increases for copper and iron ore mining; productivity increases were a result of fewer employees producing a larger output.

The productivity indexes may be used as an indicator of the shift in the average grade of ore mined. For example, in 1964 the percentage increase in productivity of recoverable copper mined was less than that of copper ore, and the percentage increase in usable iron ore mined was greater than that of crude iron ore mined. These facts implied a decline in the average grade of copper ore mined and an increase in the average grade of iron ore mined.

Preliminary data not shown here give every indication that productivity of copper and iron ore mining will decline in 1965. Both industries were forced to hire large numbers of new workers and, in both industries, the marginal output of these new workers was low.

Table 13.—Total employment in selected nonfuel mineral industries
(Thousands)

Year	Mining				
	Total	Nonmetal mining and quarrying	Metal		
			Total [1]	Iron	Copper
1961	207.2	119.8	87.4	26.9	29.0
1962	200.4	118.1	82.3	25.2	28.5
1963	r 196.7	r 117.0	r 79.7	r 24.1	27.7
1964	r 196.1	r 116.7	r 79.4	r 24.7	r 27.1
1965	203.1	119.8	83.3	26.1	29.9
	Mineral manufacturing				
	Fertilizers complete and mixing only	Cement, hydraulic	Blast furnaces, steel works, and rolling mills	Nonferrous smelting and refining	
1961	35.8	40.2	526.5	66.6	
1962	36.8	39.8	522.3	68.1	
1963	r 38.2	38.9	r 520.0	r 68.4	
1964	r 37.7	38.7	r 557.2	r 69.2	
1965	38.3	38.3	584.5	72.1	

r Revised.
[1] Includes other metal mining not shown separately.

Source: U.S. Department of Labor, Bureau of Labor Statistics. Employment and Earnings. V. 12. No. 9, March 1966, table B-2. U.S. Department of Labor, Bureau of Labor Statistics. Employment and Earnings Statistics for the United States 1909–1965. Bull. 1312–3, December 1965.

Table 14.—Average hours and gross earnings of production and related workers in the mineral industries (nonfuel) in continental United States, by industries

Year	Total [1]			Metal mining					
				Total [2]			Iron ores		
	Weekly		Hourly earnings	Weekly		Hourly earnings	Weekly		Hourly earnings
	Earnings	Hours		Earnings	Hours		Earnings	Hours	
1961	$105.68	42.9	$2.57	$113.44	41.4	$2.74	$115.50	38.5	$3.00
1962	110.33	43.2	2.56	117.45	41.5	2.83	122.19	39.8	3.07
1963	r 112.55	43.2	r 2.61	118.66	41.2	2.88	120.04	39.1	3.07
1964	r 116.19	r 43.6	r 2.67	r 122.54	r 41.4	r 2.96	125.83	40.2	3.13
1965	121.67	44.0	2.76	127.71	41.6	3.07	129.24	40.9	3.16
	Metal mining—Continued			Quarrying and nonmetallic mining			Mineral manufacturing		
	Copper ores						Fertilizers, complete and mixing only		
1961	$119.03	43.6	$2.73	$100.09	43.9	$2.28	$80.94	42.6	$1.90
1962	120.70	42.8	2.82	105.43	44.3	2.38	84.12	42.7	1.97
1963	124.56	43.1	2.89	r 108.38	r 44.6	r 2.43	r 90.67	43.8	r 2.07
1964	130.42	42.9	3.04	r 111.85	r 45.1	r 2.48	r 93.74	43.4	r 2.16
1965	136.71	43.4	3.15	117.45	45.7	2.57	96.57	43.5	2.22
	Mineral manufacturing—Continued								
	Cement, hydraulic			Blast furnaces, steel and rolling mills			Nonferrous smelting and refining		
1961	$106.52	40.5	$2.63	$123.84	38.7	$3.20	$110.16	40.8	$2.70
1962	112.75	41.0	2.75	128.31	39.0	3.29	114.95	41.2	2.79
1963	116.60	41.2	2.83	134.40	40.0	3.36	118.14	41.6	2.84
1964	121.30	41.4	2.93	140.15	41.1	3.41	r 120.22	41.6	r 2.89
1965	124.42	41.2	3.02	141.86	41.0	3.46	124.44	41.9	2.97

r Revised.
[1] Weighted average of data computed using figures for production workers as weights.
[2] Includes other metal mining not shown separately.

Source: U.S. Department of Labor, Bureau of Labor Statistics. Employment and Earnings, V. 12, No. 9, March 1966, table C–2. U.S. Department of Labor, Bureau of Labor Statistics. Employment and Earnings Statistics for the United States 1909–65, Bull. 1312–3, December 1965.

Table 15.—Labor-turnover rates in selected mineral industries [1]

(Per 100 employees)

Turnover rate	Manufacturing	Cement, hydraulic	Blast furnaces, steel and rolling mills	Nonferrous smelting and refining	Metal mining	Iron ores	Copper ores
Total accession rate:							
1963	3.9	3.3	3.2	2.4	3.1	3.4	2.2
1964	4.0	2.9	2.9	2.3	3.2	2.7	2.7
1965	4.3	2.6	2.3	2.5	3.2	2.7	2.8
Total separation rate:							
1963	3.9	3.5	2.8	2.1	3.1	2.7	2.1
1964	3.9	3.0	1.8	2.1	r 2.9	2.3	2.5
1965	4.0	2.7	3.0	2.2	3.1	2.5	2.5
Layoff rate:							
1963	1.8	2.4	1.7	.8	r 1.1	1.8	.5
1964	1.7	2.0	.5	r .7	.7	1.3	.3
1965	1.4	1.6	1.3	.3	.7	1.3	.4

r Revised.

[1] Monthly rates are available in Employment and Earnings as indicated in source.

Source: U.S. Department of Labor, Bureau of Labor Statistics. Employment and Earnings. V. 12, No. 9, March 1966, table D-2. U.S. Department of Labor, Bureau of Labor Statistics. Employment and Earnings Statistics for the United States 1909-65. Bull. 1312-3, December 1965.

Table 16.—Wages, salaries, and average annual earnings in the United States

	1963	1964	1965	Percent change 1963-64	Percent change 1964-65
Wage and salaries, millions:					
All industries, total	$311,095	$333,619	$358,389	7.2	7.4
Mining	3,956	4,115	4,314	4.0	4.8
Manufacturing	100,606	107,166	115,509	6.5	7.8
Average earnings per full-time employee, dollars:					
All industries, total	5,243	5,499	5,705	4.9	3.7
Mining	6,240	6,521	6,783	4.5	4.0
Manufacturing	5,920	6,196	6,386	4.7	3.1

Source: U.S. Department of Commerce, Office of Business Economics. Survey of Current Business. V. 46, No. 7, July 1966, pp. 30-31.

Table 17.—Labor-productivity indexes for copper- and iron-ore mining

(1957-59=100)

Year	Copper, crude ore mined per— Production worker	Copper, crude ore mined per— Man-hour	Iron, crude ore mined per— Production worker	Iron, crude ore mined per— Man-hour
1955-59 (average)	97.1	94.3	101.7	99.8
1960	116.9	108.2	122.7	116.3
1961	117.4	110.6	138.4	135.2
1962	125.8	120.7	154.6	146.1
1963	126.2	120.3	164.9	158.7
1964 p	137.7	131.9	171.4	160.6
	Copper, recoverable metal mined per— Production worker	Copper, recoverable metal mined per— Man-hour	Iron, usable ore mined per— Production worker	Iron, usable ore mined per— Man-hour
1955-59 (average)	98.4	95.6	106.1	103.9
1960	112.9	104.5	112.0	106.2
1961	115.6	109.0	115.1	112.4
1962	124.1	119.1	123.6	116.9
1963	126.0	120.1	126.3	121.5
1964 p	133.7	128.0	133.0	124.6

p Preliminary.

Source: U.S. Department of Labor, Bureau of Labor Statistics. Index of Output per Man-Hour, Selected Industries. BLS Rept. 301, December 1965, tables 8, 11, 16, 19.

PRICES AND COSTS

Index of Mine Value.—The index of average mine value of all minerals, including fuels, rose slightly in 1965. The index of total metals increased 4 percent owing to the 7-percent increase in the nonferrous metals index. As in 1964, higher copper, lead, zinc, and mercury prices were responsible for this increase. An increase in the average mine value of chemical raw materials compensated for the decline in the average mine value of construction materials, keeping the total nonmetals index stable. The gain made in the chemicals group was attributed to increased prices for phosphate rock and potassium salts.

The index of average mine value was reweighted using 1957–59 weights. The commodity coverage of the revised index is comparable to the Bureau of Mines index of physical volume. The more recent weighting period and comparability with the index of production should make the new index a more useful tool.

Index of Implicit Unit Value.—The index of implicit unit value which measures the price change implied by the Bureau of Mines indexes of volume and value increased less than 1 percent. Since 1960, the index of implicit unit value for nonmetals has been relatively stable while the index for metals has continually increased. In 1965, the index of implicit unit value for metals increased 4 percent. These indexes increase when the quantity of production rises less than the value of production. In 1965, the tendency toward lower productivity and higher commodity prices was responsible for the 8- and 10-percent increases in the ferrous and nonferrous base metals indexes.

Prices.—While most prices of processed mineral commodities rose moderately, the nonferrous metals and nonferrous scrap showed significant price increases. Slab zinc, copper ingot, and pig lead prices rose 7, 10, and 18 percent, respectively, and nonferrous scrap prices rose 19.6 percent.

Prices of most nonmetallic mineral products were slightly higher in 1965. The only significant declines were for insulation materials and gypsum products. The major price increases occurred in phosphate rock and phosphates, more than 5 percent, as demand for these products in the rapidly expanding fertilizer industry remained high. Upward price pressures on phosphate rock and phosphates were caused by the higher cost of inputs.

Costs.—Price indexes of cost items shown in table 21 increased. The average prices of machinery and equipment used in mining increased slightly more than 2 percent in 1965, but the price index for portable air compressors increased more than 9 percent. The percentage change from 1964 for major machinery and equipment items follows:

	Percent change from 1964
Mining machinery and equipment	+2.5
Power cranes, draglines, shovels, etc.	+1.7
Tractors other than farm	+2.5
Construction machinery and equipment	+2.6
Portable air compressors	+9.4

Prices of cost items shown in table 22 were mixed. The price of most items increased moderately, but prices of coal and explosives declined.

Relative Labor Cost.—The labor cost per pound of recoverable copper increased 9.1 percent, the value of recoverable copper per man-hour increased 3.5 percent, and the labor cost per dollar of recoverable copper was unchanged. A combination of higher hourly earnings and lower productivity rates caused the labor cost per pound of recoverable copper to increase, but did not adversely affect the value of recoverable copper per man-hour. The value of recoverable copper per man-hour remained constant, since copper price increases more than offset higher labor cost and lower productivity.

Also, as a result of increased wages and lower productivity, the labor cost per pound of recoverable iron ore increased 3.5 percent; but the value of recoverable iron ore per man-hour declined 2.4 percent. The labor cost per dollar of recoverable iron ore increased 3.2 percent because wages increased, productivity declined, and the price of iron ore remained constant.

Index of Principal Metal Mining Expenses.—The 4-percent increase in the index of principal metal mining expenses, the first since 1961, was due largely to higher labor costs. Labor costs increased more than 5 percent in 1965. The cost of fuels and supplies increased moderately, while electric energy cost was constant. This index excludes capital cost and contract work expenses; consequently, it does not represent changes in total unit cost of metal mining.

Table 18.—Index of average unit mine value of minerals produced in the United States by group and subgroup [1]

(1957–59 = 100)

Year	All minerals	Metals: Total	Metals: Ferrous	Metals: Nonferrous: Total	Metals: Nonferrous: Base	Metals: Nonferrous: Monetary	Metals: Nonferrous: Other	Nonmetals: Total	Nonmetals: Construction	Nonmetals: Chemical	Nonmetals: Other	Fuels
1956	96.2	111.3	93.2	129.1	141.7	94.4	105.2	97.5	97.2	99.0	96.7	93.9
1957	101.1	101.2	98.3	104.1	104.9	98.8	103.6	99.4	99.0	101.0	101.0	101.6
1958	99.5	97.5	100.6	94.4	91.0	100.6	101.8	99.4	99.3	99.7	99.3	99.8
1959	99.1	102.0	102.2	101.8	104.0	100.8	95.6	101.1	101.6	98.9	99.5	98.1
1960	99.7	103.3	102.2	104.4	109.3	101.5	91.2	102.5	103.2	100.0	100.8	98.3
1961	99.7	101.8	105.3	98.4	101.1	103.9	88.9	102.1	102.4	101.4	100.4	98.7
1962	100.0	102.8	104.8	100.8	102.3	111.8	92.7	101.8	102.4	99.4	100.0	99.0
1963	99.6	105.4	107.6	103.2	103.7	120.0	95.8	101.2	101.7	98.1	102.8	98.4
1964	99.9	110.3	110.9	109.7	112.5	120.5	98.6	101.9	101.9	101.2	103.5	98.0
1965	100.1	114.6	112.0	117.1	123.2	120.5	99.8	101.5	101.2	102.7	103.0	97.8

[1] Reweighted using 1957–59 weights.

Table 19.—Index of implicit unit value of minerals produced in the United States

(1957–59=100)

Year	All minerals	Metals: Total	Metals: Ferrous	Metals: Nonferrous: Total	Metals: Nonferrous: Base	Metals: Nonferrous: Monetary	Metals: Nonferrous: Other	Nonmetals: Total	Nonmetals: Construction	Nonmetals: Chemical	Nonmetals: Other	Fuels
1961	101.1	102.8	103.9	103.7	103.4	101.2	97.6	100.4	99.8	101.7	106.5	100.5
1962	101.6	103.6	103.5	r 106.4	106.2	108.2	99.7	99.7	99.2	100.4	110.1	r 101.2
1963	101.4	r 106.8	107.7	r 108.4	106.5	r 116.6	r 109.6	98.9	98.0	99.1	r 114.9	100.8
1964	102.0	114.6	111.9	116.5	114.7	117.6	119.6	99.1	97.9	101.3	116.1	100.2
1965 p	102.9	119.1	112.1	126.3	126.2	116.3	123.1	99.0	97.8	102.1	117.8	100.6

p Preliminary. r Revised.

INCOME

National Income Originated.—Income originating in the mining industry increased 8 percent in 1965. Nonmetallic increased 13 percent and metal mining 16 percent. These increases were considerably above that for total mining; hence the relative share of total mining income originating from these two sectors was somewhat larger.

Profits and Dividends.—The percent increase in the annual profit rate on stockholders' equity (after corporate income taxes) for all manufacturing was close to last year's rate, but the rates for primary iron and steel, stone, clay, and glass products, and chemicals were somewhat lower. Although the absolute amount of profits was at an alltime high, profits are not increasing in proportion to sales. As the mining industries strived to satisfy tremendous demand, they often operated at greater than optimal costs. Dividends paid by the minerals processing industry increased in 1965. The dividends of primary nonferrous metals increased at a rate greater than all manufacturing, but those of primary iron and steel, stone, clay, and glass products, and chemicals lagged behind manufacturing.

The number of failures in mining companies, including fuels, increased in 1965 although current liabilities of mining failures declined $15 million.

Table 20.—Price indexes for selected metals and mineral commodities

(1957–59=100)

Commodity	Annual average 1964	Annual average 1965	Percent change from 1964
Metals and metal products	102.8	105.7	+2.8
Iron and steel	100.5	101.4	+.9
Iron ore	90.6	90.5	−.1
Iron and steel scrap	79.3	81.6	+2.9
Semifinished steel products	103.5	103.3	−.2
Finished steel products	102.8	103.3	+.5
Foundry and forge shop products	104.7	106.1	+1.3
Pig iron and ferroalloys	r 77.7	80.2	+3.2
Nonferrous metals	105.9	115.2	+8.8
Primary metal refinery shapes	111.2	119.6	+7.6
Aluminum ingot	94.6	97.7	+3.3
Copper, ingot, electrolytic	110.6	121.2	+9.6
Lead, pig, common	104.6	123.2	+17.8
Zinc, slab, prime western	121.7	130.0	+6.8
Nonferrous scrap	117.3	140.3	+19.6
Nonmetallic mineral products	101.5	101.7	+.2
Concrete ingredients	102.8	103.2	+.4
Sand, gravel, and crushed stone	104.8	105.5	+.7
Concrete products	100.9	101.5	+.6
Structural clay products	r 104.2	105.1	+.9
Gypsum products	108.2	104.0	−3.9
Other nonmetallic minerals	101.5	101.3	−.2
Building lime	110.3	113.1	+2.5
Insulation materials	90.9	88.3	−2.9
Asbestos cement shingles	111.0	113.3	+2.1
Bituminous binders (1958=100)	100.0	99.9	−.1
Fuels and related products and power	97.1	98.9	+1.9
Fertilizer materials	100.1	103.5	+3.4
Nitrogenates	94.1	96.8	+2.9
Phosphates	110.4	116.0	+5.1
Phosphate rock	128.9	138.1	+7.1
Potash	113.9	117.8	+3.4
Muriate, domestic	111.1	115.0	+3.5
Sulfate	117.3	121.0	+3.2
All commodities other than farm and food	101.2	102.5	+1.3
All commodities	100.5	102.5	+2.0

r Revised.

Source: U.S. Department of Labor, Bureau of Labor Statistics. Wholesale Prices and Price Indexes, January 1966, pp. 24–26.

Table 21.—Price indexes for mining construction and material handling machinery and equipment

Year	Construction machinery and equipment	Mining machinery and equipment	Oilfield machinery and tools	Power cranes, draglines, shovels, etc.	Specialized construction machinery	Portable air compressors	Scrapers and graders	Contractors air tools, hand-held	Mixers, pavers, spreaders, etc.	Tractors, other than farm
1961	107.5	107.8	101.8	105.4	107.8	114.1	104.4	113.5	108.4	108.0
1962	107.8	108.4	103.2	106.1	107.4	113.7	105.3	113.5	110.3	108.5
1963	109.6	109.1	102.6	108.8	108.1	115.1	108.5	113.5	112.1	110.8
1964	112.4	r 110.5	r 104.3	111.8	108.5	117.6	110.8	(1)	116.3	114.7
1965	115.3	113.3	104.7	113.7	110.3	128.7	114.2	(1)	119.8	117.6

r Revised.
1 Series discontinued.
Source: U.S. Department of Labor, Bureau of Labor Statistics. Wholesale Prices and Price Statistics. January 1966, pp. 24–26, and previous years.

Table 22.—Price indexes for selected cost items in nonfuel mineral production
(1957–59=100, unless otherwise specified)

Commodity	1965 January	1965 December	Change from January (percent)	Annual average 1964	Annual average 1965	Change from 1964 (percent)
Coal	98.3	97.6	−0.7	96.9	96.5	−0.4
Coke	107.3	107.3	---	106.3	107.3	+.9
Gas fuels (January 1958=100)	121.4	128.6	+5.9	r 121.3	124.1	+2.3
Petroleum and refined products	95.2	98.4	+3.4	92.7	95.9	+3.5
Industrial chemicals	94.6	95.5	+1.0	94.2	95.0	+.8
Lumber	100.8	103.4	+2.6	100.7	101.9	+1.2
Explosives	111.5	111.4	−.1	111.8	111.4	−.4
Construction machinery and equipment	113.8	116.5	+2.4	112.4	115.3	+2.6

r Revised.

Source: U.S. Department of Labor, Bureau of Labor Statistics. Monthly Labor Review. V. 89, No. 3, March 1966, pp. 360–361; No. 4, April 1966, pp. 474–475. Wholesale Price Statistics, February 1965, p. 10, and January 1966, p. 12.

INVESTMENT

New Plant and Equipment.—Total expenditures on new plant and equipment increased from $44.9 in 1964 to $52.0 billion in 1965. A large portion of this 16-percent increase resulted from larger than expected sales which necessitated additions to the capacity of many industries.

In 1965 expenditures for new plant and equipment in the mining industry increased $110 million or 9.2 percent—a rate somewhat lower than that for all industries, manufacturing, and selected manufacturing industries. The primary nonferrous metals industry experienced rapid acceleration of demand in 1965, causing increased use of capacity. Consequently, the largest percentage increase for new plant and equipment was the 42-percent increase made by the primary nonferrous metals industry.

Issues of Mining Securities.—The extractive industries (including fuels) supplied 2 percent of the new corporate securities offered for sale in 1965. These securities consisted of 71 percent bonds and 29 percent common stock and were consistent with offerings of previous years.

Total gross proceeeds from extraction securities offered in 1965 decreased $79 million or 19 percent, whereas all corporate offerings increased 15 percent and manufacturing 78 percent. Although offering fewer securities in 1965, the extractive industries were able to satisfy increased capital requirements. The healthy state of the extractive industry made it possible to rely more on internally generated funds or on loans from financial institutions for needed financing.

Foreign Investment.—The value of direct private investment in foreign mining and

Table 23.—Indexes of relative labor costs, copper and iron ore mining [1]

(1957–59=100)

Year	Labor costs per pound of recoverable metal		Value of recoverable metal per man-hour		Labor costs per dollar of recoverable metal	
	Copper	Iron ore	Copper	Iron ore	Copper	Iron ore
1961	105	97	113	114	101	96
1962	98	96	126	112	93	100
1963	100	92	127	115	94	97
1964	99	r 87	142	r 123	89	r 93
1965 p	108	90	147	120	89	96

p Preliminary. r Revised.

[1] Computed from data found in U.S. Department of Labor, Employment and Earnings and Wholesale Price Indexes.

Table 24.—Indexes of principal metal mining expenses [1]

(1957–59=100)

Year	Total	Labor	Supplies	Fuels	Electrical energy
1961	101	100	101	101	103
1962	99	96	101	100	103
1963	98	95	102	100	102
1964	r 96	r 92	102	97	101
1965 p	100	97	103	99	101

r Revised. p Preliminary.

[1] Indexes constructed using the following weights derived from the 1958 Census of Mineral Industries: Labor, 59.37; explosives, 2.42; steel mill shapes and forms, 3.51; all other supplies, 25.24; fuels, 5.08; electric energy, 4.38; and data from U.S. Department of Labor, Bureau of Labor Statistics, Wholesale Price Index. The index is computed for iron and copper ores only because sufficient data is not available for other mining sectors.

Table 25.—National income originated in the mineral industries in the United States

Industry	Income, millions			Change from 1964 (percent)
	1963	1964	1965	
Mining	$5,954	$5,950	$6,432	+8.1
Metal mining	785	883	1,025	+16.1
Coal mining	1,212	1,284	1,361	+6.0
Crude petroleum and natural gas	2,917	2,658	2,775	+4.4
Mining and quarrying of nonmetallic minerals	1,040	1,125	1,271	+13.0
Manufacturing	143,839	155,078	170,408	+9.9
Chemicals and allied products	10,402	11,212	12,332	+10.0
Petroleum refining and related industries	4,597	4,667	5,063	+8.5
Stone, clay, and glass products	5,062	5,437	5,789	+6.5
Primary metal industries	11,521	13,126	14,747	+12.4
All industries	481,927	517,281	559,020	+8.1

Source: U.S. Department of Commerce, Office of Business Economics. Survey of Current Business. V. 46, No. 7, July 1966.

Table 26.—Annual average profit rates on shareholders equity, after taxes and total dividends, selected mineral manufacturing corporations

Industry	Annual profit rate (percent)			Total dividends (millions)		
	1964	1965	Change from 1964 (percent)	1964	1965	Change from 1964 (percent)
All manufacturing [1]	11.6	13.0	+12.1	$10,810	$11,979	+10.8
Primary metals	9.2	10.6	+15.2	913	1,034	+13.3
Primary iron and steel	8.8	9.8	+11.4	546	584	+7.0
Primary nonferrous metals	9.8	11.9	+21.4	367	450	+22.6
Stone, clay, and glass products	9.6	10.3	+7.3	326	341	+4.6
Chemicals and allied products	14.4	15.3	+6.3	1,486	1,556	+4.7

[1] Except newspapers.

Source: Federal Trade Commission, Securities and Exchange Commission. Quarterly Financial Report for Manufacturing Corporations. 1st Quarter 1965 and 4th Quarter 1965, tables 4, 8.

Table 27.—Industrial and commercial failures and liabilities

Industry	1963	1964	1965
Mining: [1]			
Number of failures	84	70	84
Current liabilities thousands	$18,269	$30,030	$14,556
Manufacturing:			
Number of failures	2,325	2,184	2,013
Current liabilities thousands	$539,430	$331,834	$335,768
All industrial and commercial industries:			
Number of failures	14,374	13,501	13,514
Current liabilities thousands	$1,352,593	$1,329,223	$1,321,666

[1] Including fuels.

Source: Dun & Bradstreet, Inc., Business Economics Department, Business Conditions Staff. Monthly Business Failures. New York, N.Y., January 1965, p. 2; Jan. 26, 1966, p. 2.

smelting industries increased $214 million in 1964. Canada gained $131 million and Australia $30 million. Data for direct private investment in 1965 are not available.

U.S. foreign investment in 1964 should be noted in relation to the U.S. Government program of voluntary restraint to improve the U.S. balance of payments deficit. In the mining and smelting industries, net capital outflow was $88 million as compared to $65 million in 1963; but increased income from foreign affiliates was one of the major elements of strength in the balance of payments. Assisted by higher prices for metals and minerals, 1964 earnings of affiliates in mining and smelting rose by over $145 million and reached $505 million. Of that total, $399 million was returned to the United States compared with $293 million in 1963.

The 1965 foreign plant and equipment expenditure of U.S. mining and smelting firms was $584 million, 39 percent more than the 1964 expenditure of $420 million. As a result of increased activity in the development of bauxite properties in Australia and iron ore production in Canada and Australia, most of the increased U.S. investments in 1965 were in those countries.

Expenditures by foreign affiliates of U.S. mining and smelting firms were $1,044 million in 1964. The affiliates relied principally on internally generated funds—net income and cash flows from depreciation and depletion, which accounted for $936 million of the $1,044 million expenditure. The most significant changes in the 1964 sources of funds were the large decrease in the amount of funds obtained from the United States and the increased amount of funds obtained from other countries. During 1964 funds obtained from the United States declined. The total negative outflow of U.S. funds was probably the result of repayments of foreign loans or transfers of funds from foreign subsidiaries.

Table 28.—Expenditures for new plant and equipment by U.S. business [1] in mining and selected mineral manufacturing industries

(Billions)

Industry	1963	1964	1965
Mining [2]	$1.04	$1.19	$1.30
Manufacturing	15.69	18.58	22.45
Primary iron and steel	1.24	1.69	1.93
Primary nonferrous metals	.41	.48	.68
Stone, clay, and glass products	.61	.68	.78
Chemicals	1.61	1.97	2.59
Petroleum	2.92	3.36	3.82

[1] Data exclude expenditures of agricultural business and all outlays charged to current accounts.
[2] Including fuels.

Source: U.S. Department of Commerce, Office of Business Economics. Survey of Current Business. V. 45, No. 3, March 1965, p. 8; v. 46, No. 3, March 1966, p. 14.

Table 29.—Estimated gross proceeds of new corporate securities offered for cash in 1965 [1]

Type of security	Total corporate		Manufacturing		Extractive [2]	
	Millions	Percent	Millions	Percent	Millions	Percent
Bonds	$13,720	85.8	$4,712	87.0	$243	71.1
Preferred stock	725	4.5	112	2.1	---	---
Common stock	1,547	9.7	593	10.9	99	28.9
Total	15,992	100.0	5,417	100.0	342	100.0

[1] Substantially all new issues of securities offered for cash sale in the United States in amounts over $100,000 and with terms of maturity of more than 1 year are covered in these data.
[2] Including fuels.

Source: U.S. Securities and Exchange Commission. Statistical Bulletin. V. 25, No. 4, April 1966, p. 9.

Table 30.—Plant and equipment expenditures of direct investments by country and major industry.

(Millions)

Area and country	1963 r			1964 r			1965 [1]		
	Mining and smelting	Petroleum	Manufacturing	Mining and smelting	Petroleum	Manufacturing	Mining and smelting	Petroleum	Manufacturing
Canada	$195	$375	$535	$220	$385	$769	$248	$377	$1,031
Latin American Republics	75	245	271	72	272	363	102	309	399
Other Western Hemisphere	34	62	37	54	55	39	54	59	21
Europe	5	642	1,107	3	643	1,293	7	728	1,737
Africa	58	164	24	41	268	63	46	287	92
Middle East	---	125	5	---	114	9	---	203	9
Far East	2	172	131	1	164	205	1	238	258
Oceania	29	64	141	29	65	242	126	83	274
International	---	40	---	---	100	---	---	66	---
Grand total	398	1,889	2,251	420	2,066	2,983	584	2,350	3,821

r Revised.
[1] Estimated on the basis of company projections.

Source: U.S. Department of Commerce, Office of Business Economics. Survey of Current Business, V. 45, No. 9, September 1965, p. 30.

Table 31.—Direct private investments of the United States in foreign mining and smelting industries in 1964 p

(Millions)

Country and areas	Mining and smelting					All industries				
	Value	Net capital outflow	Undistributed earnings of subsidiaries	Earnings [1]	Income [2]	Value	Net capital outflow	Undistributed earnings of subsidiaries	Earnings [1]	Income [2]
Canada	$1,671	$45	$77	$191	$114	$13,820	$250	$498	$1,104	$634
Latin America, total	1,098	−8	10	184	172	8,932	156	219	1,104	900
Mexico	128	5	3	17	12	1,035	94	34	92	61
Panama	19	--	(3)	(3)	--	663	25	31	73	43
Brazil	34	(4)	(4)	(4)	(4)	994	−44	58	58	5
Chile	499	−5	1	61	60	788	9	12	80	73
Peru	241	1	(3)	53	54	460	10	2	83	77
Europe	56	2	−1	3	5	12,067	1,342	410	1,112	654
Africa, total	356	2	6	38	32	1,629	135	40	343	301
South Africa, Republic of	68	1	4	20	15	467	17	38	87	46
Far East	31	(3)	1	3	1	1,731	146	47	191	148
Oceania, total	100	10	7	10	3	1,582	115	80	143	59
Australia	100	10	7	10	3	1,465	121	65	122	54
All other countries [5]	252	39	3	76	73	4,582	232	124	1,121	1,045
Total all areas [6] [7]	3,564	88	102	505	399	44,343	2,376	1,417	5,118	3,741

p Preliminary.
1 Earnings is the sum of the U.S. share in net earnings of subsidiaries and branch profits.
2 Income is the sum of dividends, interest, and branch profits.
3 Less than ½ unit.
4 Combined with other industries in source reference.
5 "All other countries" includes other Western Hemisphere, Middle East, and International.
6 Excludes Cuba and Soviet bloc countries.
7 Detail may not add to totals because of rounding.

Source: U.S. Department of Commerce, Office of Business Economics. Survey of Current Business. V. 45, No. 9, September 1965, pp. 24–25.

Table 32—Sources of funds of direct foreign investment by United States mining and smelting industries

(Millions)

Area	Net income			Funds from United States			Funds obtained abroad [1]			Depreciation and depletion			Total sources		
	1962	1963	1964	1962	1963	1964	1962	1963	1964	1962	1963	1964	1962	1963	1964
Canada	$179	$187	$318	$95	−$24	$14	$15	$70	$51	$100	$114	$116	$389	$347	$499
Latin America	246	234	278	−28	14	−72	31	15	33	80	101	98	329	364	337
Europe	5	4	3	3	7	2	(2)	−1	(2)	1	2	5	9	12	10
Other areas	64	68	80	28	44	15	61	18	65	26	22	38	179	152	198
Total	494	493	679	98	41	−41	107	102	149	207	239	257	906	875	1,044

[1] Includes miscellaneous sources.
[2] Less than ½ unit.

Source: U.S. Department of Commerce, Office of Business Economics. Survey of Current Business. V. 45, No. 11, November 1965, p. 15.

FOREIGN TRADE

Value.—The 1965 crude and processed nonfuel mineral imports rose 24 percent over the 1964 figure. Values of imported metal ores and scrap increased 14 percent, while those of crude nonmetallic minerals remained constant. Imports of processed nonmetallic minerals increased 9 percent. Imports for consumption of numerous manufactured metals showed substantial increases.

The value of nonfuel minerals exports rose 3 percent. Crude nonmetallics, which increased 33 percent, helped offset the loss of crude metals and scrap which declined 13 percent. The general trend for imports and exports was substantially higher for imports and just slightly higher for exports.

Tariffs.—In 1965 the U.S. Tariff Commission reported the results of investigations concerning alleged injury to the U.S. minerals and processing industries by foreign imports to the United States at less than fair value. It was determined that titanium dioxide imports from West Germany and Japan are not injuring and are not likely to injure the domestic industry.

A Presidential proclamation lifted the import controls on lead and zinc ores and concentrates effective on October 22, 1965, and the quotas on lead and zinc metals on November 21, 1965.

RESEARCH AND DEVELOPMENT

Obligations of funds by the Bureau of Mines for research and development during fiscal year 1966 increased 11 percent from $27.2 million to $30.3 million in an effort to insure a continuously advancing mineral industry by developing comprehensive research capabilities able to solve production and consumption problems as they arise. The Bureau's obligations for basic and applied research during fiscal years 1965 and 1966 were $24.1 and $26.3 million, respectively. During fiscal 1966, the Bureau of Mines obligated expenditures of $6.2 million for metallurgy and material research.

Most of the funds for metallurgical research went towards making domestic low-grade ores competitive with foreign ores and satisfying the demand for materials to be used at high temperatures, in corrosive environments, or under other adverse conditions. The most significant achievements of the Bureau's metallurgy research in 1965 were the development of a process for the economic production of phosphate concentrates from low-grade phosphorous-bearing shales, the development of long-fiber synthetic chrysotile asbestos, and the perfection of a process which uses the scrap steel contained in old auto bodies to upgrade low-grade nonmagnetic taconites.

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Table 33.—Uses of funds of direct foreign investment by United States mining and smelting industries
(Millions)

Area	Property, plant, and equipment			Inventories			Receivables			Other assets [1]			Income paid out			Total uses		
	1962	1963	1964	1962	1963	1964	1962	1963	1964	1962	1963	1964	1962	1963	1964	1962	1963	1964
Canada	$245	$195	$220	$20	$−12	$−20	(2)	$19	$39	$26	$60	$96	$98	$85	$164	$389	$347	$499
Latin America	95	109	126	5	5	9	$25	10	10	34	16	22	170	224	170	329	364	337
Europe	4	5	3	(2)	−1	1	2	1	2	−2	(2)	(2)	5	7	4	9	12	10
Other areas	94	89	71	20	5	16	15	15	21	(2)	5	34	50	38	56	179	152	198
Total	438	398	420	45	−3	6	42	45	72	58	81	152	323	354	394	906	875	1,044

[1] Includes miscellaneous uses.
[2] Less than ½ unit.

Source: U.S. Department of Commerce, Office of Business Economics. Survey of Current Business. V. 45, No. 11, November 1965, p. 15.

Table 34.—Value of selected minerals and mineral products imported and exported by the United States in 1965, by commodity groups and commodities [1]
(Thousands)

SITC No.	Commodity	Imports for consumption	Exports of domestic merchandise
	Metals (crude and scrap):		
663	Iron ore and concentrates	$443,807	$80,418
282	Iron and steel scrap	8,236	197,459
283	Ore and concentrates of nonferrous base metals	415,221	68,475
284	Nonferrous metal scrap	62,048	85,927
286	Ores and concentrates of uranium and thorium	189	79
	Total	929,501	432,358
	Chemicals:		
	Inorganic chemicals:		
513	Elements, oxides, and halogen salts	114,503	157,412
514	Other inorganic chemicals	42,787	100,670
515	Radioactive and associated materials	61,394	42,470
	Total	218,684	300,552

	Metals (manufactured):		
671	Pig iron, spiegeleisen, sponge iron, iron and steel powders and shot, and ferroalloys	93,968	21,847
672	Ingots and other primary forms of iron or steel	35,348	84,993
673	Iron and steel bars, rods, angles, shapes, and sections	377,156	79,272
674	Universals, plates and sheets of iron or steel	471,939	183,996
675	Hoops and strips of iron or steel	24,740	33,616
676	Rails and railway track construction material of iron or steel	2,008	13,286
677	Iron and steel wire (excluding wire rod)	78,888	15,200
678	Tubes, pipes, and fillings of iron or steel	143,990	159,895
679	Iron and steel castings and forgings, unworked, not elsewhere specified	3,367	36,509
681	Silver, platinum, and other metals of the platinum group	69,152	13,203
682	Copper	377,874	292,769
683	Nickel	206,899	30,302
684	Aluminum	264,340	158,901
685	Lead	61,270	3,714
686	Zinc	43,717	6,747
687	Tin	167,448	10,946
688	Uranium and thorium and their alloys	51	230
689	Miscellaneous nonferrous base metals employed in metallurgy	47,396	35,969
	Total	2,469,551	1,181,395
	Minerals, nonmetallic (crude):		
271	Fertilizers, crude	3,139	67,424
273	Stone, sand and gravel	17,609	13,402
274	Sulfur and unroasted iron pyrites	26,835	65,324
275	Natural abrasives (including industrial diamonds)	56,897	22,240
276	Other crude minerals	129,929	68,531
	Total	234,409	236,921
	Minerals, nonmetallic (manufactured):		
661	Lime, cement, and fabricated building materials except glass and clay materials	37,117	12,864
662	Clay, construction materials, and refractory materials	33,790	51,097
663	Mineral manufactures, not elsewhere specified	16,566	60,280
	Total	87,473	124,241
	Grand total	3,939,618	2,275,467

[1] Data in this table are for the indicated SITC numbers only and, therefore, may not correspond to the figures classified by commodity in the "Statistical Summary" chapter of this volume.

Source: U.S. Department of Commerce, Bureau of the Census. United States Imports of Merchandise for Consumption, FT 125, December 1965, table 1. United States Exports, FT 410, December 1965, table 1.

Table 35.—Bureau of Mines obligations for mining and mineral research and development
(Thousands)

Fiscal year	Applied research	Basic research	Development	Total
1962	$16,210	$4,045	$6,715	$26,970
1963	17,752	3,385	8,335	29,472
1964 [1]	18,905	4,138	2,550	25,593
1965 [1]	19,733	4,355	3,118	27,206
1966 [e] [1]	21,675	4,630	4,006	30,311

[e] Estimate.
[1] Data not strictly comparable with those for previous years because definitions of research and development were changed.

Additional funds were received in fiscal 1966 from a new appropriation for research on solid-waste disposal problems. The projects selected for concentrated investigations were either those which preliminary research indicated a high probability of success or those which would contribute most directly to alleviating the social and economic problems caused by solid waste accumulation.

Table 36.—Bureau of Mines obligation for total research, by field of science
(Thousands)

	Fiscal years		
	1964	[r] 1965	[e] 1966
Engineering sciences	$15,141	$15,702	$17,410
Physical sciences	7,105	7,558	7,994
Mathematical sciences	797	828	901
Total research	23,043	24,088	26,305

[r] Revised. [e] Estimate.

Table 37.—Federal obligated funds for metallurgy and material research
(Thousands)

Federal agency	Fiscal year 1965			Fiscal year 1966 [e]		
	Basic research	Applied research	Total research	Basic research	Applied research	Total research
Department of Defense	$15,566	$72,907	$88,473	$17,862	$78,573	$96,435
Atomic Energy Commission	10,844	13,936	24,780	11,338	13,222	24,560
National Aeronautics and Space Administration	13,361	3,572	16,933	13,416	3,459	16,875
Bureau of Mines	---	5,347	5,347	---	6,195	6,195
National Science Foundation	1,728	---	1,728	2,260	---	2,260
Department of Agriculture	238	1,619	1,857	290	1,789	2,079
Department of Commerce	755	224	979	798	237	1,035
Other	425	76	501	609	157	766
Total	42,917	97,681	140,598	46,573	103,632	150,205

[e] Estimate.
Source: National Science Foundation.

LEGISLATION AND GOVERNMENT PROGRAMS

Defense Production Act (DPA).[4]—The Defense Production Act was extended for 2 years from June 30, 1964, to June 30, 1966. By December 31, 1965, $2,119.4 million of the total $2,208.5 million borrowing authority had been spent; this left $89.1 million available for new purchases. Some of this $89.1 million had been previously allocated but not spent.

National (Strategic) Stockpile Program.[5]—The Office of Emergency Planning (OEP) continued the supply-requirements study for nuclear war and reconstruction. The results of this study will provide a basis for initiating action toward the subsequent development of nuclear war stockpile objectives. OEP for the first time established a stockpile objective for silver of 165 million fine troy ounces based upon needs for a conventional war. OEP determined that the silver objective would be fulfilled by earmarking the objective amount in the Treasury stocks. OEP has made available to the Treasury excess stockpile materials that could be substituted for silver in the subsidiary coinage program. The total stockpile objective is $4.0 billion; $3.7 billion of this total had been achieved as of December 31, 1965.

OEP prepared new basic data on crude fused aluminum oxide and on three grades of bauxite: abrasive, chemical, and refractory. At yearend, these data were awaiting

[4] Executive Office of the President, Office of Emergency Planning and General Services Administration. Report on Borrowing Authority. June 30, 1965, 78 pp.

[5] Executive Office of the President, Office of Emergency Planning. Stockpile Report to the Congress. January–June 1965, 21 pp. and July–December 1965, 28 pp.

review by the Interdepartmental Materials Advisory Committee.

On October 28, 1965, the Director of the Office of Emergency Planning issued Emergency Defense Mobilization order 8600.1, "Provision for the Release of Strategic Materials From National Stockpile and Defense Production Act Inventories by the Office of Emergency Planning Regional Directors in the Event of Enemy Attack Upon the United States."

On December 31, 1965, the strategic materials held in all government inventories amounted to $8.0 billion at acquisition cost and $7.8 billion at estimated market value. Of this total, $5.3 billion at cost was in the national stockpile, $1.4 billion in the supplemental stockpile, and $1.3 billion in the Defense Production Act (DPA) inventory. Of the total materials in government inventories, $4.7 billion at cost and $4.1 billion at estimated market value are considered to be in excess of conventional war stockpile objectives. Over 79 percent of the market value of the total excess is made up of 11 materials: aluminum, metallurgical grade chromite, cobalt, industrial diamond stones, lead, metallurgical grade manganese, nickel, rubber, tin, tungsten, and zinc.

During 1965 large quantities of copper, tin, nickel, zinc, aluminum, lead, molybdenum, magnesium, and tungsten concentrates were disposed of.

Copper, lead, and aluminum were in short supply and large stockpile releases of these commodities helped to satisfy demand and to stabilize prices. Although government sales had a tendency to hold certain prices down, the Government made a substantial profit on many of the disposals. Total stockpile disposal of mineral commodities during 1965 was $607 million, of which $21 million came from the Atomic Energy Commission, $64 million from the DPA inventory, and $522 million from the national stockpile.

Barter Program.[6]—The Commodity Credit Corporation (CCC) was inactive in the early part of 1965; consequently, only 3 barter contracts for strategic mineral materials were negotiated. These amounted to $6.9 million and were for palladium and iodine only. Although refractory grade chromite was the only material acceptable for barter offer in 1965, special invitations were extended for other strategic mineral materials.

Office of Minerals Exploration (OME).[7]—Exploration for new domestic sources of essential mineral commodities continued to be encouraged by government assistance. The OME program was still dominated by gold and silver exploration grants. At yearend 42 contracts representing a maximum government participation of $3.4 million were in force. Of the contracts, 18 were for silver, 15 for gold, 4 for mercury, and 1 each for cobalt, nickel, copper, iron ore, and molybdenum.

[6] Executive Office of the President, Office of Emergency Planning. Stockpile Report to the Congress. January–June 1965, 21 pp., and July–December 1965, 28 pp. U.S. Department of Agriculture. Foreign Agricultural Service. Office of Barter and Stockpile. Published record.

[7] U.S. Department of the Interior, Office of Minerals Exploration. 14th annual report, June 30, 1965, 9 pp. Also unpublished December 31, 1965, data from the Office of Minerals Exploration.

WORLD REVIEW

World Economy.—Although the world economy in 1965 continued to grow, it was characterized by a decline in the rate of growth. The economy of the United States, unique among the principal industrial countries, continued to expand at an accelerated rate.

World Production.—Free world production of principal metals and minerals continued to increase in 1965. The percentage of U.S. production plus imports of world production increased slightly and the established historical production-import relationships were not materially altered.

The United Nations index of world metal mining production increased 5.4 percent over that of 1964. However, the rate of growth declined in all geographical groupings with the exception of Asia which experienced a gain of 12.4 percent compared with 3.8 percent in 1964. In Latin America the growth rate fell to 2.4 percent in 1965, from 5.0 percent in 1964. The rates of growth declined less noticeably in Europe, Canada, and the United States.

The United Nations index of basic metal industries increased 6.5 percent, considerably less than the 13.2-percent increase in

Table 38.—U.S. Government stockpile disposal of mineral commodities, 1965

Commodity		Sales commitments	
		Quantity	Sales value
National stockpile inventory:			
Antimony	short tons	1,116	$921,289
Cadmium	pounds	200	610
Copper	short tons	383,872	292,915,937
Copper and copper base alloys	do	165	132,052
Cupronickel ingots	pounds	732,000	297,286
Lead	short tons	36,218	11,341,724
Lead castings	pounds	46,800	6,520
Magnesium ingots	short tons	2,650	1,662,891
Mica, punch	pounds	220,230	9,470
Molybdenum	do	3,019,783	6,121,664
Nickel oxide powder	do	1,014,191	750,381
Nickel, various forms	do	78,669,736	60,166,942
Quartz crystals	do	20,432	33,521
Silicon carbide	short tons	56	4,032
Talc, steatite, block and lump	do	17	2,656
Tantalum (nonspecified form)	pounds	25,664	222,716
Tin	long tons	21,765	83,248,600
Zinc	short tons	211,453	63,862,381
Zinc engraving plates	pounds	221,087	33,619
Zirconium ores, baddeleyite	short dry tons	15	600
Total national stockpile		-------	521,734,891
Defense Production Act (DPA) inventory:			
Aluminum	short tons	55,256	27,274,107
Asbestos, chrysotile	do	6	937
Bismuth, metal	pounds	22,901	91,601
Copper	short tons	29,543	20,423,825
Nickel	pounds	7,739,269	5,883,401
Nickel, cathodes	do	4,897,098	3,673,518
Nickel, ferro	do	4,800,428	3,620,706
Rare-earth-bearing materials	short wet tons	3,010	738,013
Tungsten concentrates		1,010,196	2,166,742
Total DPA		-------	63,872,850
Atomic Energy Commission (AEC) inventory:			
Mercury	flasks	29,751	15,509,780
Vanadium pentoxide	short tons vanadium content	1,281	5,656,113
Total AEC		-------	21,165,893
Grand total		-------	606,773,634

Source: Office of Emergency Planning. Stockpile Report to the Congress, January–June 1965, p. 9, and July–December 1965, p. 9.

Table 39.—Summary of government inventories of strategic and critical materials, December 31, 1965

	Million short tons	Acquisition cost	Market[1] value
Total inventories:			
National stockpile	25.4	$5,284,882,400	$5,641,998,800
Supplemental stockpile	17.8	1,403,044,300	1,317,351,800
Defense Production Act	6.5	1,340,915,200	840,764,600
Commodity Credit Corporation	.1	4,026,500	3,893,500
Total on hand	49.8	8,032,868,400	7,804,008,700
On order	.2	37,990,000	39,430,900
Inventories within objective: Total on hand	27.4	3,327,527,600	3,666,492,100
Inventories excess to objectives: Total on hand	22.4	4,705,340,800	4,137,516,600

[1] Market values are computed from prices at which similar materials are being traded currently; or, in the absence of current trading, an estimate of the price which would prevail in commercial markets. The market values are generally unadjusted for normal premiums and discounts relating to contained qualities, so that market values are understated for materials such as metal grade bauxite to the extent that the inventories are of premium quality. The market values do not necessarily reflect the amount that would be realized at time of sale.

Source: Executive Office of the President, Office of Emergency Planning. Stockpile Report to the Congress. July–December 1965, p. 2.

Table 40.—Indexes of world production of metal mining, basic metals, and nonmetallic mineral products

(1958=100)

Year	Free world [1]	Canada and the United States	Latin America [2]	Asia: East and Southeast [3]	Europe [4]
		METAL MINING			
1961	119	114	116	r 131	114
1962	122	115	117	134	r 112
1963	r 123	114	r 119	132	106
1964	129	121	125	137	113
1965: p					
First quarter	130	115	128	140	122
Second quarter	139	133	131	155	123
Third quarter	142	138	132	165	110
Fourth quarter	135	121	123	156	124
Annual average	136	127	128	154	120
		BASIC METAL INDUSTRIES			
1961	124	114	127	202	r 126
1962	r 128	121	r 134	r 209	r 124
1963	r 136	130	r 140	r 235	r 128
1964	154	149	155	278	142
1965: p					
First quarter	168	166	154	282	154
Second quarter	170	170	152	288	155
Third quarter	158	154	150	281	145
Fourth quarter	158	143	165	288	158
Annual average	164	158	155	285	153
		NONMETALLIC MINERAL PRODUCTS INDUSTRIES			
1961	121	114	115	r 157	126
1962	128	119	r 121	173	135
1963	r 135	126	123	187	r 140
1964	148	135	136	212	157
1965: p					
First quarter	138	124	131	214	143
Second quarter	155	146	139	220	169
Third quarter	163	155	146	226	168
Fourth quarter	159	148	144	232	164
Annual average	154	143	140	223	161

p Preliminary. r Revised.

[1] Excluding Albania, Bulgaria, China (mainland), Czechoslovakia, Eastern Germany, Hungary, Mongolia, North Korea, Poland, Rumania, the U.S.S.R., and North Viet-Nam.

[2] Central and South America and the Caribbean Islands.

[3] Afghanistan, Brunei, Burma, Ceylon, China (Taiwan), Hong Kong, India, Indonesia, Iran, Japan, Republic of Korea, Malaysia (excluding Sabah), Pakistan, Philippines, Singapore, Thailand, and The Republic of Viet-Nam.

[4] Excluding Albania, Bulgaria, Czechoslovakia, Eastern Germany, Hungary, Poland, Rumania, and the U.S.S.R.

Source: United Nations Monthly Bulletin of Statistics. V. 20, May 1966, pp. X–XIX.

1964. The United Nations world index of nonmetallic mineral product industries increased 4 percent in 1965 compared with 10 percent in 1964.

World Consumption.—World consumption of most major nonferrous metals increased in 1965, but again at a declining rate. Aluminum consumption was an exception because the 11-percent gain made in 1965 surpassed the 10-percent gain made in 1964. This increased consumption was primarily a result of rising demand in the United States. The consumption of copper, lead, and zinc expanded, but tin consumption decreased slightly. World pig iron production (a general indicator of iron ore consumption) increased by 4.5 percent, with Japan and the United States accounting for most of the increase.

World Stocks.—Movements in the volume of world stocks of major nonferrous metals varied. Aluminum and tin stocks declined while copper, lead, and zinc stocks increased. The decline in aluminum stocks was primarily a result of higher U.S. demand and limited use of aluminum as a substitute for copper. Tin stocks were reduced as consumption continued to exceed production. Tin consumption exceeds output because many of the major producers, especially in Indonesia and the Congo, have not been able to overcome certain technical and political problems which hinder tin output.

Table 41.—Comparisons of world and United States production and U.S. imports of principal metals and minerals in 1965

Mineral	World production (thousand short tons unless otherwise stated)[6]	U.S. production (percentage of world production)	U.S. imports (percentage of world production)	Total U.S. production and imports (percentage of world production 1965)	Total U.S. production and imports (percentage of world production 1964 r)
Fuels:					
Coal	3,089,465	17	(1)	17	17
Petroleum (crude) thousand barrels	11,063,154	26	8	34	35
Nonmetals:					
Asbestos	3,570	3	20	23	24
Cement[2] thousand barrels	2,544,723	15	(1)	15	16
Diamonds thousand carats	35,513	--	--	45	46
Feldspar thousand long tons	1,900	33	(1)	33	32
Fluorspar	3,170	8	26	33	33
Gypsum	51,610	19	11	31	33
Mica (including scrap) thousand pounds	435,000	55	6	61	60
Nitrogen agricultural[2 3]	18,200	27	8	35	37
Phosphate rock thousand long tons	64,600	41	(1)	41	40
Potash (K_2O equivalent)	14,800	21	13	34	31
Salt[2]	118,590	29	2	31	31
Sulfur, elemental thousand long tons	15,120	48	10	58	56
Metallic ores and concentrates:					
Bauxite thousand long tons	36,530	5	31	36	35
Chromite	5,400	--	13	13	14
Copper (content of ore and concentrate)	5,600	24	(1)	24	24
Iron ore thousand long tons	605,637	15	7	22	22
Lead (content of ore and concentrate)	2,975	10	4	14	15
Mercury thousand 76-pound flasks	275	7	6	13	22
Molybdenum (content of ore and concentrate) thousand pounds	115,400	67	(1)	67	69
Nickel (content of ore and concentrate)	472	3	31	34	34
Platinum group (Pt, Pd, etc.) thousand troy ounces	2,960	1	1	2	3
Silver do	251,000	16	22	38	36
Titanium concentrates:					
Ilmenite[4]	2,728	36	6	42	45
Rutile[4]	243	W	63	W	56
Tungsten concentrate (60 percent tungsten dioxide) short tons	59,800	13	3	16	17
Vanadium (content of ore and concentrate) short tons	9,150	57	--	57	57
Zinc (content of ore and concentrate)	4,750	13	8	21	20
Metals, smelter basis:					
Aluminum	7,415	37	8	45	45
Copper	6,020	24	3	27	27
Iron, pig	370,065	25	(1)	25	25
Lead	2,905	14	8	22	24
Magnesium short tons	174,000	47	2	48	49
Steel ingots and castings	507,540	26	2	28	28
Tin thousand long tons	194	2	21	22	20
Uranium oxide (U_3O_8)[4] short tons	20,800	50	13	63	64
Zinc	4,240	23	4	27	27

r Revised. p Preliminary. W Withheld to avoid disclosing company confidential data.
[1] Less than ½ unit.
[2] Including Puerto Rico.
[3] Year ended June 30 of year stated (United Nations).
[4] World total exclusive of U.S.S.R.

The accumulation of copper stocks in 1965 was encouraged by the high demand in the industrial nations and the unstable political conditions which prevailed in some of the major producing countries.

World Trade.—Free world trade in 1965 continued to increase, stimulated by demand for raw materials from the industrial countries, principally the United States. In addition to the growth of trade, there were indications of a shift in certain established patterns of trade. The tendency for these patterns to shift is a result of new sources of supply, erratic import supply, reduction of trade barriers, and administratively higher export prices. These higher prices may cause the importing country to find new sources of supply, use a lower cost substitute if possible, or attempt to recover more of the basic raw material from primary or secondary domestic sources.

World Prices.—The export price indexes of metal ores and total minerals increased slightly and the primary commodities in-

Table 42.—World consumption indexes of major nonferrous metals [1]

Commodity	Quantity index, 1961 = 100			
	1962	1963	1964	1965
Aluminum	112	125	138	153
Copper	102	108	121	124
Lead	104	108	117	119
Tin	101	102	106	105
Zinc	104	113	123	129

[1] Based upon consumption quantities found in source, excludes centrally planned countries.

Source: United Nations, Trade and Development Board, Committee on Commodities. Preparation of a Summary of the Current Market Situation in Selected Commodities. UNCTAD Commodity Survey 1966, May 26, 1966, pp. 44, 46; May 27, 1966, TD 66–1182, p. 42 and TD 66–1132, pp. 65, 90; May 31, 1966, p. 46.

dex, excluding nonferrous metals, declined. Releases and threats to release material from the U.S. stockpile had a depressing effect on prices; however, these actions were not sufficient to counteract the increased demand and price for certain commodities.

The United Nations price index of exports of nonferrous base metals increased 15 percent, reflecting a strong U.S. demand and the uncertain supply conditions prevalent in several of the major producing countries. Copper prices increased considerably but aluminum, lead, and zinc prices remained relatively stable. Iron ore prices were stabilized by increased production emanating from new iron ore developments.

Ocean Freight Rates.—The United Nations index of ocean freight rates increased 13 percent for general cargo, 16 percent for ores, and remained constant for fertilizers.

Table 43.—World stocks of major nonferrous metals [1]

	Volume of stocks 1963 (short tons)	Index (previous year = 100)	
		1964	1965
Aluminum [2]	99,100	98	67
Copper [2]	52,000	71	95
Lead [3]	441,000	83	91
Tin [3]	52,300	109	102
Zinc [3]	474,000	74	88

[1] Excludes centrally planned countries.
[2] U.S. stocks only.
[3] Not comparable with previous year.

Source: United Nations Trade and Development Board, Committee on Commodities. Preparation of a summary of the Current Market Situation in Selected Commodities. UNCTAD Commodity Survey 1966, TD 66–1182, May 27, 1966, p. 42 and TD 66–1195, May 31, 1966, p. 47.

Table 44.—Price indexes of selected world exports

(1958=100)

Year	Primary commodities [1]	Total minerals [2]	Metal ores	Nonferrous base metals
1961	95	92	100	110
1962	94	92	99	109
1963	100	92	96	110
1964	103	94	104	135
1965:				
First quarter	100	96	108	147
Second quarter	100	96	112	157
Third quarter	100	96	110	153
Fourth quarter	100	96	111	163
Annual average	100	96	110	155

[1] Does not include nonferrous metals.
[2] Includes fuels and metal ores.

Source: United Nations Monthly Bulletin of Statistics. March 1966, special table C, pt. 1–2.

Table 45.—Indexes of ocean freight rates

(1958=100)

Year	Trip charter freight-rate indexes [1]		
	General cargo	Ore	Fertilizers
1961	118	103	105
1962	98	79	96
1963	120	99	97
1964	124	102	108
1965:			
First quarter	131	105	(2)
Second quarter	139	125	134
Third quarter	145	122	137
Fourth quarter	143	122	(2)
Annual average	140	118	108

[1] United Kingdom indexes based upon weighted average of quotations by all flags on routes important to United Kingdom tramp fleet in 1960.
[2] Rate not determined.

Source: United Nations Monthly Bulletin of Statistics. March 1966, special table E, p. XXXII.

Review of Metallurgical Technology

By Kenneth B. Higbie [1] and Ralph C. Kirby [1]

Expenditures to advance scientific technology in general reached an alltime high in 1965 with some $22.2 billion estimated to have been allocated by government and industry. Federal Government expenditures were estimated at $15.4 billion, with almost 90 percent of the funds devoted to programs involving defense, atomic energy, and outer space efforts. With this massive effort in the United States and a very impressive effort elsewhere in the world, there is little wonder that many new metallurgical developments were announced in the technical press during the year. No effort has been made to cover all aspects of the industry, but a few of the developments are described in this chapter.

Mineral Dressing

An expanding steel industry was one of the signs of a healthy economy during 1965. Although the reserves of iron minerals are considered to be sufficient to supply the present industry for many years, extensive efforts continue to be made to expand the iron ore resources, as, for example, the nonmagnetic Mesabi taconite deposits. These vast reserves of iron ore are not being utilized by the Nation's steel industry, because the technology for concentrating the nonmagnetic portion into a suitable product has not yet been developed. Magnetic roasting, followed by low-intensity magnetic separation, has shown considerable promise, because the high iron recovery makes the ratio of concentration of many of the oxidized ores more favorable than that obtained from magnetic taconite. However, the capital and operating costs are high, and, in many cases, high-grade concentrate cannot be made without resorting to flotation of the magnetic concentrate. Lawyer and Carpenter reported a process employing a high-intensity wet magnetic separator.[2] Ore from the Lower Cherty horizon of the taconite formation in Minnesota was ground to 92 percent minus 150 mesh and, after the usual dry magnetic separation to remove a 1 percent magnet product, was fed to the high-intensity wet magnetic separator that operated at 1 ton per hour per pole pair, 40 percent solids, maximum field, with ½-inch soft iron balls. It produced concentrate analyzing 61.4 percent iron and 8.0 percent insoluble, with an iron recovery of 70 percent. Further studies are underway to determine if a flotation step following the magnetic separation can further improve the purity of the product.

Information developed by the Chemical Engineering Department of the University of North Dakota from research sponsored by Great Northern Railways Co. showed that lignite will satisfy both fuel and reductant requirements in the reduction roasting of taconites.[3] The residual carbon and fly ash were reported to have created no problems. A traveling grate reduction roasting machine was employed in the test studies. Taconite did not exhibit a tendency to clinker, the reduction reactions were not slowed by slag formation, and there was a negligible quantity of unreacted carbon in the bed. The thermal efficiency of the system with lignite was as high as with natural gas.

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[1] Staff metallurgist, Office of the Director of Metallurgy Research.

[2] Lawver, James E., and J. Hall Carpenter. Wet Magnetic Separation of Oxidized Semitaconites. Min. Eng., v. 17, No. 9, September 1965, pp. 89–91.

[3] Gleason, D. S., and D. E. Severson. Lignite Gasification for Reduction Roasting of Taconites. J. Metals, v. 17, No. 4, April 1965, pp. 338, 339.

Two processes have been tested for the recovery of iron minerals from the plant tailings of the Iron Ore Co. of Canada's plant at Labrador City, Newfoundland. The first is a magnetic separation technique in which the magnetics are removed on a cobber drum and cleaned on a rougher drum. This product, after regrind and 3-stage finisher drum treatment, has been upgraded to a 68 percent iron concentrate. The second, a flotation technique, involved desliming the tailing and thickening to 65 percent solids. The reagentized pulp is treated in an alkaline circuit, using sodium hydroxide for pH control. After carbonates are floated from silica and iron in the alkaline circuit, flotation in an acid circuit recovers a 66 percent iron concentrate.

Although the Magma Copper Co. installed a molybdenite recovery circuit in its San Manuel, Ariz., copper plant over 2 years ago, details of the process were not revealed until this year.[4] About 35,000 tons of ore, containing 0.85 percent copper and 0.025 percent molybdenite are treated daily. Flotation of the ore, ground to 5 percent plus 65 mesh and 65 percent minus 200 mesh, produces a copper concentrate which contains between 0.8 to 1.0 percent molybdenite. This is thickened to 40 percent solids and sent to the molybdenite plant for separation of the molybdenite. Briefly, the process consists of five basic steps: (1) Conditioning of the copper concentrate with hydrogen peroxide, sulfuric acid, sodium cyanide, and zinc sulfate; (2) a 2-stage rougher flotation step utilizing stove oil, sodium ferrocyanide, and methyl isobutyl carbinol as reagents; the tailings of this step go to the copper concentrate thickener for subsequent copper recovery; (3) the reagent in the first stage cleaning step is sodium ferrocyanide; (4) in the next cleaning step sodium hypochlorite and potassium ferrocyanide are employed; and (5) in the final cleaning circuit Exfoam 636 and potassium ferrocyanide are the reagents. The molybdenite concentrate, containing over 92.5 percent molybdenite and approximately 1 percent copper, is pumped to the gold plant for cyanide leaching. Reported advantages over the older sodium hypochlorite-ferrocyanide process are: Continuous operation much more readily obtainable; effective flotation capacity of the existing plant increased by 25 percent; equipment corrosion reduced; overall operation simplified leading to a limited amount of automation; and the general costs of the total process not increased materially.

The results of laboratory efforts to recover molybdenum from sulfide and oxide ores found in the vicinity of Questa, N. Mex. were reported.[5] Sodium chlorate-sulfuric acid solutions were found to have advantages over other reagents. Leaching is rapid and efficient, the dissolved molybdenum can be recovered by ion exchange or solvent extraction, and the chlorate regenerated. Bacterial oxidation of molybdenite employing Thiobacillus thiooxidans and other bacterial strains were also investigated.

Pilot plant tests of a Bureau of Mines segregation process for recovering copper from low-grade complex ores were initiated at Colorado School of Mines Research Foundation under joint sponsorship of the Mauritanian Government and U.S., Canadian, and French mining interests. The tests are being made to obtain design data for a projected $16 million plant to be built in the Republic of Mauritania. The direct-firing process is designed to recover copper and associated metals from oxide and sulfide minerals that cannot be processed conventionally. Lean ores containing 95 percent or more of quartzite, limestone, sandstone, or limonite rock are crushed and mixed with salt and coke. The crushed ores are heated for one half hour at 830°C in a reducing atmosphere, during which time the oxides and sulfides are reduced to metal which segregates into thin metal particles. The metal can be recovered by conventional flotation techniques.

Mica is being produced in the western United States by a fatty acid cationic-anionic flotation process developed by the Bureau of Mines.[6] The first commercial plant on the West Coast, located in Mariposa County, Calif., treats about 150 tons per day of mica-bearing schist. Until now, the principal commercial sources of do-

[4] Burke, Harry K., and Joseph F. Shirley. San Manuel's New Process for Molybdenite Recovery. Min. Eng., v. 17, No. 3, March 1965, pp. 79–84.

[5] Bhappu, R. B., D. H. Reynolds, and R. J. Roman. Molybdenum Recovery From Sulfide and Oxide Ores. J. Metals, v. 17, No. 11, November 1965, pp. 1199–1205.

[6] Browning, J. S., and P. E. Bennett Flotation of California Mica Ore. BuMines Rept. of Inv. 6668, 1965, 7 pp.

mestic mica have been several mica-bearing pegmatite deposits in the East.

The world population explosion requires expansion of the fertilizer industry to support increased food production. The phosphate and potash industries of this country for several years have been steadily increasing their production. In the western segment of the phosphate industry, lower grade materials are being mined and acidulated by one company as a result of improved beneficiation techniques developed by the Bureau of Mines. In addition, the industry will soon be able to treat off-grade phosphate shale that has been mined and stockpiled in anticipation of its eventual use. The new process involves roasting the ore to remove organic carbon, attrition scrubbing, sizing, and grinding to recover about half of the phosphate in a high-grade product ready for acidulation. The fines from the preceding operations are deslimed and treated by flotation to recover 25 percent of the phosphate in the starting shale as a product comparable in grade to that used as electric furnace feed to make elemental phosphorus. Complete industrial acceptance of the new process could approximately double the total reserves of western phosphate rock.

The use of heavy liquid density gradients for the quantitative mineral analysis of rocks, ores, slags, and ceramic materials was described by Muller and Burton.[7] Specific examples were cited in the analysis of two pelatite concentrates. However, it was indicated that the technique, as presently developed, could be employed to identify mineral constituents having almost identical densities, up to a maximum density of about 5.0, and whose particle size was as small as 10 microns. Either organic or heavy liquids or Clerici solutions may be used.

A newly developed technique which appears to be gaining more acceptance is that of the column flotation machine. Developed by Pierre Boutin, the device has been tried by Iron Ore Co. of Canada and is undergoing further testing at Opemiska Copper Mines. Basically, the design consists of a tall cylinder about 30 feet high, with conditioned feed entering about 6 feet from the overflow lip. The air diffuser is near the column bottom and slightly above the discharge point. Small air bubbles course up thorugh the descending pulp and encounter a downward stream of wash water admitted slightly below the overflow line. The flotation chemistry is the same in either froth or column flotation. However, the reagent requirements are apparently drastically reduced in column flotation. Crest Exploration, Ltd., found that only 0.25 pound per ton of fatty acid and 0.375 pound per ton of AC 825 were required to float their iron minerals in the column, whereas in the standard flotation cells, 1.0 and 1.5 pounds per ton respectively were required.

Hydrometallurgy

The use of cyanides in the extractive metallurgy of copper has led to a new laboratory technique for the recovery of copper from both sulfide and oxide copper-bearing minerals.[8] Initially the ground ore is leached in alkaline cyanide solutions at atmospheric temperatures and pressures. A cyanide ratio of 3.0 grams NaCN equivalent per gram of contained copper extracted 81.6 percent of the copper in chalcocite and 94.2 percent of the copper in malachite in 15 minutes. Recovery of the dissolved copper was achieved by addition of sulfuric acid and sodium sulfide or sodium bisulfide to precipitate copper sulfide. On acidification of the pregnant solutions in the precipitation step, the free cyanide and the cyanide in the copper complex are converted to hydrocyanic acid which is recoverable by air, steam, or inert gas stripping at ambient or higher temperatures.

Kennecott Copper Corp. patented an apparatus and process for precipitating copper from highly dilute acidic solutions[9] such as natural waters from copper mines and water that has been percolated through waste dumps. Sponge or powdered iron is employed as the cementation

[7] Muller, L. D., and C. J. Burton. The Heavy Liquid Density Gradient and Its Applications in Ore Dressing Mineralogy. 31st Technical Session of the Eighth Commonwealth Mining and Metallurgical Congress, Melbourne, Australia, 1965, Preprint No. 49.

[8] Lower, George W., and Robert E. Booth. Recovery of Copper by Cyanidation. Min. Eng., v. 17, No. 11, November 1965, pp. 56–60.

[9] Back, Alexander E., Kenneth E. Fisher, and John Kocherhans. Process and Apparatus for the Precipitation of Copper From Dilute Acid Solutions. U.S. Pat. 3,154,411, March 20, 1962.

agent. The process is carried out on a semicontinuous basis, in a conical shaped vessel. The dilute copper-bearing solution is fed into the bottom apex of the cone and allowed to rise to the top, while the finely divided iron powder settles through it. Thus, the solution reaching the top or wide portion of the inverted cone is flowing relatively slowly and is barren of copper. This solution overflows the top of the cone and is sent to waste. The cemented copper particles are removed at the bottom of the cone and sent as a slurry to filtration for recovery of copper.

A contact sulfuric acid plant was simulated on a digital computer in a study for fourth year chemical engineering students at McMaster University, Hamilton, Ontario. The study of the 315 tons per day plant operated by Canadian Industries, Ltd., proved the applicability of the PACER (Process Assembly Case Evaluation Routine) executive program to simulation. Experience gained enabled improvement in the program, so that future plans call for use of PACER in the design of a larger plant.[10]

A new process employing cation exchange resins for treating waste sulfuric acid pickle liquor from the steel industry was announced by Crucible Steel Co. The resins remove the iron and regenerate the sulfuric acid. The iron is recovered from the resin as an iron nitrate solution, which is processed in an autoclave at above 350° F with oxygen to precipitate iron oxide powder. Unlike other ion exchange processes which merely substituted a self-created acid solution disposal problem for the one generated by the original pickle liquor, the new process recovers for reuse the nitric acid used to elute iron from ion exchange resin. The oxide produced can be agglomerated for iron and steel processes, reduced directly to iron powder, or used in pigments.

Operating details of the first industrial facility employing hydrochloric acid for pickling steel strip rather than the standard sulfuric acid were revealed.[11] United States Steel Corp.'s plant at Gadsden, Ala., represents a combination of an Austrian process for hydrochloric acid tower pickling and an English process for the recovery of hydrochloric acid pickle liquor. The action of the hydrochloric acid in removing scale is exactly the opposite of the action of sulfuric acid. Hydrochloric acid dissolves oxides, attacking the parent metal at a much slower rate. Sulfuric acid, on the other hand, reacts only slowly with the oxide but attacks the parent metal, generating hydrogen which causes the oxide layer to pop off. This difference makes the under and over pickling inherent in sulfuric acid treatment unlikely in a hydrochloric line. In addition, the hydrochloric acid treatment will remove more easily rolled-in scale. Many efforts now appear to be under-way to convert pickling lines from sulfuric acid to hydrochloric acid media.

A sulfation roast process for recovering nickel and cobalt from laterite ores in Australia was described.[12] The complex mineralogy of the laterite has made it impossible to concentrate them by conventional mineral dressing processes. The ore was first ground to minus 100 mesh and then mixed with concentrated sulfuric acid (30 percent acid by weight of dry ore); the moist solids were dried at 400° to 500° C by direct firing and then roasted in indirectly fired furnaces at a temperature of 650° to 700° C. During this roasting, a selective sulfation of the nickel, cobalt, and manganese is accomplished. The roasted product is discharged directly into agitated quench tanks and water leached for ½ to 1 hour at 70° to 80° C. After filtration, the clear leach liquor having a pH of about 2 and containing 5 to 6 grams per liter nickel, 0.5 grams per liter cobalt, and 5 to 10 grams per liter iron is treated with hydrogen sulfide at 120° C under 30 to 35 pounds per square inch gage. At the increased pressure, the hydrogen sulfide is highly soluble thereby insuring complete precipitation of the valuable metals. Only a very small amount of iron and none of the magnesium and manganese is found in the precipitate. Nickel extractions of 85 percent and cobalt extraction of 90 percent were obtained.

Wah Chang Corp. patented a process for the beneficiation of ilmenite to produce a rutile-like product of improved character that is reportedly particularly effec-

[10] British Chemical Engineering. Computer Simulation of an Operating Chemical Plant. v. 10, No. 11, November 1965, pp. 770–771.

[11] Poole, David E. Hydrochloric Acid Pickling of Steel Strip. J. Metals, v. 17, No. 3, March 1965, pp. 223–224.

[12] Zubryckyi, N., J. I. Evans, and V. N. Mackiw. Preferential Sulfation of Nickel and Cobalt in Lateritic Ores. J. Metals, v. 17, No. 5, May 1965, pp. 478–486.

tive, by reason of the minimization of fines, as feed material for the fluidized bed chlorination process to produce titanium tetrachloride. The invention provides for a two-step leaching process in which the total hydrochloric acid values utilized do not exceed about a 20-percent excess over the stoichiometric amounts required for dissolution of the undesired acid-soluble nontitaniferous values in the ores. The first leach consists of acid from the second leach stage of a previous cycle plus additional fresh concentrated acid to provide 60 percent of the stoichiometric amount required to react with the iron and other acid soluble values other than TiO_2 in the ore. The second leach employs fresh commercial grade hydrochloric acid for about 50 percent of the remaining iron and other acid soluble values other than TiO_2 in the once-leached product. Both of the leaching steps proceed under a pressure of 30 to 35 pounds per square inch gage and with an operating temperature of about 105° to 110° C. Under these conditions, each leaching step requires only about 4 to 6 hours, and the resultant liquor contains 95 percent or more of the iron values present in the original ilmenite. The remaining solids assay over 90 percent TiO_2 and have essentially the same particle size range as that of the starting ilmenite ore.

The use of ion exchange resins in the cadmium recovery process employed at the Cockle Creek Works of Sulphide Corp. Pty. Ltd., Sidney, New South Wales, Australia, resulted in a major increase in the recovery and purity of cadmium produced as a byproduct for the company's lead-zinc facility.[13] A clarified sulfuric acid solution of hot gas electrostatic precipitator sludge is fed to a series of two columns containing Zeocarb 225 cation exchange resin. Arsenic, also present in the precipitator sludge and soluble in sulfuric acid, does not become attached to the resin since it is in anionic form. The loaded resins are washed free of cadmium by a sodium chloride solution. The strip liquor is collected in neoprene rubber-lined tanks, steam heated to 70° C, and trommeled with zinc rods to precipitate cadmium sponge. The sponge is collected and melted under a caustic soda flux to produce a crude cadmium metal which is subsequently purified by distillation to a marketable grade metal.

The application of rare-earth phosphors in the color TV tube necessitated expanded facilities and new processes for extracting europium and other family members from their rare-earth minerals. Details of such a process released during the year was that employed by the Molybdenum Corporation of America for the processing of bastnaesite at Mountain Pass, Calif.[14] The ore is concentrated by froth flotation from an essentially barite, calcite tailing, and it is acid leached to remove residual calcium. The resulting concentrate, averaging about 75 percent rare-earth oxides, is the feed material for the rare-earth chloride process employed at the company's plant in York, Pa. Here it is digested in hydrochloric acid at 200° F for 4 hours. After this period, the liquors are decanted from the reaction mass, and the undissolved solids subjected to a caustic metathesis step to recover any undigested rare earths. The metathesis cake (rare-earth hydroxide) is waterwashed and added to the original mother liquors, neutralizing the excess hydrochloric acid; the iron, lead, and excess sulfate content are reduced; and thorium is precipitated as hydroxide. The final solution, after clarification, is evaporated, yielding a mixed rare-earth chloride product. Details pertaining to the specific extraction and separation of europium from the mixed rare-earth chlorides have not been released.

A solvent extraction process was reported to be the key to recovering beryllium from minerals found on Topas Mountain, Utah. Laboratory and pilot plant studies by The Brush Beryllium Co. produced high-purity BeO from ore containing 0.5 to 1.5 percent of the oxide. In the new process, an organophosphate chelating agent selectively ties up the beryllium. The clay is first crushed, and then 10 percent sulfuric acid is added. The pH is kept at 0.5 to 1.5. The slurry is separated, with the beryllium-bearing solution fed into tanks where it is mixed with the organic phase containing the organophosphate. The organic phase then flows into mixing tanks where it is agitated with an alkaline solution which strips

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[13] Baker, F. H., and J. G. Munro. Cadmium Recovery by Ion Exchange. J. Metals, v. 17, No. 3, March 1965, pp. 255–260.

[14] Kruesi, Paul R., and George Duker. Production of Rare Earth Chloride From Bastnasite. J. Metals, v. 17, No. 8, August 1965, pp. 847–849.

the contained metal. The beryllium in the alkaline stripping solution is precipitated, washed, and calcined by conventional means to the oxide.

A new technique for the recovery of palladium and platinum from gold electrolyte that is said to eliminate many of the drawbacks of the zinc dust cementation process was developed and placed in operation by Canadian Copper Refiners, Ltd.[15] Discarded electrolyte from the gold recovery process is neutralized with caustic and oxalic acid added to precipitate the slight gold content. After a series of filtration steps, the resulting dark brown solution is heated with live steam to 180° F, and powdered sodium formate is slowly added. When all the palladium and platinum have precipitated, the solution turns clear white or green. The black precipitate is collected, dried, and analyzed. It will average 87.5 percent palladium and 8.0 platinum.

An electrolytic process for the refining of vanadium products containing as little as 80 percent vanadium was described by the Bureau of Mines.[16] Laboratory production tests were successful in preparing ductile, 99.6 percent metal from a metal analyzing 90 percent purity. The molten salt electrolyte contained lithium posassium and vanadium chlorides operated at 620° C and at cathode current densities of 250 to 400 amp per square foot. Hardness values as low as Rockwell B 21 were achieved for the pure metal. Metal recovery averaged slightly over 80 percent.

Another electrolytic process described was for the preparation of uranium and rare-earth metals from their oxides.[17] A cell was developed for the electrolytic reduction of the metal oxide from an electrolyte containing fluorides of lithium, barium, and the desired metal. Oxide solubility ranged from 2 to 4 percent in the fluoride melts used for electrolysis. Operating temperatures varied from 850° to 1,300° C depending upon the base metal. At this temperature, the product was in the molten state and collected at the bottom of the cell. By careful design of the cell, the valuable product could be tapped periodically, thereby avoiding shorting out of the electrodes by accumulation of the product and permitting continuous operation of the cell. Cerium, lanthanum, and uranium metals having purities in excess of 99.8 percent were obtained. Oxygen impurity values as low as 10 ppm were noted. The technique was believed modifiable for preparation of other reactive metals.

Pyrometallurgy

Cost estimates on changing technology in the steel industry are now being published. An economic evaluation of different types of blast furnace burdens, based on representative material cost figures and production results of tests and actual blast furnace operations, was presented at the AIME 94th Annual Meeting and subsequently published.[18] It was stated that economics will dictate a continuation of the shift, already in progress, toward higher and higher percentages of pellets in blast furnace burdens; and that as capital becomes available to build more pelletizing capacity, the operations which produce natural ores, coarse ore, and sinter fines will gradually be completely phased out of existence. Exceptions will be those mines which enjoy a preferred position due to either high ore quality, low cost of mining, or a favorable geographic location.

Cost evaluations published on the Kaldo oxygen steel-making process and the LD basic oxygen process indicated that their operating costs were very close; $53.14 per ton against $53.02 per ton, respectively, on the basis of 160 ingot tons of steel per heat.[19] The Kaldo process, developed in Sweden by Professor Bo Kalling at the Domnarvet Works of Stora Kopparberg Corp., was installed in the United States for the first time at the Sharon Steel Corp. Roemer Works in Farrell, Pa. The LD process was developed in Switzerland and Austria several years after World War II. Rapid expansion of oxygen steelmak-

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[15] Elkin, E. M., and P. W. Bennett. Palladium and Platinum From Gold Electrolyte. J. Metals, v. 17, No. 3, March 1965, pp. 252–254.

[16] Sullivan, T. A. Electrorefining Vanadium. J. Metals, v. 17, No. 1, January 1965, pp. 45–48.

[17] Henrie, T. A. Electrowinning Rare-Earth and Uranium Metals From Their Oxides. J. Metals, v. 16, No. 12, December 1964, pp. 978–981.

[18] Graff, Howard M., and Sidney C. Bouwer. Economics of Raw Materials Preparation for the Blast Furnace. J. Metals, v. 17, No. 4, April 1965, pp. 389–394.

[19] Dittman, Frank W. Oxygen Steelmaking Cost Comparison—Kaldo vs. LD. J. Metals, v. 17, No. 4, April 1965, pp. 372–379.

ing in the United States is taking place at the expense of two older processes, the basic open hearth and the acid bessemer process. Advantages and disadvantages of the four processes were described by F. W. Dittman in preparing his evaluations. He points out the remarkable change which has taken place in steelmaking that has had its toll upon the scrap metal industry. The Kaldo process employs about 44 percent scrap, whereas the LD process requires less than 30 percent. Since his cost calculations show that the two processes are competitive under U.S. economic conditions today, other factors must be considered in selecting one process over the other; such as the kinds of steels to be made, ease of process control, and percentage of scrap which should be utilized in the best overall economic interest of a given company.

A computerized study of blast furnace operation and thermal control was reported at the 23rd Ironmaking Conference.[20] Through the use of an IBM 1710 computer, a dynamic model of the blast furnace was first prepared which could be used for continuous process control, production control, and quality control of an actual blast furnace. The model controlled the process by using heat balance, quantitative analysis of top gas, temperature of top gas, and the measurement of heat loss in lower furnace. Having determined on a theoretical basis how the blast furnace should react under a given set of conditions, the model was tied into two actual blast furnace operations: One using 100 percent self-fluxing sinter and the other using a burden of ore and sinter. The results obtained from the test sequence indicated that a Wu factor (the energy transmitted by the gas to the burden at a temperature above 1,000° C, after correction for thermal losses) could be used as the basic indicator for qualitative control of blast furnace operation.

Lukens Steel Co. revealed late in 1964 that it had installed an IBM 1710 computer at its Coatesville, Pa., plant to control the electric furnaces in the melt shop.[21] The computer acts only as a data recorder during the charging and meltdown periods, and the operation of equipment is not fully automatic; the computer simply tells the furnace operator what to do, based upon the various input data fed to the machine from both automatic and manual operation. Use is on a round-the-clock basis for guidance during the refining period on carbon steel grades. Eventually, after sufficient data has been collected, it is believed that the computer could be employed effectively in scheduling other operations and facilities at Coatesville.

Changing steelmaking techniques were reflected by the placing on stream of a continuous degassing plant, capable of treating 1 ton of special steel per minute, at the Low Moor Alloy Steelworks, Ltd., Bradford, England. In the continuous degassing process, steel is sucked from a tundish into a preheated, refractory-lined vacuum vessel and discharged through a barometric seal into a second tundish. During preheating, glass is melted in the tundish to form the seal. When preheating is complete, the chamber is evacuated. As soon as the inlet tundish is full of metal, it is raised, breaking the steel rupture disc on the inlet pipe. The molten metal explodes into droplets as it is drawn into the vacuum chamber. When sufficient metal has been admitted to fill the outlet pipe and form a shallow pool in the hearth, the seal on the outlet pipe is broken. The metal is discharged continuously into the tundish until all the available metal has been used. By this technique 2.5-ton heats of high-chromium steels were degassed with about 50 percent hydrogen removal at an operating pressure of 1.6 to 10.0 torr. About 14 percent manganese was lost, with no significant change in oxygen or nitrogen content.

Conversion of old automobile and other waste metal appliances into a reusable steel product was the objective of several programs initiated by the Bureau of Mines. One research effort involves the incineration of scrap metal from autos, refrigerators, and other consumer items at controlled high temperatures to remove thin coatings and low melting point metals. Once such metals as aluminum, magnesium, zinc, and copper are removed, the remainder of the steel skeleton is melted at higher temperatures in a second furnace. The metal is cast into ingots ready

[20] Staib, Claude, and Jean Michard. On-Line Computer Control for the Blast Furnace. Part I. J. Metals, v. 17, No. 1, January 1965, pp. 33–39; Part II. J. Metals, v. 17, No. 2, February 1965, pp. 165–170.

[21] Gloven, Daniel O. Computer Control for Electric Furnace Steelmaking. J. Metals, v. 16, No. 11, November 1964, pp. 963–966.

for shipment to the reuser. Initial laboratory tests are being expanded to pilot plant scale to determine the factors which influence the rate at which the metal contaminants can be removed.

In another phase of the concerted attack on the problem of ever-increasing quantities of waste materials, the Bureau of Mines found that scrap steel from old auto bodies can be used to upgrade low-grade iron concentrates in a reduction roasting processs. In the process, both the scrap metal and the iron content of nonmagnetic taconite ores are converted to magnetic iron oxide which is easily recoverable in relatively pure form. Nonferrous impurities in the auto body scrap are removed during the magnetic separation step, and unconverted scrap is removed by screening for recycle. The net result is the total conversion of the iron and steel in auto body scrap (a material which is currently accumulating over the country in large, unsightly dumps) and the iron oxide in the nonmagnetic taconite (a material the country possesses in large quantities but which cannot now be economically used) into a high-grade iron ore readily usable by industry. Pilot plant studies are underway to develop sufficient information to design and build a demonstration production facility.

Electroslag remelting has reportedly been adapted to the production melting of special steels and alloys by Firth Brown, Ltd., of Sheffield, England. Electric current is passed through the slag layer which covers the molten steel. The slag's function is to convert electrical energy into heat without arcing and to protect the molten metal. The melting technique virtually eliminates nonmetallic inclusions, and segregation is considerably less than in conventionally melted steel. The cleanliness of the metal produced approaches that of vacuum-remelted steel.

Published information shows that 16 companies in the United States have authorized, are constructing, or are operating some type of continuous casting machine. Although continuous casting has been practiced almost exclusively with small heats of steel (5 to 30 tons), at least five of the new American machines authorized or under construction are designed to handle heats ranging from 180 to 300 tons.

The prime problem of continuous casting facing the industry are (1) the removal of gases contained in the metal prior to pouring, (2) the rolling of the slabs without cutting from the actual casting, and (3) automation of the entire process. Various techniques have been proposed for degassing, both in the ladle prior to addition to the casting unit and in a head tank above the casting unit. One such method uses a separate vacuum tank which sucks up metal from a feed trough and then passes it to the casting unit. Selection of off-machine ladle degassing or on-machine continuous degassing will likely depend upon the type of steel being cast.

The first curved-mold, continuous slab caster for stainless and alloy sheet to be installed in North America was placed in operation at Atlas Steel Company's plant at Tracy, Quebec, Canada. The machine is of the single strand curved-mold type, 34 feet high, and built to curve the strand to the horizontal on a 30-foot radius. In normal operation, steel is tapped from a 60-foot furnace to a 75-ton bottom pouring ladle and then fed to the machine which casts slabs up to 6 by 52 inches in cross section, at a rate of 20 to 100 inches per minute.

Another variety of continuous billet-casting unit was placed in operation at Armco Steel Corp.'s Sand Springs, Okla., works. The new Demag-Mannesmann-Bohler (DMB) casting units is a 6-strand "bow" type with an arc of 48.5-foot radius. A 75-ton ladle feeds metal at 2,925° to 2,965° F to a tundish which simultaneously casts six separate strands 2⅞, 3, or 4¼ inches square.

Kermac Nuclear Fuels Corp. of New Mexico started operation of a rotary kiln plant near Bowman, N.D., to treat 225 tons per day of raw lignite containing 0.42 percent U_3O_8 and 35 percent moisture to produce 75 tons per day of dry ash containing 0.68 percent U_3O_8 for conventional processing at Kermac's plant at Grants, N.M. Other companies, including Union Carbide Corp., have similar plants for ashing uranium-bearing lignite in the Dakotas. The 1- to 2-foot seams of lignite are strip mined from under 30 to 70 feet of overburden. Incoming ore is stockpiled at the plant, which operates all year; mining, which is on an 8-hour basis, is curtailed in winter. In the process, raw, wet ore passes over a 5-inch grizzley into hoppers that feed two double roll crushers, and then into one of the three 120-foot long by 7-foot diameter gas-fired kilns. Most of the necessary heat is supplied by the burning lignite. The kilns are unlined for the first 18 feet; and the rest is lined with 4 inches of firebrick. The ore dries in the first 25 feet, burns in the next 65 feet, and cools in the rest of the length. Additional air for burning the lignite enters through openings in the sides of the firing hoods and is controlled by dampers on the outlets of the kiln exhaust fans. Dust collectors are used in front of the fans, and the dust is added to the ash product. Ash from the kilns is sized on vibrating screens. The product is minus 6 mesh; oversize can be recycled through the kiln or crushed and rescreened.

Reynolds Metals Co. announced a freeze-purification process for producing super-pure aluminum metal from standard cell grade metal without use of the normal Hoopes 3-layer electrolytic refining cell.[22] The process comprises continuous fractional crystallization of a portion of a liquid aluminum stream during strong agitation near the surface of the growing crystal, thereby producing a solidified aluminum of substantially uniformly high purity. The slightly less pure portion of the molten stream is returned to the main metal supply. The degree of purification obtainable by freeze purification depends on the ratio of the solubility of the particular impurity in solid aluminum to its solubility in molten aluminum. Elements such as iron, slicon, copper, manganese, zinc, and gallium are greatly reduced in the final metal ingot.

Removal of inclusions from molten metal prior to casting has been the objective of many researchers. The Aluminum Company of America described two laboratory techniques it has developed for improving the quality of molten aluminum alloys before casting.[23] The first, a melt filtration process, involves passing molten metal downward through a packed bed of Tabular Alumina. This is an impingement type filter; hence, the size of the particles removed from the metal are considerably smaller than the interstices of the bed. No indication as to the minimum size of particles removed could be determined. The second technique, called the Combination Filtration-Inert Gas Fluxing Process, is a means of removing inclusions and of reducing hydrogen content of the metal. The bed of Tabular Alumina is employed, and, in addition, a stream of argon or nitrogen is added at the bottom of the filter bed. The upward sweep of the gas through the downward flowing metal permits any atomic hydrogen dissolved in the aluminum to diffuse into the inert gas, thereby reducing the hydrogen content of the final filtered metal. Reductions in hydrogen content as high as 75 percent were reported for this process.

A unique hydrogen-fluorine flame reduction process for obtaining refractory metal powders was described by investigators of the Oak Ridge Gaseous Diffusion Plant of Union Carbide Corp.[24] By changing the gas feed system so that tungsten hexafluoride is introduced to a reduction zone with fluorine gas rather than hydrogen, the resulting metal powder is much finer and pyrophoric in nature. Average crystallite size determined by X-ray diffraction is 340 Angstroms, and the surface area is about 12 square meters per gram when fluorine is present as the reduction gas. With one-third hydrogen mixed with fluorine, the resulting powders measure 447 Angstroms and have a surface area of 7.4 square meters per gram. Although the reduction reaction is highly exothermic, it is not self-sustaining, and continuous addition of fluorine is necessary. The average flame reactor product contains 300 to 500 parts per million of fluorine which can be reduced to as low as 7 parts per million by static bed treatment with hydrogen. Molybdenum, tungsten-molybdenum, and tungsten-rhenium powders also have been prepared by this technique.

Two new pyrite treating processes going into commercial use emphasize the production of an iron oxide product as well as sulfuric acid. The first, developed by Dorr-Oliver, Inc., and Montecatini, Soc. Generale per l'Industria Mineraria e Chimica for use at Follonica, Italy, employs a fluidized solids roaster to decompose pyrite and yield sulfur dioxide which is converted to sulfuric acid. The iron oxide calcine from the fluid bed and the dust recovered from the gas stream are sent to a second

[22] Dewey, John L. Freeze-Purification Process Upgrades Aluminum Purity. J. Metals, v. 17, No. 9, September 1965, pp. 940–943.

[23] Brondyke, K. J., and P. D. Hess. Filtering and Fluxing Processes for Aluminum Alloys. J. Metals, v. 17, No. 2, February 1965, pp. 146–149.

[24] Smiley, S. H., D. C. Brater, and H. L. Kaufman. Preparation of Refractory Metal Powders With Unusual Properties. J. Metals, v. 17, No. 6, July 1965, pp. 605–610

fluidized roaster for reduction to magnetite, which is further concentrated.[25] The second process is in commercial use by Outokumpu Oy at Kokkola, Finland, and another installation is under construction by the Lummus Co. for Brunswick Mining & Smelting Corp. Ltd. at Bathurst, New Brunswick, Canada. Following completion in 1966, the Canadian plant will convert 1.1 million tons of pyrite per year to 635,000 tons of iron pellets, 850,000 tons of sulfuric acid, and 250,000 tons of sulfur. In the first step of this process, a flash smelter, operating at about 2,500° F, decomposes pyrite to pyrrhotite and a gas from which sulfur is recovered as a separate product. The pyrrhotite is burned to yield sulfur dioxide, which is converted to sulfuric acid. The residual iron oxide is recovered for iron-blast furnace feed.[26]

Materials

Perhaps the one new material released in 1965 which will become familiar to every American is the sandwich-type, composite coin issued by the U.S. Government to reduce the ever-increasing demands for silver metal. Quarters and dimes, which have been made for the past 173 years from a 90 percent silver and 10 percent copper alloy, are now being minted from a material whose outside surfaces consist of an alloy of 75 percent copper and 25 percent nickel and whose core is pure copper. The half dollar is also being minted from a sandwich material consisting of outer layers of an 80 percent silver and 20 percent copper alloy over a core of 21 percent silver and 79 percent copper. The new half dollar contains only 40 percent silver instead of 90 percent as formerly. The new dimes and quarters contain no silver. The materials which are sandwiched together are produced by either a rolling or an explosive process that binds the metals together under very high pressure. The final bond is as stong as the individual metals, and the composite material can be bent, twisted, stamped, or heated without separation.

The technology for preparing solid shapes and the coating of others with refractory metals or their compounds by chemical vapor decomposition (CVD) has become a much more useful scientific accomplishment in the past year. A review of the history and the various technologies involved in CVD was presented at the 94th Annual Meeting of the AIME in Chicago this year.[27] Even though this technology is relatively old, its potential has not been fully realized because of the lack of fundamental knowledge. These include thermal decomposition (pyrolysis), hydrogen or active-metal-vapor reduction of volatile inorganic compounds, disproportionation reactions, and displacement reactions involving the substrate. At the present time, the metal receiving the greatest amount of attention is tungsten, largely because of its strength at high temperatures and its wide spread use as a thermionic-emitter.

Chemical vapor deposition processes continue to be the subject of increasing interest for applications in which it is difficult or impossible to use conventional methods for coating objects with metals or metal compounds.[28] Metal chelates of fluorocarbon-B-diketones were found satisfactory for obtaining coatings of copper, nickel, and rhodium on glass or stainless steel surfaces at temperatures as low as 250° C and at atmospheric pressure. Hydrogen gas is the reducing agent.

Chemical vapor deposition techniques have been investigated for coating steel tools and machine parts with titanium nitride and titanium carbide in an effort to improve the wear resistance and maintain good sliding properties.

General Technologies Corp. of Alexandria, Va., reported a process to deposit pure aluminum coatings of variable thicknesses on almost any substrate by vaporizing aluminum alkyl. Coatings produced in the laboratory ranged from 0.0003 to 0.1 inch and took 2 minutes per mil to deposit. Operating temperature is 350° F. In addition to the alkyl, a purging gas such as nitrogen is used to keep air out of the system and to act as carrier or

25 Journal of Metals. From Pyrite: Iron Oxide Pellets and Sulfuric Acid. V. 16, No. 11, November 1964, p. 866.

26 Chemical Week. Finding New Value in Fool's Gold. V. 96, No. 1, Jan. 2, 1965, pp. 27–29.

27 Sherwood, E. M., and J. M. Blocher, Jr. Vapor Deposition: The First Hundred Years. J. Metals, v. 17, No. 6, June 1965, pp. 595–599.

28 Van Hemert, R. L., L. B. Spendlove, and R. E. Sievers. Vapor Deposition of Metals by Hydrogen Reduction of Metal Chelates. J. Electrochem. Soc., v. 112, No. 11, November 1965, pp. 1123–1126.

dilutant. A proprietary suppressant gas is used by General Technologies to avoid reactions that might lead to formation of aluminum carbide or hydride.

Two methods for applying coatings of tungsten or molybdenum to the surface of powdered magnesia, alumina, and other refractory particles were investigated by the Bureau of Mines.[29] In one case coatings were applied by the vapor phase hydrogen reduction of tungsten or molybdenum chlorides at 750° to 900° C. Coating rates up to 6 grams of metal per hour were obtained on a particle bed of 100 grams. The second process was a 2-step system in which an oxide of either metal was first applied to the particle and subsequently reduced by hydrogen. Trioxide particles of either tungsten or molybdenum were added to a heated, fluidized bed of the particles to be coated at 850° to 1,000° C, thereby forming a coating on the latter. After lowering the chamber temperature to 750° to 850° C, the addition of hydrogen reduced the surface oxides to metal coatings. By repeating the two steps any number of times, any thickness of coating could be obtained.

The feasibility of producing tungsten, iron, and nickel base alloys with or without a dispersal phase using very fine sized elemental powders and standard powder metallurgical techniques for space applications was investigated by many research groups. Researchers at Aerospace Corp., El Segundo, Calif., found that 10 volume percent of thorium oxide in a 68 percent tungsten, 20 percent tantalum, 12 percent molybdenum alloy increased oxidation resistance from three to ten times at temperatures ranging from 1,600° to 3,000° C.[30]

Foote Mineral Co. developed an alloy steel that contains only 12.5 percent nickel yet has the characteristics of maraging steels containing 18 percent nickel. Actual alloy composition is 12.5 percent nickel, 2 percent manganese, 0.2 percent titanium, 0.1 percent aluminum, and the balance iron. Part of the nickel was replaced by less costly manganese. Increasing or decreasing the manganese content from 2 percent did not improve the alloy characteristics.

A review of the theory and practice of making synthetic diamond was presented this year before the Eighth Commonwealth Mining and Metallurgical Congress of Australia and New Zealand.[31] Problems of die material and design as well as techniques for measuring temperatures and pressures at the reaction point still need to be solved.

Brush Beryllium Co., Elmore, Ohio, expanded part of its metal processing system. Improved production equipment for making uniformly sized pure beryllium pebbles for alloying with other metals has been installed. Using a modified wet grinding system, 500 pounds of pebbles are obtained in 4 hours. The grinder is charged with 6,600 pounds of crushed billets containing beryllium pebbles, used beryllium fluoride, and fused magnesium fluoride. During wet grinding in a ball mill, water leaches out the beryllium fluoride, while the more friable magnesium fluoride grinds down and passes through the discharge screen. Direction of the mill is reversed at the end of the run to discharge the beryllium pebbles. The equipment is fabricated of 316 stainless steel to withstand corrosion. During operation, the system is sealed under slightly negative pressure to avoid leakage.

Beryllium sheet rolled directly from ingot rather than from powder metallurgy billets was produced as a result of a research and development program sponsored by the U.S. Air Force and The Beryllium Corp. The directly rolled sheet is characterized by low oxygen content, which results in significantly greater ductility at forming temperatures. Analyses indicate less than 0.30 percent BeO and almost a total absence of nonmetallic inclusions.

The potentials of extreme strength, high modulus, and light weight are pushing the development of numerous new fiber reinforced composite materials which are expected to create metalworking problems. It is not yet known if metallic composites will be made amenable to extrusion or subsequent forming operations after they are pressed in their original shape. Even with this problem, Air Force attention is centered on metallic matrix composites,

[29] Landsberg, A., T. T. Campbell, and F. E. Block. Tungsten and Molybdenum Coated Nonmetallic Powders. J. Metals, v. 17, No. 8, August 1965, pp. 850–855.

[30] White, J. E. Alloy and Dispersion Strengthening by Powder Metallurgy. J. Metals, v. 17, No. 6, June 1965, pp. 587–593.

[31] James, G. S. Some Metallurgical Aspects of the Production of Synthetic Diamonds. 36th Technical Session of the Eighth Commonwealth Mining and Metallurgical Congress, Melbourne, Australia, 1965, Preprint No. 151.

because they seem to offer definite advantages over improved resinous composites. Among the advantages, metallic matrices can utilize all the strength of either short or long fibers, whereas resin composites require continuous fibers for proper reinforcement.

Even though a major research and development effort is aimed at fiber-reinforced composites with metallic matrices, glass filament resin composites are being used extensively. Glass filament rocket cases are used in the upper stage of the Polaris A-3 and the third stage of the Minuteman 3 missiles to achieve remarkably extended ranges as a result of the weight reduction. In addition to light weight, glass filament materials are attractive for radar-deceiving capabilities because they do not reflect radar waves.

Near the end of the year, Union Carbide Corp.'s Carbon Products Division announced a new graphite filament called Thornel which was said to be the strongest and stiffest fiber for its weight ever produced. It can be used for reinforcing both resin and metal-matrix composites. Laboratory fibers were reported with tensile strength of 400,000 pounds per square inch, modulus of elasticity of 50 million pounds per square inch, and density of 0.054 pound per cubic inch. One variety of the material, Thornel 25, is being sold for $500 a pound and has a tensile strength of 200,000 pounds per square inch and a modulus of 25 million pounds per square inch for the 0.2 mil filaments. In comparison, boron filaments cost $1,500 a pound for material having tensile strength of 350,000 pounds per square inch, modulus of elasticity up to 50 million pounds for square inch, and density of 0.1 pound per cubic inch. Laboratory strength and modulus have been reported double these figures for boron. Boron filament is made by vapor deposition of boron on an inert tungsten filament. Thornel is thought to be made by an improvement in Carbide's technique used since 1959 for carbon yarn in which a carbon-chain synthetic organic fiber is pyrolized. Research is starting on the effectiveness of the new filament and potential matrix materials. The high-temperature strength of graphite is a major advantage; its tensile strength is unaffected at 2,800° F.

The Carborundum Co. announced a decrease in price of silicon carbide whiskers from $45,000 to $1,000 a pound as the whiskers became available for commercial distribution. Tensile strengths of the whiskers are about 1 million pounds per square inch, with an elastic modulus of 70 million pounds per square inch.

Two researchers at the General Electric Co. Research and Development Laboratory in Schenectady, N.Y., found that the addition of iodine to ordinary lubricating oils will allow the use of such metals as stainless steel or titanium for moving parts in machines where formerly parts fabricated from these metals would gall and stick even where the surfaces were coated with oil. They found that iodine reacts with clean titanium and stainless steel surfaces to form titanium and iron diiodides. These compounds have a lamellar crystal structure similar to graphite and have planes of very low shear strengths which allow them to act as effective lubricants. Normally the metals are unreactive to iodine, but in the presence of a sliding interface, the protective oxides are ruptured through spot pressure welding and the fresh metal exposed forms the diiodides. Compared with conventional products, lubricants containing 0.25 to 0.5 percent iodine reduce the coefficient of friction up to 75 percent. When used in cutting oils, they increase the cutting speed by 100 percent and the cutting depth by 400 percent.

Metalworking problems in tooling and lubrication are also expected to arise from expanded use of ceramic, superalloy, and refractory materials. Titanium alloys require special attention with regard to contamination and cleanliness; there is enough chlorine in tap water to cause cracking. Beryllium requires incremental cuts of no more than 0.0005 inch to avoid notching efforts. Columbium alloys are the most highly considered of the refractory metals, but temperature control in processing is critical for maximum properties. Brittleness is the major problem in handling ceramics and graphite. The high-temperature vapor deposition used to make pyrolitic graphite results in high residual stresses on cooling, thereby thwarting machining. Electron beam or laser cutting may have to be used for shaping.

Review of Mining Technology

By James E. Hill [1,2] and Thomas M. Nasiatka [1,2]

Tremendous improvements in mining technology have been witnessed during the past 100 years. For example, before 1860 all blastholes were drilled manually and blasting was done with low-energy blackpowder. During the 1860's both the pneumatic rock drill and high-energy dynamite were introduced, ushering in an era of mining mechanization that has steadily progressed since that time.

Today, with the rapid implementation of the latest advances in communication science, mining technology is moving into a new era that goes beyond mechanization as such. Transistors, transducers, scanners, telemetry, and the like, all terms largely derived from the new communication sciences, add up to what is popularly know as automation—the communication of machine with machine. Automation is now playing an important role in selected parts of the mining process, such as hoisting, hydraulic roof supports, and underground surface locomotive haulage and belt conveyor systems. But this year marked the first attempt to automate the total mining process with the commencement of production at the British National Coal Boards Bevercotes mine. If this full-scale experiment proves successful, it could lead towards other fully automated mines in both Britain and other parts of the world. This decade, therefore, could be considered the one that provided the foundation for the mines of the future.

Although the inauguration of automated mining is considered the technological highlight of 1965, there were other significant advancements in mining technology. Generally, the advancements were in the form of wider application and improvements in practices initiated earlier. There were, however, several innovations, such as a novel drive-method for monorail systems, a rigmounted computer to control drilling, a special multiple-impact hammer for cable drilling, a new process for sharpening tungsten carbide bits and use of odorless oils in ammonium nitrate-fuel (AN–FO) oil blasting agents.

EXPLORATION AND SAMPLING

Several new techniques were reported during the year that appear promising in certain areas of mineral exploration. A truck-mounted transistorized gamma-ray spectrometer was used to successfully determine the intensity of hydrothermal alteration zones surrounding base metal deposits in Arizona.[3] Equating spectrometric with chemically analyzed data gave standard errors of 0.06 percent potassium, 3 parts per million thorium, and 10 parts per million uranium for outcrop analysis with the spectrometer. The amount of potassium introduced by hydrothermal alteration in some areas is believed to be of sufficient quantity to be detected by either surface or aerial spectrometry. Another possible method of locating economically important ore bodies is through spectrophotometric trace element analysis. High concentrations of the base metals were ascertained through spectrophotometric analysis of soil horizons above a copper-

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[1] Mining engineer, Office of the Director of Mining Research.

[2] Compiled in part from material submitted by Bureau of Mines Mining Research Centers and Laboratories.

[3] Moxham, R. M., R. S. Foote, and C. M. Bunker. Gamma-Ray Spectrometer Studies of Hydrothermally Altered Rocks. Econ. Geol., v. 60, No. 4, June–July 1965, pp. 653–671.

zinc ore deposit.[4] This sensitive method is also useful in geochemical exploration for ore deposits of gold, silver, lead, and bismuth.[5] A new electron microprobe analyzer used extensively in France has been responsible for a number of accurate determinations of trace elements occurring in ores.[6] The microanalyzer, based on the principle of direct X-ray spectrography, can become an important tool for rare mineral exploration. It is reported to be the only instrument that will enable a thorough evaluation of mineral associations. The main feature of this instrument is the possibility of completing a series of elemental analyses of practically "point" areas. Tests are effected on polished surfaces and are nondestructive. In a different domain, a sonar probe has been developed which is capable of discerning the depth and contours of sea-bottom sedimentary layers and locating buried objects down to 50 feet from the bottom.[7] The probe can also be used near the surface of the sea for preliminary reconnaissance operations.

A new concept of prime ore control in Missouri's Lead Belt has resulted in discovering an essentially new district.[8] Ore control was premised on paleophysiography and sedimentation rather than on mechanical deformation.

A statistical investigation of copper lode distribution in a shear zone in India relative to several geological factors indicated that structure was the guiding control in locating these ore deposits.[9] It was reported that similar analysis could be an aid in locating favorable exploration sites in other areas of mineralization and could be utilized as an added tool in exploration programs. Statistical methods were used also to recognize anomalous samples in geochemical surveys.[10] Statistical evaluation indicated that it is relatively easy to guarantee recognition with a probability of success greater than 0.99.

Several reports were published by the Bureau of Mines regarding pertinent applications of mathematical statistical theory to mineral sampling.[11] One of the reports describes a more efficient and flexible method of spacing exploratory holes. The method is useful in delineating any mineral deposit from a limited number of drill hole samples. A formula is provided for laying out a grid or pattern for additional sampling holes as required. As each hole is drilled and samples from various depths are analyzed, the data are immediately correlated with the previous samples. In this manner, it can be determined whether additional holes are desirable as well as their location and depth. Although a computer was used for the original calculations, it is not required in applying the method.

The Mohole project was reactivated and plans made to drill to a depth of 35,000 feet in the Pacific Ocean near Hawaii. The work is of interest to the mining and petroleum industry from the standpoint of pioneering deep exploration equipment. The large, specially designed drilling platform was under contract for construction. A turbocorer drill has been developed, differing from the conventional turbodrill in that the hollow stem permits a rock core to be taken. Drill tests to 3,000 feet in basalt at the Uvalde, Tex., test site indicated a penetration rate of more than 5½ feet per hour and as much as 200 hours between bit changes.

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[4] Scott, B. P., and A. R. Byers. Trace Copper and Zinc in the Coronation Mine Overburden. Canadian Min. and Met. Bull., v. 58, No. 637, May 1965, pp. 534–537.

[5] Lakin, H. W., and H. M. Nakagawa. Simplified Spectrophotometric Determination for Gold. Eng. and Min. J., v. 166, No. 10, October 1965, pp. 108–110.

[6] Canadian Mining Journal. Electron Microprobe Analyzer—A New Tool for the Geologist. V. 86, No. 3, March 1965, p. 58.

[7] Mining Magazine. Pinger Probe. V. 112, No. 1, January 1965, p. 41.

[8] Henshaw, Paul C. Exploration for Lead in Southeast Missouri. Min. Cong. J., v. 51, No. 12, December 1965, pp. 28–30.

[9] Ghosh, A. K. A Statistical Approach to the Exploration of Copper in the Singhbhum Shear Zone, Bihar, India. Econ. Geol., v. 60, No. 7, November 1965, pp. 1422–1430.

[10] Langford, F. F. A Method to Evaluate the Probability of Success of a Geochemical Survey. Econ. Geol., v. 60, No. 2, March–April 1965, pp. 360–372.

[11] Becker, Robert M. Some Generalized Probability Distributions With Special Reference to the Mineral Industries (in Five Parts). 3. Computer Programs of Distribution Moments. BuMines Rept. of Inv. 6598, 1965, 79 pp.

Becker, Robert M. Some Generalized Probability Distribution With Special Reference to the Mineral Industries (in Five Parts). 4. Experimental Confirmation. BuMines Rept. of Inv. 6627, 1965, 57 pp.

Hewlett, Richard F. Design of Drill-Hole Grid Spacings for Evaluating Low-Grade Copper Deposits. BuMines Rept. of Inv. 6634, 1965, 46 pp.

Schottler, George R. Statistical Analysis of Gamma-Ray Log Sample Data From a Uranium Deposit, Ambrosia Lake Area, McKinley County, N. Mex. BuMines Rept. of Inv. 6645, 1965, 49 pp.

DEVELOPMENT

Prospects for a breakthrough in mine development technology were made brighter during 1965 as indicated by continuous mechanical boring machine activities. Tests with a 7-foot-diameter boring machine in a Michigan iron ore mine were completed and it was reported that this method can be more economical than conventional methods and that the heading advancement rate per man-shift can at least be tripled.[12] A 100-horsepower machine equipped with 14 disc cutters and a center three-cone bit, bored through rock having a compressive strength of 8,000 to 20,000 pounds per square inch in drifts and inclines with gradients up to 22 degrees at a rate of 4 feet per hour. Based upon a conservative estimate, headings could be advanced 52 feet per day with a larger 150 horsepower boring machine. Although the anticipated major rewards of boring through rock will be more rapid advancement per man-shift and lower cost per foot, the principle of boring instead of blasting has other important advantages. The ground is not disturbed as with blasting and the smooth circular cross section has greater strength, and therefore ground support problems are minimized. In addition, materials handling is simplified because the excavated rock is smaller in size. Other encouraging boring activities outside the mining industry are the continuing successes in general purpose tunneling. A 1,000-horsepower boring machine is driving a 20-foot-diameter tunnel through sandstone having a compressive strength of 5,000 to 6,000 pounds per square inch at speeds up to 120 feet per day.[13] The machine which maintains grade and line with a guidance system incorporating a laser beam was reported to be the most powerful hard rock tunneling machine ever built. It weighs 280 tons and exerts a thrust of 1.4 million pounds against the face. An unusual feature of the machine is a cutting head capable of drilling three different hole sizes ranging from 19 feet 10 inches to 21 feet 2 inches. The larger diameter holes are bored as needed to provide adequate space for placing ring-beam supports. The cutterhead having 43 rolling burr-type cutters rotates up to 5 revolutions per minute. Muck removal is accomplished by a system of buckets mounted on the rotating cutterhead which feeds an overhead conveyor belt extending from the front to the rear of the machine. Another machine was used to bore a 13-foot-diameter tunnel up to 200 feet per day through shale having a compressive strength of 3,000 to 11,000 pounds per square inch.[14]

A new world shaft sinking record was claimed by a South African team.[15] A 20-foot-diameter, 4,295-feet-deep concrete-lined shaft was sunk in 180 days. The average sinking rate was 23 feet 9 inches per day. An unusual shaft was sunk at a Montana mine.[16] Part of the shaft is inclined and part is vertical, requiring a unique underground hoisting arrangement because the shaft changes direction from vertical to 71.5 degrees. The International Nickel Company of Canada, Ltd., has announced the initial opening of the deepest single mine shaft in the western hemisphere at its Creighton mine.[17] The 21-foot-diameter shaft will be sunk to a depth of 7,150 feet. This deep, single-stage hoisting shaft was made possible because of the high-tensile-strength ropes now available. The four 2-1/5-inch-diameter ropes required a breaking strength of 270 tons and weigh 30 tons each.

DRILLING

A logical approach to lower drilling costs involves more intelligent use of variables affecting drillability. This approach was successfully demonstrated with the aid

[12] McAuliffe, J. D. Testing of a Seven-Ft. Tunnel Borer. Min. Cong. J., v. 51, No. 6, June 1965, pp. 49–55.

[13] Engineering News-Record. Mole Bores Tunnel No. 1; Miners, No. 2. V. 175, No. 20, Nov. 11, 1965, pp. 26–33.

Mining Engineering. Hughes Tool Manufactures a Big 20-Ft. Diameter Tunneling Machine. V. 17, No. 6, June 1965, p. 27.

[14] Engineering News-Record. Rock Mole Makes 200 ft. a Day. V. 174, No. 19, May 13, 1965, p. 30.

[15] Skillings' Mining Review. Shaft Sinking Record at Western Holdings Gold Mine. V. 54, No. 35, Aug. 28, 1965, p. 20.

[16] O'Donnel, J. C. A New Angle in Shaft Sinking. Min. Eng., v. 17, No. 11, November 1965, pp. 75–76.

[17] Canadian Mining Journal. INCO Marks Opening of Continent's Deepest Single Mine Shaft. V. 86, No. 11, November 1965, pp. 88–89.

of the first electronic computer to be used on a drilling rig.[18] Optimum drilling energy values for respective formation intervals within the borehole and for given drilling equipment, based upon analyses of extensive drilling data, were fed into a small computer on the rig. The computer instantly calculated and precisely controlled the appropriate bit weight for any rotary speed used and also limited the weight to any predetermined value. Substantial reductions in rotating time and better bit performance were reportedly achieved resulting in attractive reductions in drilling costs.

A precision drilling technique for long holes using ordinary hammer drills with 1¼-inch-diameter extension drill steel was described.[19] The technique used in Sweden for driving raises up to 165 feet in length, involves the use of guide tubes which are significant in maintaining the desired hole direction. With the standard equipment outlined in the report, it is possible to achieve a drilling precision of approximately 0.5 percent deviation over the length of the hole.

A recent innovation, called a "chatter hammer" was described as the first major breakthrough in cable drilling in more than a century. The hammer looks like any other ordinary drill stem, but has a sealed, self-contained unit with no exterior moving parts and no requirement for lubrication or adjustment. An internal piston-action mechanism which automatically produces at least two impacts for a single tool stroke is the special feature of the tool. Standard hammer sizes are 4½ inches by 17 feet and 4½ inches by 20 feet for 6- and 8-inch holes, respectively, and can be used on any make of cable-tool-drilling machine. The hammer is reported to have been a major factor in doubling drilling speed and bit life.[20]

The continued interest and developments in thermal rock drilling were indicated in several published reports. One report about jet piercing and chambering provided performance data, reviewed the equipment in use, and described the most recent developments.[21] On a one-shift basis a single air-fuel oil jet-piercing machine weighing 30 tons was responsible for the production drilling of 9,000 yards of ore at 2 cents per yard. The largest jet-piercing machine used industrially when this report was written weighed 45 tons and drilled a 55-foot-deep hole with an oxygen-fuel oil rotary drill. It drills a nominal 9-inch diameter hole which can subsequently be chambered to diameters up to 24 inches, if desired, for the explosive load. A future development which reportedly is progressing favorably is the conversion of oxygen-fuel oil rotary drills to air-fuel oil rotary drills with the expectation of equal drilling rates at a much lower cost. Other reports about thermal drilling described the thermal conductivity of six rocks amenable to this method of fragmentation,[22] and a drilling technique that utilizes an electrically heated bit of refractory metal to melt its way through rock.[23] A 2-inch electrical bit which was heated to 1,200° C from a portable 5-kilowatt generator drilled through basalt at a rate of 50 feet per day. The bit is internally water-cooled and with low pressure, the melted rock is extruded upward through the center tube then flaked away and blown out of the drill string. It is believed that the bit could be scaled up to 8 inches in diameter and could be heated adequately with a 90-kilowatt generator.

Drilling and blasting was the primary subject of a meeting held during the year.[24] Most of the papers presented stressed the behavior of rock under dynamic loads induced by rock penetration and fragmentation processes and the nature of these processes themselves. Some of the subjects discussed were thermal and explosive drilling, tungsten carbide bits, and a drillability index. The proposed index classifies

[18] Mechem, O. E., and Hal B. Fullerton, Jr. Computers Invade the Rig Floor. Oil and Gas J., v. 63, No. 41, Oct. 11, 1965, pp. 125–140.

[19] Caspar, Jorgan. Raising by Long-Hole Drilling. Min. Mag., v. 112, No. 4, April 1965, pp. 220–241.

[20] Coal Age. Breakthrough Announced in Cable-Tool Drilling. V. 70, No. 8, August 1965, p. 108.

[21] Short, J. F. Jet Piercing and Chambering for Improved Open-Pit Operations. Canadian Min. and Met. Bull., v. 58, No. 639, July 1965, pp. 729–731.

[22] Marovelli, Robert L., and Karl F. Veith. Thermal Conductivity of Rock: Measurement by the Transient Line Source Method. BuMines Rept. of Inv. 6604, 1965, 19 pp.

[23] Armstrong, Dale E., and others. Rock Melting as a Drilling Technique. Los Alamos Scientific Lab., Los Alamos, N. Mex., LA–3243, TID–4500, 37th ed., Mar. 15, 1965, 39 pp.

Engineering and Mining Journal. New Thermal Drill Bit Melts its Way in Rock. V. 160, No. 5, May 1965, pp. 104–105.

[24] Colorado School of Mines, and others. VII Symposium on Rock Mechanics 1965, Pennsylvania State Univ., June 14–16, 1965 Proc. Preprints. Society of Mining Engineers of AIME, v. 1, 208 pp.; v. 2, 323 pp.

a given rock type under the three major drilling systems; rotary, percussive, and rotary-percussive. The drillability index was based upon 98 kinds of rocks.

Some interesting Canadian open-pit performance and drilling cost data were published during the year. At one mine where copper-iron ore is being extracted, tests showed that an electric-powered rotary drill was superior to both an electric powered down-the-hole percussion drill and a diesel-powered rotary drill.[25] The drilling cost of 1 cent per ton broken was half as much and the tons drilled per shift were twice as much with the electric-powered rotary drill as compared with the other drill types. At another mine where copper ore is being extracted down-the-hole drills were claimed to be most efficient.[26] The operating cost averaged about 4 cents per foot of depth for 6-inch-diameter holes.

A spark erosion process developed for sharpening tungsten carbide bits could liberate rock bit design limitations now imposed by conventional grinding.[27] The new process was used to restore most of the bits at a Canadian mine. It is basically a controlled application of the same occurrence which takes place when an electric knife switch is opened and closed. By using a generator system to continually charge a capacitor bank, a steady stream of sparks flow from the electrode to the bit. Any desired shape can be imparted to the bit by altering the electrode design. Although this method of sharpening bits is not quite as cheap as conventional methods, the overall bit cost of drilling is reduced. Bit life has been increased 50 percent because of less metal being removed, lower residual stresses, and a more accurate profile.

A world drilling record was set in Canada with a recently developed button bit.[28] Using an 8¾-inch-diameter bit with compressed air as the circulating medium, 5,460 feet of rock was drilled in 66 hours without changing the bit. It was reported that this was about 1/10 the drilling time required, using mud with conventional bits that must be changed every 150 feet. The new record of 83 feet per hour is 25 feet per hour faster than the former record set in Texas. Button bits are also finding wide application for percussion drilling of hard rock holes as small as 1¼ inches in diameter.

FRAGMENTATION

Since ammonia nitrate was introduced to the mining industry as a blasting agent 10 years ago, it has been rapidly adopted, particularly at surface mines. Today for example, only one surface coal operation is known to be using liquid oxygen and none are using dynamite as the sole blasting agent.[29] All other surface coal operations are using AN–FO for blasting. The application of AN–FO for underground blasting in non-coal mines is increasing also. It has almost replaced nitroglycerine at the Great Boulder mine because of lower overall blasting cost and improved fragmentation.[30] With the increased use of ammonium nitrate explosives, the static electricity problem has become more critical, especially during bulk loading in dry atmospheres. This problem has been mitigated substantially by a recently introduced electric blasting cap.[31] The improved cap provides a fivefold increase in static electricity resistance and a threefold increase in arc resistance.

Outside the coal stripping industry where more powerful explosives are required, high energy metallized blasting slurries appear destined to replace AN–FO. A number of larger mines are already blasting by this method.[32] Some of the reported advantages of using this blasting method other than its higher energy are speed of loading, complete filling of the blasthole, flexibility of pumping several

[25] Gibbs, J. M. Open-Pit Drilling and Blasting at Craigmont Mines Limited. Canadian Min. and Met. Bull., v. 58, No. 638, June 1965, pp. 628–631.

[26] Kermee, J. S. Drilling and Blasting at the Phoenix Mine. Canadian Min. and Met. Bull., v. 58, No. 638, June 1965, pp. 632–633.

[27] Engineering and Mining Journal. TC Bits Sharpened by Spark Erosion. V. 166, No. 4, April 1965, p. 6.

[28] Canadian Mining Journal. B. A. Drilling Crew Sets World Record. V. 86, No. 8, August 1965, p. 92.

[29] Dannenberg, Joe. How Much Did AN/FO Lower the Highwall? Coal Min. and Proc., v. 2, No. 6, June 1965, pp. 22–27.

[30] Mining Magazine. Great Boulder Changes to AN/FO. V. 113, No. 4, October 1965, pp. 309–313.

[31] Mining Magazine. New Caps Provide Extra Safety. V. 112, No. 6, June 1965, p. 417.

[32] Conger, H. M. Metallized Slurry Blasting. Min. Eng., v. 17, No. 11, November 1965, pp. 52–53.

Cook, Vernon O. Will Slurry Blasting Agents Replace AN/FO? Metal Min. and Proc., v. 2, No. 3, March 1965, pp. 25–26.

grades of explosive, safety of on-site mixing, and lower overall cost.

Continued interest is being shown in inclined blast holes. Experiments at a Mesabi range taconite mine in Minnesota have indicated that inclined holes are desirable.[33] Additional tests are being made to determine the most advantageous blasting pattern. Results thus far indicate that the best hole angle is 10 degrees. Although fragmentation is satisfactory at 20 and 30 degree angles, the muck pile is too flat.

Results of several research studies on blasting were published during the year. One study showed that a presplit fracture plane did not cause a significant reduction in the vibration level during the primary fragmentation blast in the area behind the fracture plane.[34] It was also shown that the vibration levels from the blast used to form the presplit can be higher than any of the primary rock breakage blasts. Another study showed that decoupling the charge is of greater importance than the type of stemming for producing the maximum transfer of explosive energy to the rock.[35] A third study showed correlations between methods of evaluating explosives.[36]

There was an increased interest in developing unconventional methods of breaking rock. Progress and future potentialties of these techniques were described including ultrasonic vibration, steady and pulsed high-pressure water, thermal, electrical, chemical, and compressed air-abrasive methods.[37] Other reports described the feasibility of using nuclear explosives for removing overburden from certain types of deposits[38] and for fragmenting oil shale through 2-foot diameter boreholes.[39]

A new world record for tonnage of ore broken and amount of explosives used in a single blast was established in a Canadian mine.[40] The biggest blast in the history of underground mining broke 3.75 million tons of ore and 1.5 million tons of rock. More than a year of planning went into the blast which required 1 million feet of drilling in 16,700 holes. Delivery and loading of the 19,000 cases of cartridge powder weighing a total of 464 tons required a week involving 130 men per shift. The full 31-cap delays were used to spread the total blast over 3 seconds.

MATERIALS HANDLING

The ability of some mines to lower costs and increase production was attributed in a large degree to automated or improved materials handling practices. Costs at an Arizona open pit mine for example, were reduced substantially by introducing radio remote control equipment as an aid in operating more than 20 haulage trains.[41] This reportedly is the first large-scale application of radio remote equipment to standard gage railroad trains. Higher production and lower costs were attributed to reducing train crews from two men to one man, ease of spotting cars, and fewer derailments. Completely automated trains are being used at the Carol mine of the Iron Ore Company of Canada to haul ore approximately 6 miles to a concentrating plant.[42] The system includes four 1,750-horsepower diesel-electric locomotives, each handling 15 ore cars of 100-ton capacity, and it is used to haul a minimum of 55,000 tons per day of ore. The operation of each locomotive is controlled automatically from the wayside by coded alternating current. The current is interrupted at various code rates to provide the required commands. At another mine, production was claimed to be increased 30 percent by installing an improved materials handling system between a continuous coal mining machine

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[33] Gilmore, Emmett M. Angle Hole Drilling. Min. Cong. J., v. 51, No. 8, August 1965, pp. 39–42.

[34] Devine, James F., Richard H. Beck, Alfred V. C. Meyer, and Wilbur I. Duvall. Vibration Levels Transmitted Across a Presplit Fracture Plane. BuMines Rept. of Inv. 6695, 1965, 29 pp.

[35] Fogelson, D. E., D. V. D'Andrea, and R. L. Fischer. Effects of Decoupling and Type of Stemming on Explosion-Generated Pulses in Mortar: A Laboratory Study. BuMines Rept. of Inv. 6679, 1965, 18 pp.

[36] Sadwin, L. D. and W. I. Duvall. A Comparison of Explosives by Cratering and Other Methods. Trans. AIME, v. 232, June 1965, pp. 110–115.

[37] Farmer, I. W. New Methods of Fracturing Rocks. Min. and Minerals Eng., v. 1, No. 5, January 1965, pp. 177–184.

[38] Sighal, R. K. Explosives for Surface Mining. Min. Mag., v. 112, No. 6, June 1965, pp. 372–381.

[39] Canadian Mining Journal. Progress in Oil Shale Studies. V. 86, No. 6, June 1965, pp. 71–72.

[40] Engineering and Mining Journal. INCO's Big Blast. V. 166, No. 2, February 1965, p. 6.

[41] Orr, D. H., Jr., and F. G. Berra. One-Man Remote Control Rail Haulage. Min. Eng., v. 17, No. 4, April 1965, pp. 75–79.

[42] Travis, Leslie. Automated Railroad Haulage. Min. Cong. J., v. 51, No. 9, September 1965, pp. 104–107.

and the main haulage conveyor.[43] The system comprises a unique mobile bridge conveyor and an extensible panel conveyor providing continuous material flow from the mining machine to the main haulage conveyor. An additional benefit of the new system is that it is cheaper to maintain than commonly used shuttle cars. Maintenance costs are no more than 2 cents per ton as compared with 5 to 13 cents per ton for shuttle car maintenance.

Surface mining materials handling equipment sizes continued to increase. A 240-ton capacity truck was placed in operation at a coal pit that is using a 180-cubic yard shovel.[44] The truck which is 96 feet long has a 1,000-horsepower diesel engine and tractor at each end. It can be operated similarly to a shuttle car at a maximum speed of more than 40 miles per hour. Both the truck and shovel are the largest in the world. In hard rock pits where truck capacities normally range from 35 to 85 tons, new units are being marketed with capacities of 100 and 110 tons.[45] Instead of using trucks to haul overburden, The Anaconda Company will use a belt conveyor system at one of its open pit mines because of the depths, tonnages, and operating costs involved.[46] The conveyor system will be 11,000 feet long, including a single section 8,300 feet long. It has been described as the longest known single overland belt conveyor used in open pit mining in the United States. The 5-foot-wide conveyor will be reinforced with high-tensile steel cable under a ½-inch-thick top rubber cover.

The use of monorail systems for transporting both men and material in Europe and South Africa continued to expand. This expansion is attributed to certain basic advantages over conventional twin-rail methods.[47] Major advantages claimed are the ease in negotiating steep gradients, sharp curves, corners, and undulations; virtual impossibility of derailment; and the simplicity and speed in extending the monorail. Also, maintenance and operating costs are reported to compare favorably with conventional haulage. One system recently installed in a South African gold mine is capable of negotiating 25-foot radius curves on either horizontal or vertical planes.[48] The system consists of a locomotive powered by a diesel engine, a train of cars, and an overhead track fabricated from standard 10- by 8-inch rolled steel joists. A special feature of the 3½-ton-capacity cars is their ability to negotiate turns of just over a 2-foot radius. Another monorail system having a novel drive system has been introduced by a British firm and is called the "Huntrider."[49] Carriers are supported on an overhead rotating tubular track by carrying heads, each having rollers which can be turned with a lever to various angles in relation to the revolving track. The gripping action will move the carrier at different speeds in either direction. At present both personnel and multiple-head material carriers with capacities up to 4 tons are available. Several monorail installations of American manufacture have been installed in western uranium mines.

Another materials handling device finding wide application in European mines and tunnels was a rail-mounted shuttle car. One of the newer types, equipped with moving conveyor bottoms, may be used singly or in trains in drifts and tunnels having cross-sectional areas as small as 43 square feet.[50] Available in six sizes with capacities ranging from 7 to 15 cubic yards, the cars offer up to 5 times the load capacity of conventional models. By using shuttle trains of several cars, a complete round can be mucked continuously without interruptions for switching. Two self-propelled versions of the shuttle cars are available—one air-powered for short hauls and the other diesel-powered for longer hauls.

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[43] Mining Engineering. Bell & Zoller Company Pioneers the Mobile Bridge Haulage Systems. V. 17, No. 4, April 1965, pp. 68–71.

[44] Mining Congress Journal. 180-Cu Yd Shovel and 240-Ton Truck in Operation. V. 51, No. 11, November 1965, pp. 55–56.

[45] Engineering and Mining Journal. New Products Digest. V. 166, No. 11, November 1965, pp. 56–57.

[46] Engineering and Mining Journal. Anaconda to Install Belt Conveyor to Haul Overburden. V. 166, No. 8, August 1965, p. 126.

[47] Mining & Minerals Engineering. Monorail Transport Systems, V. 1, No. 5, January 1965, pp. 185–192.

[48] Mining Engineering. News From Mine and Mill. V. 17, No. 1, January 1965, p. 24.

[49] Nash, W. L. Graham. Huntrider Transport System Features Unusual Design. Coal Min. and Proc., v. 2, No. 3, March 1965, pp. 36–37.

[50] Mining Magazine. Shuttle Train From Sweden. V. 112, No. 2, February 1965, pp. 107–109.

GROUND SUPPORT AND CONTROL

Rock mechanics studies and applications continued to contribute towards a better understanding of ground conditions and towards improving ground support and control methods. The borehole stress-relief method and other proven techniques were used to determine stresses or changes in stresses in rocks around mine openings.[51] In another study using model pillars, a mathematical expression was developed for predicting the creep rate of quasiplastic rocks.[52] The expression has special engineering significance because it can be used as an aid in designing mine pillars. Other studies provided pertinent information regarding the energy necessary for and available from rockbursts in high-stress fields [53] and the factors governing the stability of open pit slopes.[54] An electrical analog was used successfully to predict the strata movement of three crosscuts above a stabilizing pillar in an African mine.[55] The prediction agreed well with observed movements. The analog was being used to assist mining engineers in determining the feasibility of raising ahead of unmined low-grade blocks to reestablish a longwall face at depth in economical higher grade blocks. Interpretation of the data revealed that conditions at one site would have been bad and that more favorable conditions existed at other sites. In time the analog may become a valuable tool to assist in mine layouts.

Rockbolts gained wider attention and application during the year. Under conditions where previously only timber was used, rockbolts were used successfully to support a 9- by 10-foot haulageway 5,900 feet beneath the surface while a stope above was advanced.[56] The rockbolts which had a ¾-inch diameter were placed on 2½- to 3-foot centers on both the sidewalls and hanging wall. In a surface application, rockbolts grouted with resin were found to be an efficient method of bonding an exposed rock formation in Canada. The tests demonstrated that 1¼-inch-diameter 6-foot bolts grouted their entire length and cured for 3½ hours withstood loads up to 90 tons before the bolt broke. This method is also finding increased use for bonding rock in underground mines. It has been reported that 50,000 to 70,000 resin-bonded bolts have been placed in the Sudbury mines in Canada.[57] A Bureau of Mines report contributed further to the understanding of rock bolt pull tests.[58] It was reported that in testing a prestressed bolt there is a range of loading during which bolt load is greater than the jack-applied load. Furthermore, it was shown that preload as well as size, shape, and type of bearing plate, and also the geometry of the system determine the point at which bolt load and applied load become equal.

Hydraulically filling underground openings with mill tailings continued to be recognized as an efficient ground support and control method. Several mines in the United States and Canada are adding cement to the fill to increase support capability, to prevent fines from being lost in the fill, and to provide a smooth, relatively strong working surface for equipment.[59] The strength and support properties of fill are improved substantially if the fill is in as dense a state as possible immediately following placement. Tests

[51] Bolmer, R. L. Stresses Induced Around Mine Development Workings By Undercutting and Caving, Climax Molybdenum Mine, Colorado (in Two Parts). 2. Strain and Deformation Measurement. BuMines Rept. of Inv. 6666, 1965, 27 pp.
Morgan, Thomas A., William G. Fischer, and William J. Sturgis. Distribution of Stress in the Westvaco Trona Mine, Westvaco, Wyo. BuMines Rept. of Inv. 6675, 1965, 58 pp.
Utter, Stephen, and Willard J. Tesch, Jr. Stresses Induced Around Mine Development Workings by Undercutting and Caving, Climax Molybdenum Mine, Colorado (in Two Parts). 1. Use and Evaluation of Gages for Measuring Strain or Deformation. BuMines Rept. of Inv. 6653, 1965, 26 pp.

[52] Obert, Leonard. Creep in Model Pillars. BuMines Rept. of Inv. 6703, 1965, 23 pp.

[53] Duvall, W. I., and D. E. Stephenson. Seismic Energy Available From Rockbursts and Underground Explosions. Trans. AIME, v. 232, pp. 235–241.

[54] Rauch, D. O. Rock Structure and Slope Stability. Min. Eng., v. 17, No. 6, June 1965, pp. 58–62.

[55] Mining Magazine. Benefits From Rock Mechanics Research. V. 113, No. 2, August 1965, pp. 161–163.

[56] Mining Magazine. Rockbolts in a Rand Haulage. V. 112, No. 4, April 1965, pp. 267–269.

[57] Canadian Mining Journal. Resin Grouting for Rock Support. V. 86, No. 7, July 1965, p. 63.

[58] Osen, Lars, J. L. Habberstad, E. W. Parsons, and E. R. Rodriguez. Load Relations in Preloaded Rockbolt Testing. BuMines Rept. of Inv. 6613, 1965, 24 pp.

[59] Holmes, Roy. Uppers and Wagon Drills in Cut-and-Fill Stoping. Canadian Min. and Met. Bull., v. 58, No. 642, October 1965, pp. 1064–1069.
Mamen, Chris. Mining Technology—Trends and Developments in 1964. V. 86, No. 2, February 1965, pp. 151–162.

by the Bureau of Mines in Idaho metal mines have shown that fill density can be increased significantly by vibration.[60] This was accomplished with a standard 2-inch concrete vibrator. In one test the average density of the fill was increased by an estimated 20 percent. The results of these tests are the latest reported by the Bureau of Mines in the course of general studies being made of backfilling practices. The field is a promising one for research and further investigations are underway.

HEALTH AND SAFETY

The Public Health Service conducted a 2½-year study on the extent and severity of pneumoconiosis among bituminous coal miners.[61] Nearly 10 percent of the miners working in the coalfields of Appalachia has radiographic evidence of this disease. Among inactive miners, the study revealed that about 20 percent were afflicted. On the brighter side, Swedish scientists are proving that by exhaustive medical-profiling and "clean air" research pneumoconiosis cannot only be contained but can be almost entirely eradicated as an occupational hazard to miners.[62] A 16-year case-free record has been set at a high-silica lead mine by a unique combination of strict dust control and applied preventative medicine. The studies showed that miners with certain lung diseases are considerably more susceptible to pneumoconiosis; therefore, these men are kept out of quartz-dust laden working areas. This isolation was said to be just as vital as rigid dust control. An effective method of controlling dust is to suppress it at its source. Normally, the dust is wetted with water, but recently there has been a rapid and widespread increase in using a water detergent mixture for dust suppression.[63] The mixture is introduced into the air stream of drilling equipment. This method not only suppresses dust effectively but is also cheap. The cost of detergent is reportedly less than 20 cents per drill shift.

Another threat, particularly in coal mines, to the health and safety of miners besides dust is methane. There is an increasing effort to develop methods of controlling methane emission underground and to develop devices that can be mounted on a mining machine to warn personnel or interrupt the machine power supply before methane concentrations reach the explosive range. One such device was recently tested in a coal mine, and it was concluded that it offers considerable promise as a machine-mounted warning system.[64] Continued interest in developing methane drainage controls was demonstrated by the allocation of $850,000 by the European Coal and Steel Community to provide 70 percent of the total cost for research in the emission of methane in French mines.[65]

As industry probes deeper into the earth's crust for minerals, one of the major problems encountered is higher temperatures which must be reduced to provide a healthy and efficient working environment. Following a practice used in other countries, several mines in the United States, have begun to use refrigeration units to lower underground temperatures. In the Homestake mine where air temperatures are as high as 120° F, mobile refrigeration units are taken within 100 to 1,000 feet of the mining area to provide a more comfortable working environment.[66] The rail-mounted units, rated at 30 tons, are being used in headings as small as 8 by 8 foot and have a 6,000-cubic-foot-per-minute fan to force cool air through vent tubing. Other mines are using surface refrigeration units to supply chilled water for stationary underground air conditioning plants.[67] These plants incorporate an air washing chamber where the

[60] Wayment, William R., and D. E. Nicholson. Improving Effectiveness of Backfill. Min. Cong. J., v. 51, No. 8, August 1965, pp. 28–32.

[61] Brown, Murray C. Pneumoconiosis in Bituminous Coal Miners. Min. Cong. J., v. 51, No. 8, August 1965, pp. 44–48.

[62] Engineering and Mining Journal. High-Silica Lead Mine Eliminates Silicosis. V. 166, No. 4, April 1965, pp. 98–99.

[63] Dannenberg, Joe. No Wonder Detergent Drilling Is Making History—Its Cost Averages Less Than 20 Cents Per Drill Shift. Pit and Quarry, v. 58, No. 5, November 1965, pp. 129–131.

Malmgren, Carl. Dry Percussion Drilling With Detergent Mist. Min. Cong. J., v. 51, No. 1, January 1965, p. 62.

[64] Beerbower, R. C., Jr. Field Experience With a Methane Monitor. Coal Age, v. 70, No. 1, January 1965, pp. 77–79.

[65] Colliery Guardian. ECSC Spends Millions on Technical Research. V. 210, No. 5424, Apr. 2, 1965, pp. 447–448.

[66] Engineering and Mining Journal. Homestake Spot Cools Hot Work Levels. V. 166, No. 4, April 1965, p. 91.

[67] Warren, John W. Supplemental Cooling for Deep-Level Ventilation. Min. Cong. J., v. 51, No. 4, April 1965, pp. 34–38.

air is thoroughly scrubbed with the chilled water before entering a heat absorber section.

A series of potentially destructive coal mine "bumps" were successfully predicted several days in advance as a result of seismic studies carried out by the Geological Survey.[68] The forecast was based on a change in the number and intensity of tremors from less hazardous toward more hazardous areas of the mine. These tremors were detected by a network of seismic monotoring devices placed around the mining area.

An American Mining Congress committee has developed standards for roof-bolt drill bits and plates intended to assure mine operators that roof-bolting materials meet minimum quality and performance standards.[69] The primary objective of establishing the standards is to improve mine safety.

MINING PRACTICE AND PERFORMANCE

Automation in mining reached a climax with the commencement of production at the National Coal Board's Bevercotes colliery.[70] This ambitious full-scale experiment incorporated the most up-to-date techniques in mechanization and automation and may well foreshadow the degree of technological progress that will encompass not only the coal mines of the future but world mining in general. All of the operations are automated and integrated from coal fragmentation at the face through processing on the surface. The underground network is divided into four sectors: The remotely operated longwall faces; the transport system; the coal-hoisting shaft; and the service shaft for men, supplies, and materials. Each sector is supervised by a senior mine official, and the whole network is directed from a central control station located on the surface. Each sector has facilities for remote control of equipment within the sector from its own console. Also, information and instructions can be transmitted to and received from the surface control center and other sectors.

Production which started in October 1965 came from five remotely operated advancing longwall faces. On each 810-foot-long face, a shearer loader mines the coal, with power-advanced roof supports and an armored chain conveyor as ancillary equipment. The operation of this equipment is coordinated with machines that mine out the stables at each end of the face, with roadway cutting machines that drive the gate roads, and with a complex of belt conveyors that extends from the face area to the coal-hoisting shaft. The coal skips, loaded alternately from a shaft bottom bunker, are hoisted automatically to the surface from a 2,800-foot depth. A complex fail-safe system insures that the hoisting is coordinated with the filling and emptying of the skips. Another shaft that is operated conventionally is used to hoist men, supplies, and waste.

It was anticipated that Bevercotes would have an annual output of 1.5 million tons from five longwall faces by 1968, with a labor force of 770 men producing 8 tons per man-shift. This compares with an original productivity target of 3 tons per man-shift by conventional methods which illustrates the dramatic increase in productivity envisaged. If the experiment at this mine is successful, an estimated half of Britain's coal mines will be fully automated within 10 years.

Because longwalling a test panel 1,200 feet beneath the surface was a technical success, the White Pine Copper Co. has developed a production-size panel to determine the economic feasibility of hardrock longwalling.[71] The production panel is 565 feet wide and 1,200 feet long and is equipped with self-advancing hydraulic supports and chain conveyors. The test panel was equipped with individual hydraulic roof supports that had to be advanced and set manually. The major

[68] Mining Engineering. Successful Forecast of Mine "Bumps" Reported by U. S. Geologists. V. 17, No. 3, March 1965, p. 42.

[69] Gaddy, Frank L. Standards for Roof Bolt Plates and Drill Bits. Min. Cong. J., v. 51, No. 10, October 1965, pp. 39–41.

[70] Grierson, A. Towards the Manless Mine. Min. Mag., v. 113, No. 1, July 1965, pp. 4–9.

Nash, W. L. Graham. Britain's Mine of the Future Goes Into Production. Coal Min. and Proc., v. 2, No. 11, November 1965, pp. 16–19.

Mining Magazine. Bevercotes—Design for The Future. V. 113, No. 2, August 1965, pp. 104–111.

Sheppard, W. V. Longwall Automation of Coal Mine. Min. Cong. J., v. 51, No. 9, September 1965, pp. 88–91.

[71] Huebner, G. R. White Pine Copper Developing Mechanized Hardrock Longwall Mining Techniques. Skillings' Min. Rev., v. 54, No. 34, Aug. 21, 1965, pp. 1–6.

problems encountered in adopting mechanized longwall equipment to hardrock mining were the protection of the roof support system from blast damage and the development of drilling and mucking equipment for use in the very limited space between the supports and face.

A mining practice that was expanding rapidly in a variety of applications was precision blasting.[72] This practice is described under numerous names such as smoothwall, presplit, perimeter, cushion, sculpture, contour or line blasting. The common objective of these techniques is to reduce overbreak and to provide smoother and more competent walls, backs, and slopes. Climax Molybdenum Co. is using the presplit technique as a boundary cut-off device to minimize dilution and the smoothwall method to reduce overbreak in slusher drifts which are to be concreted. Other benefits derived from precision blasting are: 10 to 15 percent reduction in slushing or mucking time, 25 percent decrease in scaling time, improvement in safety because of fewer rockfalls, and less time required for installing supports because the opening is smoother and more competent. Climax reported that spectacular results have been achieved in hard ground, but the most beneficial results were obtained in areas where the ground is relatively soft and highly fractured. The smoothwall blasting technique was also used successfully by Homestake Mining Co. to enlarge a 1,200-foot-long ventilation drift. In addition to minimizing overbreak and damage to the walls and back, the desired drift shape and smoothness was obtained, resulting in greater airflow per fan horsepower. Another successful application of precision blasting is being used by Craigmont Mines Ltd., to improve the stability of open pit walls. Line holes on 10-foot centers are blasted to provide a plane of weakness adjacent to the final pit wall for the main blast.

Computers continue to find wider application in the mining industry. Kennecott Copper Corp. Western Mining Division is using computers as an aid in designing alternate pit layouts and evaluating mine properties.[73] A similar application of computers is being used by National Asbestos Mines Ltd.[74] A computer program was developed to aid in optimizing the pit configuration. The fixed input data are essentially mathematical descriptions based on a three-dimensional coordinate system of the orebody's physical dimensions, including footwall and hanging-wall contacts, original topography, diamond drill core evaluation, pit limitations imposed by buildings and property lines, overall pit slopes, tonnage factors, minimum operating widths, and bench heights. Variable input data included cut-off value, recovery coefficient, mining and processing costs, royalty payments, and mining cost increments for the pit depth. Another recent application of computers is being used by Consolidation Coal Co.'s Hanna Division to calculate stripping volumes for production control.[75] Formerly these monthly calculations were done by hand and required an average of 120 hours. Now overburden volume calculations reportedly can be made in about 4 hours.

A number of noteworthy papers on mining technology and research were presented at the Eighth Commonwealth Mining and Metallurgical Congress in Australia and New Zealand. The papers included such topics as current practices; present and future research needs; application of mathematical and statistical principles and use of computers for planning and control; exploration techniques; safety; ventilation; and open pit slope stability. Highlights of a few of the numerous papers given during the 7-week meeting are discussed in the following paragraphs.

Several interesting operating practices have been introduced at the Sullivan lead and zinc mine in Canada.[76] A bland odorless oil has been substituted for fuel oil in ammonium nitrate explosive to reduce odors and skin irritations and for

[72] Engineering and Mining Journal. How and Why Mines Go to Smoothwall Blasting. V. 166, No. 10, October 1965, pp. 92–95.
Ludwig, J. J., and A. K. Smith. Evolution of Pre-Splitting and Controlled Blasting. Min. Cong. J., v 51, No. 10, October 1965, pp. 66–71.
Smith, Albert K., and Ralph M. Barnett. Smoothwall Blasting Shows Promise at Climax. Min. Eng., v. 17, No. 7, July 1965, pp. 162–166.

[73] Engineering and Mining Journal. Open Pit Mining in 1965. V. 166, No. 9, September 1965, pp. 101–103.

[74] O'Brien, Noel, and F. J. Nowak. An Application of a Computer to Open-Pit Mine Operation. Canadian Min. and Met. Bull., v. 58, No. 638, June 1965, pp. 649–654.

[75] Cook, Paul A. C., and Joseph Hickle. Rapid Calculation of Overburden Volumes. Min. Cong. J., v. 51, No. 1, January 1965, pp. 45–49.

[76] Hurdle, B. E. Recent Developments at the Sullivan Mine of the Consolidated Mining & Smelting Co. of Canada Ltd. Eighth Commonwealth Min. and Met. Cong. Australia and New Zealand, 1965, 6th tech. sess. Metal Mining, Melbourne, Australia, preprint 46, 1965, pp. 1–5.

secondary blasting the prilled mixture is pulverized by jetting against a stainless steel plate to provide a more effective explosive. The noise level of diamond drills has been reduced to satisfactory levels, and about 90 percent of the noise energy developed by percussion drilling machines is absorbed by application of a rubber-sleeved type muffler with reduction of some 10 decibels in the significant speech range. The company has also reduced the dust count substantially in development headings by using a supplementary system for sweeping the heading with clean air. The air supply system consists of 6-inch metal pipe and telescoping polyethelene tubing connected to a venturi type air mover.

A new stoping configuration, the cascade continuous retreat method, has been developed at the Mufulira mine in Rhodesia to mine 30- to 35-degree dipping ore bodies which range from 30 to 70 feet in thickness.[77] This method was devised to reduce pillars to the minimum by retreating continuously along the strike allowing caving of the hanging wall some distance back from the working face; to do as much development as possible in ore, thereby minimizing waste development; to make use of gravity in dipping ore bodies by reducing stope back length and creating an artificial stoping footwall; to use development headings of large cross section where possible so that blastholes may be drilled with 6-foot extension steels and large autofeed drifters and so that large capacity rock handling equipment may be used in both the development and production stages; and to reduce the effects of dilution from premature collapse of the hanging wall to as small an area as possible by reducing back lengths of individual stopes.

Rock and soil mechanics figured prominently in the stope design and the selection of the type of fill for the Mt. Charlotte ore body of Gold Mines of Kalgoorlie (Australia) Ltd.[78] The ore will be selectively mined by the cut-and-fill method with buttress pillars as support. Stope design was resolved after an examination of primary rock stress conditions and in situ deformation moduli of the rock in the ore body. Dry unclassified mill tailings will be used as fill material.

At Mount Isa Mines Ltd., mining in hot ground (temperature above 135° F and up to 250° F) has given rise to special rules which govern the use of explosives.[79] Because of problems with misfires and the eventual inevitable decomposition of nitroglycerine based explosives at temperatures above 165° F, these explosives have been replaced by AN-FO where the ground temperature is higher than 150° F. However the use of AN-FO also has complications because of its reactions under certain conditions, which result in rapid elevation of the temperature within a blasthole to above 500° F. These reactions have been eliminated in development headings by separating AN-FO from the hole walls with suitable hole linings and in ring-firing by using special high temperature cartridged explosives.

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[77] Airey, L. D. The Introduction of Mechanized Mining Methods at Mufulira Copper Mines Limited. Eighth Commonwealth Min. and Met. Cong. Australia and New Zealand, 1965, 6th tech. sess. Metal Mining, Melbourne, Australia, preprint 91, 1965, pp. 16–26.

[78] Simpson, R. C. Operations at Mount Charlotte. Eighth Commonwealth Min. and Met. Cong. Australia and New Zealand, 1965, 6th tech. sess. Metal Mining, Melbourne, Australia, preprint 125, 1965, pp. 6–15.

[79] Cox, David M. The Use of Explosives in Hot Ground at Mount Isa Mines Limited. Eighth Commonwealth Min. and Met. Cong. Australia and New Zealand, 1965, 6th tech. sess. Metal Mining, Melbourne, Australia, preprint 20, pp. 42–50.

Technologic Trends in the Mineral Industries
(Metals and Nonmetals Except Fuels)

By F. L. Wideman [1]

Output of ore and waste from metal and nonmetal mines in the United States continued an upward trend and established a new high. The tonnage of ore handled increased 6 percent over that moved in 1964 and the tonnage of waste rose almost 10 percent. Earth moving by these two activities exceeded 3.2 billion tons, an increase of 7 percent over the 1964 total. Crude material from which metal or nonmetal products were derived continued to be about 75 percent of the total material handled.

In 1965, surface mining methods were used to produce about 93 percent of the ore, 99 percent of the waste, and 95 percent of the total material handled. These percentages have remained almost constant since the beginning of this decade.

Exploration and development increased 25 percent over that performed in 1964 and totaled more than 18.6 million feet. However, the total remained below the high of 21.9 million feet established in 1961.

A rapid growth in the treatment of raw materials by froth flotation characterized the mineral industries in 1960–65. The number of plants treating coal increased from 31 to 69 and the number of mills processing other raw material rose from 163 to 186. The daily capacity of the latter mentioned mills rose 23 percent to more than 860,000 tons and ore treated increased 38 percent to 269 million tons. In 1960, 31 percent of the ore mined—coal, sand and gravel, and stone excluded—was treated by froth flotation. In 1965, the ratio increased to 38 percent.

Material Handled.—Output of ore and waste at metal and nonmetal mines in the United States totaled 3,213 million tons, an increase of 7 percent over that of 1964. At metal mines, crude ore production increased 4 percent and output of waste rose 10 percent. Ore and waste were 48 percent and 52 percent, respectively, of the total materials handled at metal mines. Copper and iron ore mines accounted for 79 percent of the crude ore (77 percent in 1964) and 85 percent (82 percent) of the total material handled. For the second consecutive year, the Peter Mitchell mine of Reserve Mining Co. was the largest producer of ore in the United States. However, an enormous tonnage of waste added to a large tonnage of ore mined by Kennecott Copper Corp., Utah Copper Division, placed the mine in first place in total materials handled.

The tonnage of all materials handled at nonmetal mines increased 7 percent over that of 1964 and totaled 2,224 million tons. Output of usable raw material increased almost 7 percent, 1 percent more than the increase in 1964. Waste removal rose 7 percent and with the large increase in waste removed at metal mines contributed to the rise in total tonnage of waste removed. The combined material handled at sand and gravel pits and stone quarries totaled about 1.77 billion tons and was 80 percent (81 percent in 1964) of the total materials handled at nonmetal mines and quarries.

Increased production added Ohio and Pennsylvania to the list of States handling more than 100 million tons of material in 1965. Mines in each of six other States—Arizona, California, Florida, Michigan, Minnesota, and Utah—also produced more than 100 million tons of material. California replaced Arizona for first place with the production of 267 million tons of material handled. Minnesota was in second place with 263 million tons and Arizona was in third place with 261 million tons.

[1] Commodity specialist, Division of Minerals.

Table 1.—Material handled at surface and underground mines, by commodities, in 1965

(Thousand short tons)

Commodity	Surface			Underground			All mines		
	Crude ore	Waste	Total	Crude ore	Waste	Total	Crude ore	Waste	Total
Metals:									
Bauxite	2,095	555	2,650	209	-----	209	2,304	555	2,859
Beryllium	2	1	3	-----	-----	-----	2	1	3
Copper	149,434	286,048	435,482	26,043	547	26,590	175,477	286,595	462,072
Gold:									
Lode	1,493	6,993	8,486	2,504	309	2,813	3,997	7,302	11,299
Placer	27,198	5,309	32,507	-----	-----	-----	27,198	5,309	32,507
Iron ore	179,104	172,480	351,584	21,678	2,397	24,075	200,782	174,877	375,659
Lead	148	221	369	6,460	641	7,101	6,608	862	7,470
Manganese ore	-----	-----	-----	24	7	31	24	7	31
Manganiferous ore	646	2,892	3,538	-----	-----	-----	646	2,892	3,538
Mercury	236	634	870	154	151	305	390	785	1,175
Molybdenum	158	4,647	4,805	14,353	140	14,493	14,511	4,787	19,298
Silver	315	396	711	469	142	611	784	538	1,322
Titanium: Ilmenite	19,535	4,915	24,450	-----	-----	-----	19,535	4,915	24,450
Tungsten	-----	-----	-----	442	78	520	442	78	520
Uranium	1,797	19,529	21,326	3,369	892	4,261	5,166	20,421	25,587
Zinc	598	48	646	11,738	945	12,683	12,336	993	13,329
Other [1]	7,150	522	7,672	-----	-----	-----	7,150	522	7,672
Total metals	389,909	505,190	895,099	87,443	6,249	93,692	477,352	511,439	988,791
Nonmetals:									
Abrasives [2]	143	89	232	37	-----	37	180	89	269
Asbestos	2,401	2,802	5,203	62	16	78	2,463	2,818	5,281
Barite	6,516	4,094	10,610	227	-----	227	6,743	4,094	10,837
Boron minerals	10,291	7,095	17,386	2	-----	2	10,293	7,095	17,388
Clays	54,055	48,049	102,104	1,646	25	1,671	55,701	48,074	103,775
Diatomite	1,132	5,398	6,530	-----	-----	-----	1,132	5,398	6,530
Feldspar	1,420	273	1,693	6	-----	6	1,426	273	1,699
Fluorspar	60	51	111	815	5	820	875	56	931
Gypsum	7,997	11,020	19,017	2,506	541	3,047	10,503	11,561	22,064
Mica	588	170	758	-----	-----	-----	588	170	758
Perlite	586	13	599	3	-----	3	589	13	602
Phosphate rock	81,548	135,928	217,476	1,421	-----	1,421	82,969	135,928	218,897
Potassium salts	-----	-----	-----	19,178	1,376	20,554	19,178	1,376	20,554
Pumice	3,464	133	3,597	-----	-----	-----	3,464	133	3,597
Salt	6,630	-----	6,630	11,355	833	12,188	17,985	833	18,818
Sand and gravel	895,601	-----	895,601	-----	-----	-----	895,601	-----	895,601
Sodium carbonate (natural)	-----	-----	-----	1,947	7	1,954	1,947	7	1,954
Stone:									
Crushed and broken	755,954	71,180	827,134	37,626	246	37,872	793,580	71,426	865,006
Dimension	5,252	2,919	8,171	264	-----	264	5,516	2,919	8,435
Sulfur:									
Frasch-process mines	8,193	-----	8,193	-----	-----	-----	8,193	-----	8,193

Other mines	4	-----	4	-----	-----	-----	4	-----	4
Talc, soapstone, and pyrophyllite	379	390	769	613	56	669	992	446	1,438
Vermiculite	1,177	2,746	3,923	-----	-----	-----	1,177	2,746	3,923
Other [3]	3,829	3,378	7,207	76	8	84	3,905	3,386	7,291
Total nonmetals	1,847,220	295,728	2,142,948	77,784	3,113	80,897	1,925,004	298,841	2,223,845
Grand total	2,237,129	800,918	3,038,047	165,227	9,362	174,589	2,402,356	810,280	3,212,636

[1] Antimony, magnesium, nickel, platinum-group metals, rare-earth metals, rutile, tin, vanadium, and zirconium.
[2] Emery, garnet, and tripoli.
[3] Brucite, graphite, greensand marl, kyanite, lithium minerals, magnesite, olivine, sodium sulfate (natural), and wollastonite.

Table 2.—Material handled at surface and underground mines (including sand and gravel and stone), by States, in 1965

(Thousand short tons)

State	Surface			Underground			All mines		
	Crude ore	Waste	Total	Crude ore	Waste	Total	Crude ore	Waste	Total
Alabama	32,031	29,444	61,475	848	79	927	32,879	29,523	62,402
Alaska	39,209	4,599	43,808	122	5	127	39,331	4,604	43,935
Arizona	98,344	145,820	244,164	15,968	375	16,343	114,312	146,195	260,507
Arkansas	37,272	1,396	38,668	1,272	-----	1,272	38,544	1,396	39,940
California	215,394	49,867	265,261	1,630	256	1,886	217,024	50,123	267,147
Colorado	26,722	908	27,630	16,016	857	16,873	42,738	1,765	44,503
Connecticut	16,262	253	16,515	-----	-----	-----	16,262	253	16,515
Florida	133,511	116,350	249,861	-----	-----	-----	133,511	116,350	249,861
Georgia	34,933	25,613	60,546	1,069	-----	1,069	36,002	25,613	61,615
Idaho	18,360	18,844	37,204	1,541	416	1,957	19,901	19,260	39,161
Illinois	83,282	8,090	91,372	3,611	12	3,623	86,893	8,102	94,995
Indiana	50,614	1,661	52,275	903	2	905	51,517	1,663	53,180
Iowa	45,653	10,193	55,846	1,901	-----	1,901	47,554	10,193	57,747
Kansas	29,562	1,541	31,103	3,773	35	3,808	33,335	1,576	34,911
Kentucky	27,398	3,815	31,213	6,777	5	6,782	34,175	3,820	37,995
Louisiana	27,462	-----	27,462	3,661	21	3,682	31,123	21	31,144
Maine	18,467	11	18,478	24	39	63	18,491	50	18,541
Maryland	32,212	787	32,999	92	-----	92	32,304	787	33,091
Massachusetts	28,678	114	28,792	5	-----	5	28,683	114	28,797
Michigan	113,724	16,583	130,307	16,987	1,369	18,356	130,711	17,952	148,663
Minnesota	169,209	91,769	260,978	2,451	43	2,494	171,660	91,812	263,472
Mississippi	12,533	1,725	14,258	-----	-----	-----	12,533	1,725	14,258
Missouri	48,461	5,896	54,357	16,487	310	16,797	64,948	6,206	71,154
Montana	31,934	2,856	34,790	4,076	32	4,108	36,010	2,888	38,898
Nebraska	16,298	3,746	20,044	-----	-----	-----	16,298	3,746	20,044
Nevada	31,531	45,346	76,877	317	44	361	31,848	45,390	77,238
New Hampshire	10,872	12	10,884	-----	-----	-----	10,872	12	10,884
New Jersey	31,916	596	32,512	946	6	952	32,862	602	33,464
New Mexico	23,791	28,515	52,306	20,952	1,201	22,153	44,743	29,716	74,459
New York	69,056	8,078	77,134	6,455	62	6,517	75,511	8,140	83,651
North Carolina	34,866	1,137	36,003	38	-----	38	34,904	1,137	36,041
North Dakota	8,115	2,193	10,308	-----	-----	-----	8,115	2,193	10,308
Ohio	87,106	9,379	96,485	5,753	477	6,230	92,859	9,856	102,715
Oklahoma	22,698	2,352	25,050	1,379	-----	1,379	24,077	2,352	26,429
Oregon	46,140	628	46,768	22	5	27	46,162	633	46,795
Pennsylvania	76,601	17,188	93,789	8,174	1,794	9,968	84,775	18,982	103,757
Rhode Island	2,089	-----	2,089	-----	-----	-----	2,089	-----	2,089
South Carolina	15,643	4,801	20,444	-----	-----	-----	15,643	4,801	20,444
South Dakota	15,957	635	16,592	2,107	206	2,313	18,064	841	18,905
Tennessee	41,035	6,316	47,351	6,923	365	7,288	47,958	6,681	54,639
Texas	87,640	4,109	91,749	273	-----	273	87,913	4,109	92,022
Utah	49,730	90,113	139,843	1,580	784	2,364	51,310	90,897	142,207
Vermont	5,971	652	6,623	241	3	244	6,212	655	6,867
Virginia	52,945	3,293	56,238	3,334	100	3,434	56,279	3,393	59,672
Washington	44,962	1,274	46,236	171	52	223	45,133	1,326	46,459
West Virginia	11,648	1,815	13,463	2,799	42	2,841	14,447	1,857	16,304
Wisconsin	54,231	400	54,631	1,103	-----	1,103	55,334	400	55,734
Wyoming	17,013	29,802	46,815	3,446	365	3,811	20,459	30,167	50,626
Other States [1]	8,048	403	8,451	-----	-----	-----	8,048	403	8,451
Total	2,237,129	800,918	3,038,047	165,227	9,362	174,589	2,402,356	810,280	3,212,636

[1] Delaware and Hawaii.

Table 3.—Crude ore and total material handled at surface and underground mines, by commodities in 1965

(Percent)

Commodity	Crude ore		Total material	
	Surface	Underground	Surface	Underground
Metals:				
Bauxite	91	9	93	7
Beryllium	100	---	100	---
Copper	85	15	94	6
Gold:				
Lode	28	72	75	25
Placer	100	---	100	---
Iron ore	90	10	94	6
Lead	---	100	5	95
Manganese ore	---	100	---	100
Manganiferous ore	100	---	100	---
Mercury	59	41	74	26
Molybdenum	1	99	25	75
Nickel	100	---	100	---
Rare-earth metals and thorium	100	---	100	---
Silver	39	61	54	46
Titanium:				
Ilmenite	100	---	100	---
Rutile	100	---	100	---
Tungsten	---	100	---	100
Uranium	25	75	83	17
Zinc	4	96	5	95
Total metals	82	18	91	9
Nonmetals:				
Abrasives:				
Emery	100	---	100	---
Garnet	100	---	100	---
Tripoli	48	52	62	38
Asbestos	97	3	99	1
Barite	96	4	98	2
Boron minerals	100	---	100	---
Clays	97	3	98	2
Diatomite	100	---	100	---
Feldspar	100	---	100	---
Fluorspar	6	94	12	88
Graphite	100	---	100	---
Gypsum	76	24	86	14
Kyanite	100	---	100	---
Lithium minerals	100	---	100	---
Magnesite	100	---	100	---
Marl, greensand	100	---	100	---
Mica: Scrap	100	---	100	---
Olivine	100	---	100	---
Perlite	100	---	100	---
Phosphate rock	98	2	99	1
Potassium salts	---	100	---	100
Pumice	100	---	100	---
Salt	7	93	9	91
Sand and gravel	100	---	100	---
Sodium carbonate (natural)	---	100	---	100
Sodium sulfate (natural)	100	---	100	---
Stone:				
Crushed and broken	95	5	96	4
Dimension	95	5	97	3
Sulfur: Frasch-process mines	100	---	100	---
Talc, soapstone, and pyrophyllite	38	62	54	46
Vermiculite	100	---	100	---
Wollastonite	2	98	1	99
Total nonmetals	96	4	97	3
Grand total	94	6	95	5

Comparison of Production From Surface and Underground Mines.—Surface mines produced 93 percent of the ore and 95 percent of the total materials handled in 1965. Both percentages were unchanged from those of the two previous years. Crude ore and waste produced at metal mines by surface mining were 82 percent and 99 percent, respectively, of the total output, both percentages were unchanged from 1964. Crude nonmetal materials and waste produced from surface mines remained at 96 percent and 99 percent, respectively, of the total; ratios unchanged in the last 7 years.

Three commodities—manganese ore, tungsten, and sodium carbonate (natural), excluding that produced from brines—were produced by underground mining methods only. Ores of four metals—placer gold, manganiferous ore, nickel, and ilmenite and rutile—were produced by surface mining only. Nonmetals mined by surface methods only included mica, pumice, sand and gravel, sulfur (other than Frasch-process), and vermiculite.

Underground mining continued to account for substantial percentages of ore produced in the same four States as in 1964—Colorado, 37 percent (36 percent in 1964); Kentucky, 20 percent (20 percent); Missouri, 26 percent (25 percent); and New Mexico, 47 percent (49 percent). Underground mining was not reported in 10 States.

Table 4.—Crude ore and total material handled at surface and underground mines, by States, in 1965

(Percent)

State	Crude ore		Total material	
	Surface	Underground	Surface	Underground
Alabama	98	2	99	1
Alaska	100	---	100	---
Arizona	86	14	94	6
Arkansas	97	3	97	3
California	99	1	99	1
Colorado	63	37	62	38
Connecticut	100	---	100	---
Delaware	100	---	100	---
Florida	100	---	100	---
Georgia	97	3	98	2
Hawaii	100	---	100	---
Idaho	93	7	95	5
Illinois	96	4	96	4
Indiana	98	2	98	2
Iowa	96	4	97	3
Kansas	89	11	89	11
Kentucky	80	20	82	18
Louisiana	93	7	93	7
Maine	100	---	100	---
Maryland	100	---	100	---
Massachusetts	100	---	100	---
Michigan	88	12	88	12
Minnesota	99	1	99	1
Mississippi	100	---	100	---
Missouri	74	26	76	24
Montana	89	11	90	10
Nebraska	100	---	100	---
Nevada	99	1	100	---
New Hampshire	100	---	100	---
New Jersey	99	1	99	1
New Mexico	53	47	70	30
New York	92	8	92	8
North Carolina	100	---	100	---
North Dakota	100	---	100	---
Ohio	94	6	94	6
Oklahoma	94	6	95	5
Oregon	100	---	100	---
Pennsylvania	90	10	90	10
Rhode Island	100	---	100	---
South Carolina	100	---	100	---
South Dakota	89	11	88	12
Tennessee	86	14	87	13
Texas	100	---	100	---
Utah	98	2	99	1
Vermont	96	4	97	3
Virginia	95	5	95	5
Washington	100	---	100	---
West Virginia	82	18	85	15
Wisconsin	98	2	98	2
Wyoming	83	17	93	7
Total	94	6	95	5

Magnitude of the Mining Industry.—Crude ore production was reported from 8,600 mines (7,093 in 1964)—1,621 (1,449) metal and 6,979 (5,644) nonmetal—exclusive of sand and gravel pits. Output of ore from individual mines ranged from 1 to more than 30 million tons and total materials handled at one mine exceeded 116 million tons. The number of metal mines that handled less than 1,000 tons of ore increased from 716 in 1964 to 747 and the number of nonmetal mines in this class increased from 565 to 627. The number of metal mines that produced more than 10 million tons increased from 7 in 1964 to 10 in 1965 and the number of nonmetal mines in this class remained unchanged at 2.

Table 5.—Number of domestic metal and nonmetal mines in 1965, by commodity and magnitude of crude ore production

Commodity	Total number of mines	Less than 1,000 tons	1,000 to 10,000 tons	10,000 to 100,000 tons	100,000 to 1,000,000 tons	1,000,000 to 10,000,000 tons	More than 10,000,000 tons
Metals:							
Antimony	4	4	---	---	---	---	---
Bauxite	14	---	5	6	2	1	---
Beryllium	10	10	---	---	---	---	---
Copper	128	55	12	22	17	17	5
Gold:							
Lode	180	84	52	30	12	1	1
Placer	103	90	7	2	3	1	---
Iron ore	155	5	12	26	67	42	3
Lead	119	79	24	8	7	1	---
Manganese ore	4	1	1	2	---	---	---
Manganiferous ore	3	---	---	2	1	---	---
Mercury	146	123	14	9	---	---	---
Molybdenum	5	2	1	---	1	---	1
Silver	135	63	62	7	3	---	---
Tin	4	2	1	1	---	---	---
Titanium concentrates	6	---	---	1	1	4	---
Tungsten	5	4	---	---	1	---	---
Uranium	423	195	116	49	63	---	---
Zinc	172	30	13	38	88	3	---
Other [1]	5	---	---	1	1	3	---
Total metals	1,621	747	320	204	267	73	10
Nonmetals:							
Abrasives [2]	27	15	8	4	---	---	---
Asbestos	11	3	1	3	3	1	---
Barite	45	9	6	12	17	1	---
Boron minerals	4	1	1	---	---	2	---
Clays	1,247	88	321	687	151	---	---
Diatomite	15	3	4	4	4	---	---
Feldspar	89	53	17	14	5	---	---
Fluorspar	16	4	5	4	3	---	---
Gypsum	75	1	11	24	39	---	---
Kyanite	6	---	---	1	5	---	---
Marl, greensand	2	---	2	---	---	---	---
Mica	25	7	7	10	1	---	---
Olivine	6	1	2	3	---	---	---
Perlite	17	3	8	4	2	---	---
Phosphate rock	51	---	5	6	24	15	1
Potassium salts	11	---	---	---	6	5	---
Pumice	137	25	39	60	13	---	---
Salt	62	2	11	15	29	5	---
Sodium carbonate (natural)	3	---	---	---	2	1	---
Stone:							
Crushed and broken	4,422	154	422	1,438	1,984	423	1
Dimension	597	234	268	82	13	---	---
Sulfur:							
Frasch-process mines	11	---	---	1	7	3	---
Other mines	2	1	1	---	---	---	---
Talc, soapstone, and pyrophyllite	80	19	36	24	1	---	---
Vermiculite	6	1	2	1	2	---	---
Wollastonite	4	3	---	1	---	---	---
Other [3]	8	---	1	1	5	1	---
Total nonmetals	6,979	627	1,178	2,399	2,316	457	2
Grand total	8,600	1,374	1,498	2,603	2,583	530	12

[1] Magnesium, nickel, platinum-group metals, rare-earth metals, and zirconium.
[2] Emery, garnet, and tripoli.
[3] Brucite, graphite, lithium minerals, magnesite, and sodium sulfate (natural).

Underground Mining Methods.—Ore extracted by underground mining methods remained at 7 percent of the total produced in the United States. However, the percentage of ore of some commodities produced by certain types of methods varied widely. Ore produced by open stoping was approximately 74 percent (75 percent in 1964) and output from caving methods was 25 percent (24 percent). All the bauxite, boron minerals, feldspar, potassium salts, tripoli, and wollastonite mined underground were extracted from naturally supported open stopes. Most of the molybdenum ore was produced by caving methods. The percentage of copper ore mined by underground methods that was extracted by caving decreased from 51 percent to 48 percent and the ratio for iron ore, produced by this method, decreased from 45 percent to 38 percent.

Surface Mining.—Practically all the material handled at surface mines continued to be loaded mechanically. In metal mining, a large percentage of the ore required drilling and blasting before loading. A large percentage of the total ore at metal mines came from multiple bench operations. Barite, phosphate rock, sand and gravel, and dimension stone, commodities that supplied 94 percent of the total output of nonmetals, were mined with little or no blasting.

Exploration and Development.—The upward trend in exploration and development accelerated in 1965 and totaled 18.7 million feet, 25 percent more than in 1964 (9 percent more in 1964 than in 1963). For metals, the total was 11.9 million feet compared with 10.8 in 1964, whereas the footage for nonmetals rose from 4.1 million to 6.8 million. Footage excavated by shaft sinking, raising, drifting, and crosscutting decreased 6 percent.

In 1965, drilling accounted for 17.0 million feet which was 91 percent of the total footage of exploration and development and resulted in a 31 percent increase over that of 1964. Footage by diamond drilling decreased 10 percent and was 13 percent (17 percent in 1964) of the total footage of drilling. Although the footage reported

Table 6.—Mining methods used in underground operations, by commodities

(Percent)

Commodity	Open stoping: Natural support		Open stoping: Artificial support		Caving		Other and unspecified	
	1964	1965	1964	1965	1964	1965	1964	1965
Metals:								
Bauxite	100.0	100.0	----	----	----	----	----	----
Copper	37.7	42.0	11.3	8.8	51.0	48.3	----	0.9
Gold: Lode	4.2	20.4	95.6	13.8	.2	64.6	----	1.2
Iron ore	44.6	61.6	8.4	----	45.2	38.4	1.8	----
Lead	85.1	70.2	14.9	12.3	----	15.9	----	1.6
Manganese ore	----	.6	100.0	----	----	99.0	----	.4
Mercury	2.7	64.3	82.6	8.5	14.7	22.0	----	5.2
Molybdenum	----	2.2	----	----	100.0	97.7	----	.1
Silver	13.3	44.3	81.5	9.7	----	45.2	5.2	.8
Uranium	67.8	66.6	27.4	----	4.8	33.4	----	----
Zinc	73.9	74.9	23.9	10.7	2.2	13.1	----	1.3
Nonmetals:								
Asbestos	93.3	79.5	----	20.5	6.7	----	----	----
Barite	7.6	45.0	62.4	----	30.0	55.0	----	----
Boron minerals	100.0	100.0	----	----	----	----	----	----
Clays	94.0	94.6	5.6	.3	.4	5.1	----	----
Feldspar	36.8	100.0	63.2	----	----	----	----	----
Fluorspar	35.1	77.5	58.1	16.1	6.8	1.5	----	4.9
Gypsum	99.3	94.0	.7	----	----	----	----	6.0
Phosphate rock	29.3	69.4	67.5	----	3.2	----	----	30.6
Potassium salts	94.0	100.0	----	----	6.0	----	----	----
Pyrites	56.9	7.1	43.1	.9	----	92.0	----	----
Salt	93.8	94.8	----	----	----	----	6.2	5.2
Sodium carbonate (natural)	100.0	30.9	----	----	----	69.1	----	----
Stone:								
Crushed and broken	98.1	99.3	1.0	.3	----	.4	.9	----
Dimension	94.1	97.0	----	----	5.9	3.0	----	----
Talc, soapstone, and pyrophyllite	65.6	67.6	15.9	1.0	1.3	18.2	17.2	13.2
Tripoli	100.0	100.0	----	----	----	----	----	----
Wollastonite	100.0	100.0	----	----	----	----	----	----
Total	65.8	71.0	9.1	2.7	24.2	25.1	.9	1.2

Table 7.—Mining methods used in underground operations, by States

(Percent)

State	Open stoping: Natural support 1964	Open stoping: Natural support 1965	Open stoping: Artificial support 1964	Open stoping: Artificial support 1965	Caving 1964	Caving 1965	Other and unspecified 1964	Other and unspecified 1965
Alabama	100.0	98.8	----	----	----	1.2	----	----
Alaska	----	50.0	100.0	----	----	----	----	50.0
Arizona	7.6	8.1	9.0	2.6	83.4	89.3	----	----
Arkansas	86.5	90.2	8.5	----	5.0	9.8	----	----
California	80.2	77.9	16.7	9.2	----	5.5	3.1	7.4
Colorado	4.6	9.5	6.7	.2	88.7	90.3	----	----
Georgia	100.0	98.5	----	----	----	1.5	----	----
Idaho	6.5	3.3	89.9	82.6	2.5	2.0	1.1	12.1
Illinois	95.3	93.9	4.0	2.8	.7	2.3	----	1.0
Indiana	100.0	100.0	----	----	----	----	----	----
Iowa	100.0	100.0	----	----	----	----	----	----
Kansas	100.0	100.0	----	----	----	----	----	----
Kentucky	97.5	99.3	2.4	----	.1	.7	----	----
Louisiana	100.0	93.1	----	----	----	----	----	6.9
Maine	----	87.4	----	----	100.0	12.6	----	----
Maryland	100.0	100.0	----	----	----	----	----	----
Massachusetts	----	100.0	----	----	----	----	----	----
Michigan	77.5	87.7	4.2	----	15.8	12.3	2.5	----
Minnesota	2.1	100.0	----	----	97.9	----	----	----
Missouri	91.8	100.0	8.2	----	----	----	----	----
Montana	17.5	26.7	82.5	35.6	----	25.7	----	12.0
Nevada	5.4	77.4	14.8	6.6	77.3	.8	2.5	15.2
New Jersey	78.3	76.1	21.7	17.3	----	5.9	----	.7
New Mexico	90.4	94.5	4.0	----	5.6	5.5	----	----
New York	90.2	92.0	----	----	----	.1	9.8	7.9
North Carolina	11.0	29.1	78.0	15.7	11.0	55.2	----	----
Ohio	99.6	100.0	.4	----	----	----	----	----
Oklahoma	100.0	100.0	----	----	----	----	----	----
Oregon	50.0	100.0	50.0	----	----	----	----	----
Pennsylvania	48.9	42.7	----	----	51.1	57.3	----	----
South Dakota	1.2	78.4	98.8	21.6	----	----	----	----
Tennessee	100.0	100.0	----	----	----	----	----	----
Texas	100.0	100.0	----	----	----	----	----	----
Utah	34.6	69.4	57.4	9.9	8.0	20.7	----	----
Vermont	88.4	84.9	11.6	----	----	15.1	----	----
Virginia	89.9	91.4	.6	----	----	----	9.5	8.6
Washington	90.8	12.2	8.7	44.8	----	----	.5	43.0
West Virginia	100.0	100.0	----	----	----	----	----	----
Wisconsin	90.1	100.0	----	----	9.9	----	----	----
Wyoming	60.2	31.9	15.4	----	24.4	68.1	----	----
Total	65.8	71.0	9.1	2.7	24.2	25.1	.9	1.2

for churn drilling increased somewhat over that for 1964, the percentage of the total drilling accomplished by this method continued to decline to about 1.5 percent. Footage reported for rotary drilling and percussion drilling increased 43 percent and 40 percent, respectively. Footage by rotary drilling was 35 percent of the total drilled in 1965 and that by percussion drilling was 51 percent. Approximately 62 percent (72 percent) of the total drilling was for exploration of metals.

TRENDS IN FROTH FLOTATION

The growth of flotation in the United States in the past 5 years was measured by a comparison of data collected for 1965 with those gathered for 1960.[2] The number of flotation plants operating in the mineral industries in 1965 compared with that of 1960 increased 31 percent; the tonnage of material treated, 40 percent; the quantity of reagents consumed rose 46 percent; and the quantity of products recovered jumped

[2] Based on data collected from flotation plant operators by Mineral Resource Area Offices for a national canvass conducted by Charles W. Merrill and James W. Pennington. *Also see* Merrill, Charles W. and James W. Pennington. The Magnitude and Significance of Flotation in the Mineral Industries of the United States. AIME, Froth Flotation, 50th Anniversary Volume, 1962.

———. Trends in Froth Flotation—Reagent Use and Product Recovery. Min. Cong. J., v. 52, No. 11, November 1966, pp. 22–26, 28, 31.

Irving, Donald R. Technologic Trends in the Mineral Industries (Metals and Nonmetals Except Fuels). BuMines Minerals Yearbook, 1961.

Table 8.—Kind of surface mining operation, by commodities, in 1965

(Percent of crude ore)

Commodity	Open pit	Single bench	Multiple bench
Metals:			
Bauxite	33	9	58
Copper	7	8	85
Gold: Lode	6	10	84
Iron ore	12	3	85
Manganiferous ore	---	10	90
Mercury	57	26	17
Nickel	---	---	100
Rare-earth metals and thorium	5	---	95
Tin	90	10	---
Titanium:			
Ilmenite	70	---	30
Rutile	86	---	14
Uranium	17	78	5
Zinc	---	---	100
Nonmetals:			
Abrasives:			
Emery	100	---	---
Garnet	6	16	78
Tripoli	100	---	---
Aplite	---	---	100
Asbestos	---	7	93
Barite	75	13	12
Boron minerals	---	---	100
Clays	47	33	20
Diatomite	1	2	97
Feldspar	32	27	41
Fluorspar	---	1	99
Gypsum	53	30	17
Kyanite	---	13	87
Lithium minerals	91	---	9
Marl, greensand	---	100	---
Mica: Scrap	36	7	57
Olivine	91	9	---
Perlite	---	62	38
Phosphate rock	92	---	8
Pumice	32	63	5
Sand and gravel	100	---	---
Stone:			
Crushed and broken	42	27	31
Dimension	27	21	52
Sulfur, other than Frasch	---	---	100
Talc, soapstone, and pyrophyllite	59	9	32
Vermiculite	---	1	99

80 percent. Increases were reported for almost every type of ore treated in 1965 compared with the 1960 figures and large percentage increases were reported for iron ore and bituminous coal. Copper, copper-molybdenum and molybdenum ores, phosphate rock, and potash continued to be the leading materials treated.

An outstanding feature of froth flotation was the growth in diversity and quantity of materials processed in the past 30 years. In 1935, concentration by froth flotation was almost entirely confined to the treatment of sulfide ores of 5 metals and native copper ore, whereas by 1965 the number of different materials treated increased to almost 30. Comparison of flotation reagent data for 1965 with those of 1935 emphasizes significant differences in the numbers and quantities of reagents used. The total of almost 100 different reagents used in 1965 was nearly three times the number reported in 1935. Apparently, this resulted from treating a wider variety of material, a more extensive use of selective flotation, and increased recovery of byproducts.

Magnitude of Flotation.—The number of flotation plants reported operating in the minerals industry in the United States increased from 194 in 1960 to 255 in 1965, and their combined daily capacity increased from 729,300 tons to 908,200 tons. Of the plants, 117 (96 in 1960) treated metallic minerals; 69 (67) nonmetallic minerals; 64 (26) bituminous coal; and 5 (5) anthracite. Combined daily capacity of the plants was as follows: metallic minerals 665,500 tons (558,800 tons in 1960);

Table 9.—Kind of surface mining operation, by States, in 1965

(Percent of crude ore)

State	Open pit	Single bench	Multiple bench
Alabama	93	2	5
Arizona	12	14	74
Arkansas	90	2	8
California	63	4	33
Colorado	81	14	5
Connecticut	63	24	13
Delaware	90	---	10
Florida	97	1	2
Georgia	74	13	13
Hawaii	36	47	17
Idaho	48	1	51
Illinois	45	27	28
Indiana	55	21	24
Iowa	54	20	26
Kansas	93	5	2
Kentucky	74	8	18
Louisiana	99	1	---
Maine	98	2	---
Maryland	55	20	25
Massachusetts	82	7	11
Michigan	52	14	34
Minnesota	16	2	82
Mississippi	94	6	---
Missouri	77	9	14
Montana	87	1	12
Nebraska	69	23	8
Nevada	15	7	78
New Hampshire	98	1	1
New Jersey	86	7	7
New Mexico	23	5	72
New York	43	15	42
North Carolina	83	2	15
North Dakota	77	23	---
Ohio	51	34	15
Oklahoma	90	2	8
Oregon	95	1	4
Pennsylvania	29	41	30
Rhode Island	81	1	18
South Carolina	72	8	20
South Dakota	85	13	2
Tennessee	85	9	6
Texas	88	7	5
Utah	19	2	79
Vermont	59	8	33
Virginia	46	23	31
Washington	91	4	5
West Virginia	54	5	41
Wisconsin	78	11	11
Wyoming	24	53	23

Table 10.—Exploration and development by methods and selected metals and nonmetals in 1965

(Feet)

Commodity	Shaft and winze sinking	Raising	Drifting and cross-cutting	Trenching	Diamond drilling	Churn drilling	Rotary drilling	Percussion drilling	Other	Total
Metals:										
Beryllium	10	-----	-----	-----	1,627	240	44,027	-----	10,000	55,904
Copper	3,341	37,847	130,646	4,170	724,160	36,395	114,808	34,645	3,372	1,089,384
Gold	1,889	19,780	68,362	9,203	96,762	4,449	21,437	673,089	30,750	925,721
Iron ore	920	60,661	118,327	3,000	318,906	21,262	218,289	2,024,662	153,215	2,919,242
Lead	2,254	22,275	88,837	8,910	369,003	136,356	13,183	563,286	57,275	1,261,379
Mercury	833	3,090	6,176	3,050	27,707	3,272	88,331	27,547	14,475	174,481
Molybdenum	-----	7,295	42,932	400	78,807	-----	47,619	-----	-----	177,053
Silver	2,240	7,104	40,359	2,512	51,039	21,250	31,470	315,135	500	471,609
Tungsten	278	4,774	7,961	2,200	22,186	-----	-----	150	-----	37,549
Uranium	1,383	11,499	183,118	695	116,839	190	1,687,030	929,446	4,218	2,934,418
Zinc	5,073	14,684	88,260	-----	189,742	25,240	11,405	1,386,513	16,462	1,737,379
Other [1]	76	277	1,890	6,425	6,900	4,898	50,993	7,200	-----	78,659
Total metals	18,297	189,286	776,868	40,565	2,003,678	253,552	2,328,592	5,961,673	290,267	11,862,778
Nonmetals:										
Asbestos	-----	790	2,270	-----	2,373	-----	37,271	-----	15,000	57,704
Barite	-----	245	1,879	6,965	2,104	3,000	-----	-----	12,315	26,508
Clays	60	500	2,800	900	3,107	-----	558,376	27,690	35,688	629,121
Diatomite	-----	-----	-----	2,000	711	-----	3,800	-----	-----	6,511
Fluorspar	637	266	1,523	-----	9,567	847	-----	45,000	-----	57,840
Gypsum	246	-----	14,209	-----	9,352	-----	667,166	82,298	6,500	779,771
Mica: Scrap	-----	-----	-----	8,650	-----	-----	2,000	400	1,500	12,550
Phosphate rock	-----	3,424	14,687	1,600	10,142	-----	263,863	28,919	16,222	338,857
Potassium salts	-----	200	34,700	-----	12,955	-----	31,506	-----	-----	79,361
Pumice	-----	-----	-----	-----	57	-----	108	-----	2,500	2,665
Sodium carbonate (natural)	1,625	-----	47,866	-----	1,112	-----	53,881	-----	-----	104,484
Stone	622	420	31,884	2,850	132,016	20,200	1,726,723	1,890,639	5,000	3,810,354
Sulfur: Frasch process mines	-----	-----	-----	-----	-----	-----	181,504	-----	-----	181,504
Talc, soapstone, and pyrophyllite	1,280	6,733	7,129	120	31,695	-----	675	2,560	38,990	89,182
Other [2]	-----	80	150	750	-----	2,800	41,200	571,345	-----	616,325
Total nonmetals	4,470	12,658	159,097	23,835	215,191	26,847	3,568,073	2,648,851	133,715	6,792,737
Grand total	22,767	201,944	935,965	64,400	2,218,869	280,399	5,896,665	8,610,524	423,982	18,655,515

[1] Antimony, bauxite, manganese ore, nickel, platinum-group metals, rare-earth metals and thorium, and tin.
[2] Abrasives, feldspar, lithium minerals, vermiculite, and wollastonite.

Table 11.—Exploration and development activity in the United States, by methods

Method	Metals		Nonmetals		Total	
	Feet	Percent of total	Feet	Percent of total	Feet	Percent of total
1964:						
Shaft and winze sinking	16,860	0.2	12,694	0.3	29,554	0.2
Raising	202,825	1.9	21,157	.5	223,982	1.5
Drifting and crosscutting	839,724	7.8	139,956	3.4	979,680	6.5
Diamond drilling	2,288,147	21.2	178,903	4.4	2,467,050	16.5
Churn drilling	243,095	2.2	23,387	.6	266,482	1.8
Rotary drilling	1,949,804	18.0	2,159,625	52.5	4,109,429	27.5
Percussion drilling	4,832,634	44.7	1,318,660	32.0	6,151,294	41.3
Trenching	38,318	.3	2,305	.1	40,623	.3
Other	401,704	3.7	256,890	6.2	658,594	4.4
Total	10,813,111	100.0	4,113,577	100.0	14,926,688	100.0
1965:						
Shaft and winze sinking	18,297	0.6	4,470	0.6	22,767	0.5
Raising	189,286	1.5	12,658	.1	201,944	1.0
Drifting and crosscutting	776,868	6.5	159,097	2.3	935,965	5.0
Diamond drilling	2,003,678	16.8	215,191	3.1	2,218,869	11.8
Churn drilling	253,552	2.1	26,847	.3	280,399	1.5
Rotary drilling	2,328,592	19.6	3,568,073	52.5	5,896,665	31.6
Percussion drilling	5,961,673	50.2	2,648,851	38.9	8,610,524	46.1
Trenching	40,565	.3	23,835	.3	64,400	.3
Other	290,267	2.4	133,715	1.9	423,982	2.2
Total	11,862,778	100.0	6,792,737	100.0	18,655,515	100.0

nonmetallic minerals 195,700 tons (144,000 tons); bituminous coal 42,000 tons (21,500 tons); and anthracite 5,000 tons (5,000 tons).

In 1965, approximately 279 million tons (200 million in 1960) of raw material was treated in froth flotation plants. Concentrates produced from the material totaled 38.7 million tons (21.5 million in 1960) and consisted of 30 different commodities—various metallic and nonmetallic minerals and coal.

Distribution of Flotation Plants.—The 255 flotation plants were located in 35 States compared with 32 States in 1960. A flotation mill in Minnesota, reported operating in 1960, did not report activity in 1965. However, data were reported for the first time on plants in Kansas, Oregon, South Dakota, and Texas. Concurrent with the large increase in the number of plants treating bituminous coal, the number of plants in West Virginia increased from 9 to 38 and in Pennsylvania from 12 to 22. The number of mills in Colorado and Arizona each were 20 or more, and more than 10 plants were operating in each Florida, New Mexico, and Idaho.

Consumption of Energy, Water and Grinding Media, Including Mill Liners.—The consumption of energy in the operation of flotation plants increased from 3,210 million kilowatt-hours in 1960 to 4,077 million kilowatt-hours in 1965. Energy consumption included all that was consumed by processes preceding or following flotation, such as crushing, grinding, conveying, classifying, flotation, filtering, and materials handling.

Water used in the flotation plants increased from 222 billion gallons in 1960 to 322 billion gallons in 1965 and the average consumption per ton of ore increased from 1,140 gallons to 1,240 gallons. Total quantities are reported and included recirculated and new or makeup water.

Grinding media consumed during the preparation of ores for flotation were rod, 50.3 million pounds; balls, 201.7 million pounds; and liners, 16.9 million pounds. Consumption of these items per ton of ore was rod, 0.549 pound; balls, 1.088 pounds; and liners, 0.138 pound. Comparable data are not available for 1960. Use of grinding media was predominantly in the preparation of ores of metals for flotation.

Consumption of Reagents.—Total consumption of flotation reagents increased from 850.3 million pounds in 1960 to 1,243.9 million pounds in 1965. The average consumption of reagents per ton of ore treated increased from 4.297 pounds in 1960 to 4.507 pounds in 1965. During the interval, the total value of reagents increased from $21.8 million to $31.0 million,

Table 12.—Exploration and development by methods and States in 1965

(Feet)

State	Shaft and winze sinking	Raising	Drifting and cross-cutting	Trenching	Diamond drilling	Churn drilling	Rotary drilling	Percussion drilling	Other	Total
Alabama	-----	-----	-----	4,000	2,045	6,006	237,000	11,000	20,565	280,616
Alaska	434	84	770	40	-----	4,551	-----	-----	10,395	16,274
Arizona	1,835	30,991	103,862	3,074	501,677	29,526	63,110	20,713	-----	754,788
Arkansas	-----	245	1,839	-----	2,000	-----	6,770	-----	-----	10,854
California	2,529	8,663	21,419	8,985	110,689	20,977	302,958	807,083	80,196	1,363,499
Colorado	1,027	16,626	103,573	5,450	189,888	2,314	97,379	169,134	25	585,416
Florida	-----	-----	-----	-----	-----	-----	96,825	-----	7,290	104,115
Georgia	-----	-----	-----	-----	13,200	3,000	371,812	-----	-----	388,012
Hawaii	-----	-----	-----	-----	-----	-----	-----	185,000	-----	185,000
Idaho	928	19,715	46,666	5,110	105,091	-----	47,677	1,796,977	3,297	2,025,461
Illinois	562	266	1,523	-----	9,567	847	2,810	-----	6,724	22,299
Indiana	-----	-----	-----	-----	1,974	-----	102,000	-----	-----	103,974
Iowa	-----	-----	-----	-----	7,259	-----	17,200	-----	-----	24,459
Kansas	-----	-----	1,000	-----	-----	5,912	109,427	8,855	-----	125,194
Kentucky	125	150	500	100	3,300	20,000	441,511	171,000	-----	636,686
Louisiana	400	-----	130	-----	-----	-----	165,435	-----	-----	165,965
Maine	410	747	6,429	-----	13,721	-----	-----	250,000	-----	271,307
Massachusetts	-----	-----	-----	-----	2,400	-----	-----	-----	-----	2,400
Michigan	582	38,294	86,006	-----	174,963	-----	13,931	13,637	-----	327,413
Minnesota	-----	400	950	-----	121,082	4,607	40,083	4,156	132,650	303,928
Mississippi	-----	-----	-----	-----	-----	-----	400	-----	-----	400
Missouri	1,950	23,683	126,383	7,565	368,022	147,205	34,936	1,251,468	66,336	2,027,548
Montana	556	4,367	20,359	5,870	1,090	-----	36,106	85,214	9,432	162,994
Nebraska	-----	-----	-----	-----	-----	-----	5,600	-----	-----	5,600
Nevada	2,090	2,617	16,876	14,450	39,356	8,471	555,775	658,106	21,330	1,319,071
New Mexico	2,723	12,528	155,939	1,001	138,113	5,245	1,177,631	633,485	1,625	2,128,290
New York	-----	2,348	2,769	-----	-----	-----	-----	-----	-----	5,117
North Carolina	540	-----	300	5,000	75,881	-----	21,000	1,335,582	1,500	1,439,803
North Dakota	-----	-----	-----	-----	-----	-----	19,559	-----	-----	19,559
Ohio	60	-----	-----	-----	-----	-----	-----	-----	-----	60
Oklahoma	-----	-----	-----	-----	-----	363	29,698	20	9,348	39,429
Oregon	15	580	617	-----	3,600	2,410	-----	4,075	2,650	13,947
Pennsylvania	-----	-----	1,480	-----	396	-----	16,380	-----	-----	18,256
South Carolina	-----	-----	-----	-----	-----	-----	500	-----	-----	500
South Dakota	-----	12,058	43,023	-----	86,527	-----	150,178	-----	-----	291,786
Tennessee	2,427	7,276	48,027	-----	118,102	900	311,130	148,874	12,066	648,802
Texas	-----	-----	-----	-----	330	-----	704,230	212,443	-----	917,003
Utah	771	9,484	54,052	810	91,556	-----	98,849	529,852	477	785,851
Vermont	50	2,100	350	-----	10,168	-----	-----	-----	-----	12,668
Virginia	246	-----	6,909	250	-----	-----	102,577	-----	-----	109,982
Washington	70	4,825	9,964	2,000	-----	-----	-----	271,068	12,076	300,003
Wisconsin	-----	-----	-----	-----	6,500	18,065	9,882	30	-----	34,477
Wyoming	2,437	3,897	74,250	695	20,372	-----	506,306	42,752	26,000	676,709
Total	22,767	201,944	935,965	64,400	2,218,869	280,399	5,896,665	8,610,524	423,982	18,655,515

Table 13.—Froth flotation in 1965

Plants: Type	Plants: Number	Plants: Capacity (short tons per day)	Ore treated (short tons)	Concentrates produced (short tons)	Energy used (kilowatt-hours): Total (million)	Energy used: Per ton	Water used (gallons): Total (million)	Water used: Per ton	Rod consumption (pounds): Total	Rod consumption: Per ton	Ball consumption (pounds): Total	Ball consumption: Per ton	Liner consumption (pounds): Total	Liner consumption: Per ton
Antimony	1	NA	W	W	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Copper	16	181,100	55,793,000	1,821,781	895.7	16.3	40,495.9	745	11,633,968	0.358	31,602,579	0.813	6,613,629	0.170
Copper-molybdenum	13	303,600	106,963,300	2,791,610	1,623.3	15.2	76,668.7	755	14,339,601	.579	110,704,702	1.259	3,597,104	.083
Copper-lead-zinc	14	30,000	8,562,300	343,081	152.9	18.1	4,188.0	495	3,280,826	.413	4,752,232	.573	116,041	.021
Copper-zinc-iron	4	11,000	3,302,800	1,034,559	59.5	18.0	2,687.5	815	1,058,425	.327	2,091,724	.633	----------	-----
Gold-silver	7	1,100	175,400	2,503	3.2	18.9	115.0	670	8,638	3.531	326,354	1.901	42,411	.247
Lead-zinc	10	10,300	2,600,000	255,987	38.0	14.6	1,831.6	705	820,651	.449	1,388,640	.534	160,127	.064
Lead-zinc-silver	31	30,000	5,206,000	627,748	111.4	25.5	3,818.6	790	1,519,174	.932	8,581,501	1.716	1,914,596	.431
Zinc	10	15,000	3,740,500	289,232	61.5	16.4	1,585.9	425	1,160,972	.318	659,942	.203	137,303	.063
Barite	4	2,250	366,400	225,402	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Bastnaesite	1	W	W	W	W	W	W	W	W	W	W	W	W	W
Feldspar-mica-quartz	18	10,200	2,211,000	1,269,860	35.8	16.2	5,572.8	2,500	973,635	.984	W	W	76,092	.155
Fluorspar	6	2,000	516,200	232,881	30.9	44.1	905.1	1,290	----------	-----	533,356	1.033	160,434	.311
Garnet	1	W	W	W	NA	NA	W	W	NA	NA	NA	NA	NA	NA
Ilmenite	2	W	W	W	NA	NA	NA	NA	W	W	W	W	W	W
Iron ores	6	40,000	14,046,600	6,055,863	318.5	22.7	25,871.1	1,840	15,103,731	1.075	17,624,712	1.267	1,017,939	.123
Kyanite	4	W	W	W	NA	NA	NA	NA	W	W	----------	-----	W	W
Limestone-magnesite	5	4,500	1,064,200	795,918	NA	NA	NA	NA	----------	-----	W	W	W	W
Mercury	1	NA	W	W	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Molybdenum	1	W	W	W	W	W	W	W	----------	-----	W	W	W	W
Phosphate	18	122,400	32,477,500	11,221,018	268.2	8.3	145,299.6	4,475	W	W	890,577	.154	----------	-----
Potash	9	50,000	16,083,000	4,226,180	306.2	19.0	4,271.4	265	NA	NA	NA	NA	NA	NA
Talc	2	W	W	W	NA	NA	NA	NA	W	W	W	W	W	W
Tungsten	1	W	W	W	NA	NA	W	W	----------	-----	W	W	----------	-----
Vermiculite	1	W	W	W	NA	NA	NA	NA	W	W	W	W	W	W
Anthracite	5	5,000	744,600	407,000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Bituminous coal	64	42,000	8,755,600	6,625,500	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total	255	908,200	278,986,500	38,707,917	4,076.9	15.4	321,757.7	1,240	50,318,958	.549	201,681,715	1.088	16,913,140	.138

NA Not available. W Withheld to avoid disclosing individual company confidential data; included in "Total."

Table 14.—Consumption of reagents by types and plants in froth flotation in 1965

Type of plant	Reagent consumption (pounds)													
	Modifiers		Activators		Depressants		Collectors		Frothers		Flocculants		Total	Per ton
	Total	Per ton	Total	Per ton	Total	Per ton	Total	Per ton	Total	Per ton	Total	Per ton		
Copper	297,478,380	5.621	---------	-----	42,528	0.004	4,342,671	0.078	3,612,205	0.065	68,122	0.003	[1]417,893,123	[1]7.508
Copper-molybdenum	406,620,011	3.801	220,045	0.016	4,252,212	.065	6,282,405	.059	8,795,662	.082	140,213	.004	426,310,548	3.986
Copper-lead-zinc	14,845,428	4.410	596,829	.110	2,558,861	.444	571,742	.068	468,520	.055	12,505	.004	19,053,885	2.252
Copper-zinc-iron	18,694,074	5.660	1,052,687	.664	312,624	.163	860,729	.261	311,937	.096	14,708	.005	21,246,759	6.398
Gold-silver	874,178	2.199	9,819	.120	939	.006	40,731	.236	11,941	.070	2,412	.014	440,020	2.545
Lead-zinc	1,895,397	1.351	1,597,275	.617	96,101	.037	442,386	.171	268,220	.104	2,278	.003	4,301,657	1.662
Lead-zinc-silver	7,134,420	2.089	3,489,665	.702	2,496,192	.502	1,010,396	.203	601,261	.121	8,814	.005	14,740,748	2.963
Zinc	718,880	3.536	2,016,773	.539	47,792	.034	285,554	.076	804,632	.215	939	.002	3,874,570	1.036
Barite	W	W	W	W	W	W	W	W	W	W	W	W	W	W
Bastnaesite	W	W	W	W	W	W	W	W	W	W	W	W	W	W
Feldspar-mica-quartz	4,434,117	2.325	---------	-----	356,180	.780	3,814,418	2.000	943,677	.769	433,561	1.074	9,981,953	5.234
Fluorspar	5,295,394	10.259	511,677	1.038	1,121,347	2.275	536,753	1.040	163,382	.332	28,606	.055	7,657,159	14.834
Ilmenite	W	W	W	W	W	W	W	W	W	W	W	W	W	W
Iron ore	10,167,642	2.842	---------	-----	59,407	.513	20,344,666	1.448	749,254	.087	4,802	.009	31,325,771	2.230
Kyanite	W	W	W	W	W	W	W	W	W	W	W	W	W	W
Limestone-magnesite	---------	-----	---------	-----	---------	-----	1,669,247	1.654	18,347	.152	10,994	.013	1,698,588	1.683
Molybdenum	W	W	W	W	W	W	W	W	W	W	W	W	W	W
Phosphate	42,981,014	1.362	---------	-----	---------	-----	173,788,798	5.508	2,113,052	.442	88,356	.263	218,971,220	6.940
Potash	1,174,654	.137	---------	-----	2,566,798	.296	6,756,072	.440	1,616,935	.105	2,625,822	.171	14,740,281	.959
Talc	W	W	W	W	W	W	W	W	W	W	W	W	W	W
Tungsten	W	W	W	W	W	W	W	W	W	W	W	W	W	W
Vermiculite	W	W	W	W	W	W	W	W	W	W	W	W	W	W
Anthracite	---------	-----	---------	-----	---------	-----	1,772,224	2.380	211,021	.283	---------	-----	1,983,245	2.663
Bituminous coal	298,274	1.922	---------	-----	---------	-----	2,283,082	1.762	1,343,780	.156	2,301,001	.365	6,226,137	.711
Total	836,144,179	3.579	9,494,770	.292	16,798,085	.143	239,851,534	.911	22,790,826	.095	6,517,337	.059	[1]1,243,945,948	[1]4.507

W Withheld to avoid disclosing individual company confidential data; included in "Total."
[1] Includes 112,349,217 pounds (4.867 pounds per ton) other reagents.

Table 15.—Froth flotation plants in 1965, by States

State	Number
Alabama	7
Arizona	20
Arkansas	2
California	8
Colorado	21
Florida	16
Georgia	4
Idaho	12
Illinois	5
Kansas	1
Kentucky	4
Maryland	1
Michigan	8
Missouri	5
Montana	5
Nevada	7
New Jersey	1
New Mexico	14
New York	5
North Carolina	8
Ohio	1
Oklahoma	2
Oregon	2
Pennsylvania	22
South Carolina	3
South Dakota	1
Tennessee	6
Texas	1
Utah	8
Vermont	1
Virginia	5
Washington	5
West Virginia	38
Wisconsin	5
Wyoming	1
Total	255

or at the average rate of 7 percent per year. The average cost of reagents per ton of ore treated was $0.112, reflecting an increase of two-tenths of a cent.

In 1965, total consumption by classes of flotation reagents was modifiers, 836.1 million pounds (567.6 million pounds in 1960); activators, 9.5 million pounds (12.4 million pounds); depressants, 16.8 million pounds (15.9 million pounds); collectors, 239.9 million pounds 220.1 million pounds; frothers, 22.8 million pounds (16.9 million pounds); flocculants, 6.5 million pounds (17.4 million pounds); and other, 112 million pounds (no data). Average consumption per ton of ore was modifiers, 3.579 pounds (3.716 pounds); activators, 0.292 pound (0.496 pound); depressants, 0.143 pound (0.191 pound); collectors, 0.911 pound (1.125 pounds); frothers, 0.095 pound (0.097 pound); flocculants, 0.059 pound (0.303 pound); and other, 4.867 pounds (no data). Consumption of reagents in pounds per ton was calculated by dividing the quantity in pounds of reagents by the quantity in tons of ore treated.

The following classification of reagents is used in this chapter:

Modifiers—Reagents used to control alkalinity and to eliminate harmful effects of colloidal material and soluble salts.

Activators.—Reagents used to assist or improve the flotation of minerals that do not respond to a simple collector-froth combination.

Depressants.—Reagents used to improve the selective separation of minerals by lowering the floatability of specific minerals.

Collectors.—Reagents used to provide a water-repellent surface on the mineral to be floated so as to improve adherence of the mineral to air bubbles.

Frothers.—Reagents used to produce a froth of adequate durability to permit removal of mineral-carrying bubbles from the flotation machine.

Flocculants.—Reagents used to flocculate solids in aqueous suspension and thereby facilitate thickening and filtering operations.

Whenever possible, the chemical names rather than the trade names of reagents are reported. For those reagents whose chemical compositions are unknown or too complex for simple presentation, the trade names are shown. Included in those categories are Aero Depressants, Aerofloats, Aerofroths, Aero Promoters, Aeroflocs, Superflocs (products of American Cyanamid Co.), Dowfroth, Dow Z-200, Separan (products of The Dow Chemical Co.), Minerec (product of Minerec Corp.), and Nalco (product of Nalco Chemical Co.). Also, to avoid disclosing confidential information, some reagents are not identified, but are included under "other" classification, or information on two or more reagents is combined.

Changes in Types of Material Treated.—Significant changes have occurred in the types of material treated, kinds and quantities of product prepared, and reagents consumed. Data were compiled by classifying materials of similar characteristics into four groups. The groups consist of metallic sulfides, metallic oxides and carbonates, nonmetallic minerals, and solid mineral fuels. Data were compiled in greater detail for individual mineral commodities.

Sulfide Ores.—The number of concentrators processing sulfide ores increased from 95 in 1960 to 108 in 1965 and the daily capacity rose 14 percent. Sulfide ore treated and concentrate produced in 1965

Table 16. Consumption and value of reagents in froth flotation in 1965

Function and name	Consumption, pounds	
	Total	Per ton
Modifier:		
Caustic soda	17,241,226	0.653
Hydrofluoric acid	1,429,430	1.138
Lime	731,864,986	3.942
Nalco	717,992	.013
Phosphates	4,193,020	.064
Salt	3,961,348	5.194
Soda ash	4,736,533	.444
Sodium carbonate	193,235	.520
Sodium hydroxide	6,911,295	.386
Sodium silicate	22,822,202	.339
Sulfuric acid	40,029,046	.753
Other	2,043,866	.076
Total:		
Pounds	836,144,179	3.579
Value	$11,838,502	$0.051
Activator:		
Copper sulfate	9,123,896	0.405
Sodium sulfide	243,874	.080
Other	127,000	.016
Total:		
Pounds	9,494,770	.292
Value	$1,301,773	$0.040
Depressant:		
Aero Depressant 610, 633	67,339	0.085
Calcium cyanide	85,509	.008
Lignin sulfonate	382,691	.479
Phosphorous pentasulfide	879,423	.038
Quebracho	595,756	1.209
Sodium cyanide	3,224,208	.044
Sodium ferrocyanide	941,053	.057
Sodium fluoride	831,198	.959
Sodium fluosilicate	8,620	.250
Sodium hydrosulfide	2,099,096	.296
Sodium sulfite	777,735	.617
Starch	2,035,932	.104
Zinc hydrosulfite	70,506	.255
Zinc sulfate	1,681,585	.160
Other	3,117,434	.063
Total:		
Pounds	16,798,085	.143
Value	$1,888,622	$0.016
Collector:		
Aerofloat 15, 33	46,197	0.099
Aerofloat 31	206,736	.060
Aerofloat 208	33,794	.053
Aerofloat 211	165,736	.091
Aerofloat 238	277,631	.013
Aerofloat 242	70,832	.063
Aerofloat 243, 249	162,265	.024
Aero Promoter 404	110,649	.057
Aero Promoter 801, 825, 899	3,261,178	.969
Amines	4,882,498	.084
Dow Z-200	721,615	0.013
Fatty acids	48,494,790	1.348
Fuel oil	128,111,887	1.190
Collector—Continued		
Kerosine	6,193,568	.284
Minerec	639,228	.030
Petroleum sulfonate	460,411	.757
Potassium amyl xanthate	721,017	.022
Potassium ethyl xanthate	200,069	.020
Sodium Aerofloat	1,433,925	.022
Sodium ethyl xanthate	1,852,965	.030
Sodium isopropyl xanthate	2,975,285	.048
Sodium secondary-butyl xanthate	133,577	.067
Tall oil	26,400,688	2.033
Xanthates	1,759,005	.101
Other	10,535,988	.455
Total:		
Pounds	239,851,534	.911
Value	$9,539,506	$0.036
Frother:		
Aerofroth 65	639,434	0.024
Aerofroth 70, 73	7,938	.001
Aerofroth 71	243,045	.028
Aerofroth 77	382,688	.155
Barrett oil	856,642	.087
Creosote	1,305,285	.080
Cresylic acid	2,695,471	.047
Dowfroth	1,098,873	.022
Methyl isobutyl carbinol	8,566,310	.066
Pine oil	6,984,293	.079
Other	10,847	.179
Total:		
Pounds	22,790,826	.095
Value	$3,236,264	$0.013
Flocculant:		
Aerofloc 550	78,863	0.029
Alum	1,037,006	.697
Guar	691,906	.084
Lime	711,168	.049
Nalco	329,084	.048
Separan	340,254	.005
Starch	2,625,494	.414
Superfloc	154,114	.013
Other	549,448	.408
Total:		
Pounds	6,517,337	.059
Value	$1,776,171	$0.016
Other: Sulfuric acid, sponge iron		
Total:		
Pounds	112,349,217	4.867
Value	$1,375,253	$0.060
Total reagents:		
Pounds	1,243,945,948	4.507
Value	$30,956,091	$0.112

increased 29 percent and 23 percent, respectively, over that of 1960. In 1960, sulfide ore was 78 percent of the total material treated by flotation and decreased to 72 percent of the total in 1965. Concentrate produced in 1960 was 27 percent of the total material recovered but dropped to 19 percent in 1965. In the past 5 years, the ratio of concentration increased from 26.5:1 to 27.8:1.

In the period under discussion, reagent consumption rose 73 percent and consumption per ton of ore increased 34 percent. Larger consumption of modifiers and increased use of leaching and precipitating agents in the flotation of copper caused much of the increase in the consumption of reagents.

Metal Oxides and Carbonates.—This group includes iron oxide ores, ilmenite, limestone, magnesite, and manganese and tungsten minerals. Although the plants treating these materials in 1965 exceeded the number in 1960 by only one, daily plant capacity more than tripled to 47,500 tons. From 1960 to 1965, ore treated and products therefrom increased almost sixfold and more than sevenfold, respectively. The quantity of ore treated in 1960 was 2 percent of the total material processed and in 1965, it was 6 percent of the total. Products of the plants increased sharply from 4 percent of the total output from flotation plants in 1960 to 18 percent in 1965. Expanded flotation of iron oxide ores accounted for nearly all the growth in material treated and concentrate produced. In the past 5 years, the ratio of concentration decreased from 3.0:1 to 2.3:1, apparently reflecting an increase in grade of material treated.

In 1960–65, consumption of reagents used in treating this category of materials increased 24 percent. However, a large reduction in the use of activators and collectors resulted in a sharp drop in the pounds of reagents used per ton of material treated.

Table 17.—Froth flotation of sulfide ores

Operating data	1960	1965
Plants:		
Number	95	108
Capacity short tons per day	545,700	622,300
Ore treated short tons	155,125,000	200,754,000
Concentrates produced do	5,855,000	7,213,000
Ratio of concentration	26.5:1	27.8:1

CONSUMPTION OF REAGENTS

Type	Pounds, total		Pounds per ton	
	1960	1965	1960	1965
Modifier	489,706,448	765,676,534	3.710	4.114
Activator	7,858,889	8,983,093	.353	.281
Depressant	6,338,230	10,863,482	.089	.101
Collector	25,346,078	23,982,758	.163	.120
Frother	12,411,044	15,501,516	.080	.077
Flocculant	1,129,430	551,362	.026	.007
Other	----------	112,349,217	-----	4.867
Total	542,790,119	937,907,962	3.499	4.684

Table 18.—Froth flotation of metallic carbonate and oxide ores

Operating data	1960	1965
Plants:		
Number	13	14
Capacity short tons per day	13,600	47,500
Ore treated short tons	2,854,000	16,079,000
Concentrates produced do	941,000	7,086,000
Ratio of concentration	3.0:1	2.3:1

CONSUMPTION OF REAGENTS

Type	Pounds, total		Pounds per ton	
	1960	1965	1960	1965
Modifier	6,639,418	15,279,991	2.368	3.444
Activator	1,280,205	----------	5.000	-----
Depressant	609,809	1,588,578	.320	1.466
Collector	22,572,698	23,694,707	8.049	1.479
Frother	1,344,778	864,657	1.333	.090
Flocculant	1,306,029	458,285	1.618	.250
Total	33,752,937	41,886,218	12.036	2.614

Nonmetallic Ores.—In the past 5 years, the number of plants treating nonmetallic minerals increased from 55 to 64, resulting in a growth of 33 percent in their daily capacity. Quantities of raw material processed and upgraded product each increased about 45 percent. The tonnage of raw material processed in 1960 and 1965 was 18 percent and 19 percent of the total material treated by flotation, whereas concentrates produced in those years were 56 percent and 45 percent, respectively, of the total output. The ratio of concentration of nonmetallic minerals remained unchanged at 3.0:1.

Despite an increase in tonnage of raw material treated in the period under discussion, the quantity of reagents used decreased 2 percent. Almost all the drop of 30 percent in consumption of reagents, per ton of material treated, was caused by a decrease in use of modifiers and collectors in phosphate flotation.

Solid Mineral Fuels.—The number of plants treating anthracite and bituminous coal increased from 31 in 1960 to 69 in 1965 as a result of the rapid growth of flotation of bituminous coal. In the past 5 years, the daily capacity of the plants increased 77 percent. Raw product treated and clean coal produced increased 131 percent and 152 percent, respectively. Solid fuels accounted for 2 percent and 3 percent of the total materials treated in 1960 and 1965, respectively. However, during the same period, the quantities of materials recovered increased from 13 percent to 18 percent of the total.

Although the quantity of coal treated more than doubled in the past 5 years, consumption of reagents decreased 23 percent. Concurrently, consumption of reagents, per ton of coal treated, fell 67 percent as a result of sharp decreases in the use of modifiers and collectors.

Table 19.—Froth flotation of nonmetallic ores

Operating data	1960	1965
Plants:		
Number	55	64
Capacity short tons per day	143,500	191,400
Ore treated short tons	36,191,000	52,653,000
Concentrates produced do	11,888,000	17,376,000
Ratio of concentration	3.0:1	3.0:1

CONSUMPTION OF REAGENTS

Type	Pounds, total		Pounds per ton	
	1960	1965	1960	1965
Modifier	82,455,910	54,889,380	3.566	1.278
Activator	2,987,585	511,677	.887	1.038
Depressant	9,231,057	4,346,025	.755	.451
Collector	163,967,377	188,118,763	4.576	3.741
Frother	2,475,037	4,869,852	.166	.219
Flocculant	874,974	3,206,689	.129	.187
Total	261,991,940	255,942,386	7.311	5.089

Table 20.—Froth flotation of anthracite and bituminous coal

Operating data	1960	1965
Plants:		
Number	31	69
Capacity short tons per day	26,500	47,000
Raw coal treated short tons	4,112,000	9,500,000
Clean coal produced do	2,795,000	7,033,000

CONSUMPTION OF REAGENTS

Type	Pounds, total		Pounds per ton	
	1960	1965	1960	1965
Modifier	1,609,352	298,274	3.841	1.922
Collector	8,142,058	4,055,306	3.015	1.988
Frother	584,798	1,554,801	.175	.166
Flocculant	393,885	2,301,001	.332	.365
Total	10,730,093	8,209,382	2.610	.864

Table 21.—Froth flotation of copper ores in 1965

OPERATING DATA

Plants:		Water used, gallons:	
Number	16	Total, million	40,495.9
Capacity, short tons per day	181,100	Per ton	745
Ore treated:		Rod consumption, pounds:	
Short tons	55,793,000	Total	11,633,968
Grade:		Per ton	0.358
Copper, percent	0.92	Ball consumption, pounds:	
Gold, ounce per ton	0.0025	Total	31,602,579
Silver, ounce per ton	.1301	Per ton	0.813
Energy used, kilowatt-hours:		Liner consumption, pounds:	
Total, million	895.7	Total	6,613,629
Per ton	16.3	Per ton	0.170

CONCENTRATES PRODUCED

Type	Quantity, short tons	Grade: Copper, percent	Grade: Gold, ounce per ton	Grade: Silver, ounces per ton	Recovery, percent: Copper	Recovery, percent: Gold	Recovery, percent: Silver
Copper	1,821,781	23.80	0.0533	3.0510	84	71	81

CONSUMPTION OF FLOTATION REAGENTS [1]

Function and name	Total	Per ton
Modifier:		
Lime	293,743,890	5.551
Phosphate	3,337,419	.125
Nalco	397,071	.016
Total:		
Pounds	297,478,380	5.621
Value	$2,555,787	$0.048
Depressant: Total:		
Pounds	42,528	0.004
Value	$2,977	$0.0003
Collector:		
Aerofloat 33, Aerofloat 238	89,071	0.008
Aerofloat 249	130,962	.020
Aero Promoter 404	55,976	.049
Dow Z-200	183,485	.009
Potassium amyl xanthate	88,444	.027
Sodium Aerofloat	208,958	.022
Sodium isopropyl xanthate	1,952,144	.053
Other	1,633,631	.068
Total:		
Pounds	4,342,671	.078
Value	$1,141,494	$0.021
Frother:		
Aerofroth 65, Aerofroth 71	353,912	0.018
Creosote, cresylic acid	1,184,059	.079
Dowfroth 250	683,252	.035
Methyl isobutyl carbinol	396,150	.025
Pine oil	994,832	.033
Total:		
Pounds	3,612,205	.065
Value	$539,522	$0.010
Flocculant: Separan: Total:		
Pounds	68,122	0.003
Value	$85,004	$0.003
Other: Sulfuric acid, sponge iron: Total:		
Pounds	112,349,217	4.867
Value	$1,375,253	$0.060
Total reagents:		
Pounds	417,893,123	7.508
Value	$5,700,037	$0.102

[1] Based on 14 operations accounting for virtually total ore.

Copper.—The number of copper flotation plants decreased to 16 in 1965 from the 18 reported in 1960. During the interval, six plants ceased operating and four new ones started. Despite the fewer plants, in 1965 daily capacity rose 23,000 tons, quantity of ore treated increased more than 11.6 million tons, and concentrate produced exceeded that of 1960 by nearly 302,000 tons. A noteworthy change occurred in reagent consumption and costs with the quantity used per ton rising from 2.473 pounds in 1960 to 7.508 pounds in 1965 and the costs per ton increasing from 5.8 cents to 10.2 cents. Higher reagent consumption and costs were due principally to an increased use of modifiers and of leaching and precipitation reagents. The grade of ore treated and copper recovery remained unchanged at 0.92 and 84 percent, respectively. Of the 16 plants, 6 were in Arizona, 5 in Michigan, and 1 each in Idaho, Montana, Nevada, New Mexico, and Utah.

Copper-Molybdenum.—The quantity of copper-molybdenum ore treated by flotation in 1965 exceeded that of 1960 by nearly 24 million tons. Ore was concentrated in 13 plants having a combined daily capacity of 303,600 tons compared with 10 plants and 263,300 tons daily capacity in 1960. Concurrently, production of copper concentrate increased nearly 600,000 tons and that of molybdenum about 5,000 tons. Although reagent average consumption fell about 0.5 pound per ton of ore treated, average costs of reagent per ton increased about 2 cents. Average grade of ore treated remained unchanged at 0.79 percent copper and average copper recovery fell only 1 percent. The 1965 data are not comparable to those published for 1960. The latter included one operation that produced molybdenum and one operation that produced byproduct copper and molybdenum. Inasmuch as the data on those two operations distorted the copper-byproduct molybdenum data, they have been excluded from the 1965 classification.

Of the 13 flotation plants treating copper-molybdenum ores in 1965—3 being new since 1960—9 were in Arizona, 2 in Utah, and 1 each in Nevada and New Mexico.

Copper-Lead-Zinc.—Despite a drop in number of flotation plants to 14 in 1965 from the 19 in 1960, total daily capacity rose nearly 4,000 tons. This was accompanied by an increase of over 3.5 million tons of ore treated; also, output of copper, lead, and zinc concentrates in 1965 exceeded that of 1960 by 32,200, 82,000, and 21,500 tons, respectively. Average reagent consumption per ton of ore went up 0.6 pound, but average costs remained virtually unchanged.

Except for two copper, lead, and zinc flotation plants in Missouri, the remainder were in the Western States with four in Idaho, three each in Arizona and Colorado, and one each in Nevada and New Mexico.

Copper-Zinc-Iron-Sulfides.—Although the number of copper-zinc-iron sulfide flotation plants dropped from eight in 1960 to four in 1965, the combined daily capacity increased 1,000 tons. In 1965, the ore treated exceeded that of 1960 by about 925,000 tons. At the same time, production of copper concentrate was up about 18,000 tons, iron sulfide concentrate production increased about 30,000 tons, and output of zinc concentrate was down about 13,000 tons. Average copper and zinc recoveries in 1965 fell 2 and 7 percent, respectively, from 1960, whereas that of iron sulfide remained unchanged at 83 percent. Average consumption and cost of reagents per ton of ore in 1965 was about 2.0 pounds and 2 cents, respectively, lower than in 1960. Two of the four plants were in Pennsylvania, with one each in Arizona and Tennessee.

Gold-Silver.—Seven flotation plants treated gold-silver ores in 1965 compared with four in 1960. Although the total daily capacity dropped 500 tons from 1960 the quantity of ore treated rose more than 43,000 tons in 1965. However, concentrate production decreased about 900 tons and gold and silver recoveries were down 14 and 23 percent, respectively. Average consumption and cost of reagents per ton of ore increased from 0.398 pound and 14.1 cents in 1960 to 2.545 pounds and 16.9 cents in 1965. Two of the gold-silver flotation plants were in California, two in Washington, and one each in Montana, Nevada, and Oregon.

Lead-Zinc.—Lead-zinc ores were treated at 10 flotation plants in 1965 compared with 11 in 1960. There was a significant drop in total daily capacity from 21,500 tons in 1960 to 10,300 tons in 1965. At the same time the quantity of ore treated decreased about 550,000 tons and production of lead concentrate dropped 15,000 tons, but zinc concentrate output rose 27,000 tons. Average lead recovery rose 2 percent, but that of zinc jumped 16 percent. There was only a slight change in reagent use as average consumption per ton of ore increased 0.08 pound and average cost went up 1.9 cents per ton of ore.

Table 22.—Froth flotation of copper-molybdenum ores in 1965

OPERATING DATA

Plants:		Water used, gallons:	
Number	13	Total, million	76,668.7
Capacity, short tons per day	303,600	Per ton	755
Ore treated:		Rod consumption, pounds:	
Short tons	106,963,300	Total	14,339,601
Grade:		Per ton	0.579
Copper, percent	0.79	Ball consumption, pounds:	
Gold, ounce per ton	0.0011	Total	110,704,702
Silver, ounce per ton	.0617	Per ton	1.259
Energy used, kilowatt-hours:		Liner consumption, pounds:	
Total, million	1,623.3	Total	3,597,104
Per ton	15.2	Per ton	0.083

CONCENTRATES PRODUCED

Type	Quantity, short tons	Grade: Copper, percent	Gold, ounce per ton	Silver, ounces per ton	Molybdenum, percent	Recovery, percent: Copper	Gold	Silver
Copper	2,770,124	25.36	0.1814	2.174	-----	83	77	73
Molybdenite	21,486	-----	-----	-----	53.59	--	--	--

CONSUMPTION OF FLOTATION REAGENT

Function and name	Total	Per ton
Modifier:		
Lime	404,225,298	3.779
Nalco	177,852	.006
Phosphates	507,885	.014
Sodium hydroxide	194,415	.022
Sodium silicate	1,253,164	.027
Sulfuric acid	199,295	.023
Other	62,102	.004
Total:		
Pounds	406,620,011	3.801
Value	$6,271,226	$0.059
Activator: Total:		
Pounds	220,045	0.016
Value	$18,013	$0.001
Depressant:		
Dextrin-zinc sulfate	450,209	0.010
Phosphorous pentasulfide, sodium hydrosulfide	1,306,355	.016
Sodium cyanide	1,554,595	.032
Sodium ferrocyanide	941,053	.057
Total:		
Pounds	4,252,212	.065
Value	$496,991	$0.008
Collector:		
Aerofloat 238, Aero Promoter 404	200,543	.019
Dow Z-200	375,027	.014
Fuel oil	2,403,481	.038
Minerec-xanthate	862,915	.065
Potassium amyl xanthate	288,844	.011
Potassium ethyl xanthate	89,834	.010
Sodium Aerofloat	817,282	.016
Sodium ethyl xanthate	815,458	.019
Sodium isopropyl xanthate	429,021	.025
Total:		
Pounds	6,282,405	.059
Value	$1,011,595	$0.009
Frother:		
Aerofroth 65, Aerofroth 73, Aerofroth 77	8,193	0.001
Creosote, cresylic acid	2,528,328	.047
Dowfroth	253,344	.016
Methyl isobutyl carbinol	4,277,459	.059
Pine oil	1,728,338	.052
Total:		
Pounds	8,795,662	.082
Value	$1,227,206	$0.011
Flocculant: Separan, Superfloc: Total:		
Pounds	140,213	0.004
Value	$169,561	$0.005
Total reagents:		
Pounds	426,310,548	3.986
Value	$9,194,592	$0.086

Table 23.—Froth flotation of copper-lead-zinc ores in 1965

OPERATING DATA

Plants:		Water used, gallons:	
Number	14	Total, million	4,188.0
Capacity, short tons per day	30,000	Per ton	495
Ore treated:		Rod consumption, pounds:	
Short tons	8,562,300	Total	3,280,826
Grade:		Per ton	0.413
Copper, percent	0.39	Ball consumption, pounds:	
Lead, percent	2.62	Total	4,752,232
Zinc, percent	0.66	Per ton	0.573
Gold, ounce per ton	0.0506	Liner consumption, pounds:	
Silver, ounces per ton [1]	3.7478	Total	116,041
Energy used, kilowatt-hour:		Per ton	0.021
Total, million	152.9		
Per ton	18.1		

CONCENTRATES PRODUCED

Type	Quantity, short tons	Grade: Copper, percent	Grade: Lead, percent	Grade: Zinc, percent	Grade: Gold, ounce per ton	Grade: Silver, ounces per ton	Recovery, percent: Copper	Recovery, percent: Lead	Recovery, percent: Zinc	Recovery, percent: Gold	Recovery, percent: Silver
Copper	107,344	25.16	10.73	2.99	0.2821	118.6604	78	1	6	25	91
Lead	185,494	2.69	71.72	2.28	.8434	48.3392	1	93	1	46	6
Zinc	50,243	.62	.93	56.03	.0367	3.0619	1	--	84	6	1

CONSUMPTION OF FLOTATION REAGENTS [2]

Function and name	Total	Per ton
Modifier:		
Lime	14,692,120	4.410
Other	153,308	0.050
Total:		
Pounds	14,845,428	4.410
Value	$288,888	$0.086
Activator:		
Copper sulfate	352,955	0.147
Sodium sulfide	243,874	.080
Total:		
Pounds	596,829	.110
Value	$71,947	$0.013
Depressant:		
Sodium cyanide	122,712	0.184
Sodium sulfite	216,223	.397
Zinc sulfate	410,147	.753
Other	1,809,779	.367
Total:		
Pounds	2,558,861	.444
Value	$250,199	$0.043
Collector:		
Aerofloat 31, Aero Promoter 404	1,504	0.027
Aerofloat 208, Sodium Aerofloat	1,504	.027
Aerofloat 242	6,894	.020
Dow Z-200	133,241	.026
Potassium amyl xanthate	121,717	.046
Sodium isopropyl xanthate	306,882	.054
Total:		
Pounds	571,742	.068
Value	$155,427	$0.018
Frother:		
Aerofroth 71	126,657	0.026
Methyl isobutyl carbinol	292,947	.086
Pine oil	8,096	.015
Other	40,820	.013
Total:		
Pounds	468,520	.055
Value	$66,433	$0.008
Flocculant: Separan, Superfloc: Total:		
Pounds	12,505	0.004
Value	$14,369	$0.005
Total reagents:		
Pounds	19,053,885	2.252
Value	$847,263	$0.100

[1] Based on 8 operations.
[2] Based on 9 operations accounting for 99 percent of total ore.

Table 24.—Froth flotation of copper-zinc-iron sulfide ores in 1965

OPERATING DATA

Plants:		Water used, gallons:	
Number	4	Total, million	2,687.5
Capacity, short tons per day	11,000	Per ton	815
Ore treated:		Rod consumption, pounds:	
Short tons	3,302,800	Total	1,058,425
Grade, percent:		Per ton	0.327
Copper	0.82	Ball consumption, pounds:	
Zinc	1.68	Total	2,091,724
Iron sulfide	30.46	Per ton	0.633
Energy used, kilowatt-hours:			
Total, million	59.5		
Per ton	18.0		

CONCENTRATES PRODUCED

Type	Quantity, short tons	Grade: Gold, ounce per ton	Grade: Silver, ounces per ton	Grade: Copper, percent	Grade: Zinc, percent	Grade: Iron sulfide, percent	Recovery, percent: Copper	Recovery, percent: Zinc	Recovery, percent: Iron
Copper	108,700	0.0170	1.1524	20.57	-----	-----	92	--	--
Zinc	32,958	-----	-----	-----	55.26	-----	--	68	--
Iron	892,901	-----	-----	-----	-----	91.23	--	--	83

CONSUMPTION OF FLOTATION REAGENTS

Function and name	Total	Per ton
Modifier:		
Lime	3,851,326	1.166
Sulfuric acid	10,189,237	5.480
Other	4,653,511	3.060
Total:		
Pounds	18,694,074	5.660
Value	$214,224	$0.065
Activator: Copper sulfate: Total:		
Pounds	1,052,687	0.664
Value	$153,717	$0.097
Depressant:		
Sodium cyanide	281,880	0.178
Other	30,744	.076
Total:		
Pounds	312,624	.163
Value	$57,970	$0.030
Collector: Aero Promoter 404, potassium amyl xanthate, sodium ethyl xanthate, sodium isopropyl xanthate, sodium secondary-butyl xanthate: Total:		
Pounds	860,729	0.261
Value	$74,050	.022
Frother: Creosote, methyl isobutyl carbinol, pine oil: Total:		
Pounds	311,937	0.096
Value	$12,463	$0.004
Flocculant: Aerofloc 550, Nalco, Separan: Total:		
Pounds	14,708	0.005
Value	$14,251	$0.004
Total reagents:		
Pounds	21,246,759	6.398
Value	$526,675	$0.159

Of the flotation plants, 5 were in Wisconsin, and one each in Missouri, Illinois, New York, Oklahoma and Virginia. A new flotation mill of 5,000-tons per day capacity was under construction in Missouri to tread lead-zinc ore but did not operate in 1965.

Lead-Zinc-Silver.—Flotation of lead-zinc-silver ores in 1965 showed a tremendous increase over the 1960 totals. Some 31 plants with a combined daily capacity of 30,000 tons treated 5.2 million tons of ore compared with 17 plants in 1960 with a total daily capacity of 17,600 tons treating

Table 25.—Froth flotation of gold-silver ores in 1965

OPERATING DATA

Plants:		Water used, gallons:	
Number	7	Total, million	115.0
Capacity, short tons per day	1,100	Per ton	670
Ore treated:		Rod consumption:	
Quantity, short tons	175,400	Total, pounds	8,638
Grade, ounces per ton:		Per ton	3.531
Gold	0.5636	Ball consumption:	
Silver	2.2194	Total, pounds	326,354
Energy used, kilowatt-hours:		Per ton	1.901
Total, million	3.2	Liner consumption:	
Per ton	18.9	Total, pounds	42,411
		Per ton	0.247

CONCENTRATES PRODUCED

Type	Quantity, short tons	Grade, ounces per ton		Recovery, percent	
		Gold	Silver	Gold	Silver
Gold-silver	2,503	29.9501	112.0364	78	70

CONSUMPTION OF FLOTATION REAGENTS [1]

Function and name	Total	Per ton
Modifier:		
Soda ash	210,536	1.237
Other	163,642	2.000
Total:		
Pounds	374,178	0.056
Value	$9,565	$0.056
Activator: Total:		
Pounds	9,819	0.120
Value	$2,062	$0.025
Depressant: Aero Depressant 633, sodium cyanide: Total:		
Pounds	939	0.006
Value	$253	$0.002
Collector:		
Aerofloat 15, Aerofloat 31	13,073	0.148
Aerofloat 208	8,485	.050
Aero Promoter 404	3,288	.040
Potassium ethyl xanthate, sodium isopropyl xanthate	285	.100
Potassium amyl xanthate	4,560	.052
Sodium secondary-butyl xanthate	11,040	.065
Total:		
Pounds	40,731	.236
Value	$11,729	$0.068
Frother:		
Aerofroth 77, Pine oil	3,124	0.038
Dowfroth 250	8,817	.100
Total:		
Pounds	11,941	.070
Value	$4,147	$0.024
Flocculant: Aerofloc 550: Total:		
Pounds	2,412	0.014
Value	$1,463	$0.009
Total reagents:		
Pounds	440,020	2.545
Value	$29,219	$0.169

[1] Based on 6 operations accounting for 99 percent of total ore.

2.9 million tons. Output of lead and zinc concentrates jumped 64,000 and 149,000 tons, respectively, from the 1960 level. Average reagent consumption per ton of ore in 1965 dropped 0.66 pound and 1.7 cents below the 1960 level.

Of the 31 plants, 14 were in Colorado, 7 in Idaho, 3 in New Mexico, 2 each in Utah and Washington, and 1 each in Arizona, Montana, and Nevada.

Zinc.—Flotation plants treating zinc ores increased from 7 in 1960 to 10 in 1965.

Table 26.—Froth flotation of lead-zinc ores in 1965

OPERATING DATA

Plants:		Water used, gallons:	
Number	10	Total, million	1,831.6
Capacity, short tons per day	10,300	Per ton	705
Ore treated:		Rod consumption, pounds:	
Short tons	2,600,000	Total	820,651
Grade, percent:		Per ton	0.449
Lead	1.04	Ball consumption, pounds:	
Zinc	5.79	Total	1,388,640
Energy used, Kilowatt-hours:		Per ton	0.534
Total, million	38.0	Liner consumption, pounds:	
Per ton	14.6	Total	160,127
		Per ton	0.064

CONCENTRATES PRODUCED

Type	Quantity, short tons	Grade: Lead, percent	Grade: Zinc, percent	Grade: Silver, ounce per ton	Recovery, percent: Lead	Recovery, percent: Zinc
Lead	27,193	72.63	-----	-----	93	--
Zinc	228,794	-----	58.50	0.3670	--	89

CONSUMPTION OF FLOTATION REAGENTS [1]

Function and name	Total	Per ton
Modifier:		
Lime	1,865,903	1.494
Other	29,494	.191
Total:		
Pounds	1,895,397	1.351
Value	$25,507	$0.018
Activator: Copper sulfate: Total:		
Pounds	1,597,275	0.617
Value	$226,180	$0.087
Depressant:		
Sodium cyanide	96,063	0.037
Other	38	.001
Total:		
Pounds	96,101	.037
Value	$18,224	$0.007
Collector:		
Aerofloat 31, Aero Promoter 404	73,848	0.062
Aerofloat 242	44,190	.078
Sodium Aerofloat	163,633	.215
Sodium ethyl xanthate	121,673	.093
Sodium isopropyl xanthate	39,042	.252
Total:		
Pounds	442,386	.171
Value	$122,128	$0.047
Frother:		
Aerofroth 65, Aerofroth 70	1,519	0.011
Aerofroth 71	17,586	.032
Methyl isobutyl carbinol	118,814	.189
Pine oil	130,301	.093
Total:		
Pounds	268,220	.104
Value	$36,796	$0.014
Flocculant: Superfloc: Total:		
Pounds	2,278	0.003
Value	$2,539	.003
Total reagents:		
Pounds	4,301,657	1.662
Value	$431,374	$0.167

[1] Based on 10 operations accounting for 99 percent of total ore.

During that period one plant closed operations but four new plants became active. Daily plant capacity in 1965 was up only about 1,000 tons over 1960 but 1.15 million more tons of ore were treated than in 1960. However, inasmuch as the average grade of the ore dropped from 5.91 to 4.98 percent zinc, production of concentrate in 1965 exceeded that of 1960 by only 57,000 tons. Average zinc recovery rose slightly from 93 percent in 1960 to 95 percent in 1965. Average consumption of reagents per ton of ore dropped from 1.112 pounds in 1960 to 1.036 pounds in 1965 but average costs of reagents rose 1 cent per ton. Tennessee led all States with five flotation plants treating zinc ores followed by Kansas, Kentucky, New York, Oklahoma, and Pennsylvania with one plant each.

Feldspar, Mica, and Quartz.—Data on these commodities were combined to avoid disclosing company confidential information. The number of plants treating raw materials of these minerals increased from 15 in 1960 to 18 in 1965 and the rated daily capacity rose 1,400 tons. The quantity of raw material treated increased 380,800 tons and total production of upgraded products increased 106,700 tons. Increases of 178,800 tons in the output of feldspar products, 30,500 tons in mica products, and 102,400 tons in other products were partly offset by a drop of 205,000 tons in quartz products.

One plant was located in each Alabama, New Jersey, Ohio, South Carolina, and South Dakota. Distribution of the other plants was California three, Georgia two, and North Carolina eight.

Fluorspar.—Flotation plants treating fluorspar ores in 1965 remained unchanged from 1960 in number and in daily capacity. The outstanding feature of fluorspar flotation in 1965 was the increase in recovery to 92 percent from the 77 percent reported for 1960. As a result, the quantity of concentrate produced rose 43,000 tons with an increase of only 32,000 tons of ore treated In 1965, there was a corresponding increase in byproduct zinc concentrate of 7,900 tons and lead concentrate of 2,300 tons over 1960. Average total consumption of reagents per ton of ore more than doubled from 7.011 pounds in 1960 to 14.834 pounds in 1965 but average cost rose only 9 cents per ton.

As in 1960, four of the flotation plants were in Illinois and one each in Colorado and Kentucky. However, five of the plants used heavy media for preconcentration of the ore before flotation or an increase of three.

Iron Ore.—Although the number of iron ore flotation plants increased from four in 1960 to six in 1965, the rated daily input jumped from 5,700 tons to 40,000 tons. This expanded capacity resulted in an enormous rise of 12.5 million tons in quantity of ore treated and of 5.5 million tons of concentrate produced. Concurrently, more efficient use of flotation reagents was realized as total average quantity and cost per ton of ore treated dropped from 5.302 pounds and 27.7 cents in 1960 to 2.230 pounds and 12.1 cents in 1965. This was accomplished principally by using smaller quantities per ton of modifiers and collectors.

Of the six plants—three of which were in Michigan, two in Missouri, and one in New York—two used flotation only and four operated in conjunction with magnetic or gravity separation plants. Another plant in Michigan, data are excluded from this survey, operated intermittently to upgrade magnetic concentrates.

Limestone and Magnesite.—Because of the similar reagents used in the flotation of limestone and magnesite and to avoid disclosing confidential information, data on three limestone operations—one each in California, Maryland, and Texas—and two magnesite operations—one each in Nevada and Washington—have been combined. Also, the plants are too few in number to permit comparison of the 1965 and 1960 data without disclosing confidential information.

Phosphate.—Phosphate flotation in 1965 showed an increase of three plants and 33,700 tons in daily capacity over 1960. Also, the quantity of ore treated rose from 20,981,900 tons to 32,477,500 tons and of concentrate produced from 7,023,544 tons to 11,221,018 tons. Other changes from 1960 to 1965 included an increase in average grade of ore treated from 13.8 to 14.7 percent P_2O_5, a decrease in average grade of concentrate produced from 34.6 to 34.3 percent P_2O_5, and a drop of 4.0 percent average P_2O_5 recovery. A significant drop of 4.132 pounds in quantity and 6.0 cents in

Table 27.—Froth flotation of lead-zinc-silver ores in 1965

OPERATING DATA

Plants:		Water used, gallons:	
Number	31	Total, million	3,818.6
Capacity, short tons per day	30,000	Per ton	790
Ore treated:		Rod consumption, pounds:	
Short tons	5,206,000	Total	1,519,174
Grade:		Per ton	0.932
Lead, percent	2.90	Ball consumption, pounds:	
Zinc, percent	4.90	Total	8,581,501
Copper, percent	0.22	Per ton	1.716
Gold, ounce per ton	0.0328	Liner consumption, pounds:	
Silver, ounces per ton	3.1240	Total	1,914,596
Energy used, kilowatt-hours:		Per ton	0.431
Total, million	111.4		
Per ton	25.5		

CONCENTRATES PRODUCED

Type	Quantity, short tons	Grade: Copper, percent	Grade: Lead, percent	Grade: Zinc, percent	Grade: Gold, ounce per ton	Grade: Silver, ounces per ton	Recovery, percent: Copper	Lead	Zinc	Gold	Silver
Lead	221,384	1.88	58.23	7.25	0.4606	44.9737	69	90	6	69	78
Zinc	406,364	0.42	2.23	53.98	.0266	5.6843	19	5	87	7	14

CONSUMPTION OF FLOTATION REAGENTS [1]

Function and name	Total	Per ton
Modifier:		
Lime	6,016,487	2.168
Soda ash	1,117,933	.724
Total:		
Pounds	7,134,420	2.089
Value	$133,540	$0.039
Activator: Copper sulfate: Total:		
Pounds	3,489,665	0.702
Value	$478,989	$0.096
Depressant:		
Calcium cyanide	43,876	0.510
Lignin sulfonate	33,311	.052
Sodium cyanide	484,423	.120
Sodium sulfite	561,512	.786
Zinc sulfate	1,225,071	.373
Other	147,999	.238
Total:		
Pounds	2,496,192	.502
Value	$239,027	$0.048
Collector:		
Aerofloat 31	128,447	0.061
Aerofloat 208, Aerofloat 238	48,464	.071
Aerofloat 242, Aerofloat 243	51,051	.108
Aero Promoter 404	38,796	.066
Dow Z-200	29,862	.041
Potassium amyl xanthate	108,421	.069
Potassium ethyl xanthate	47,739	.047
Sodium Aerofloat	64,539	.120
Sodium ethyl xanthate	148,152	.083
Sodium isopropyl xanthate	232,584	.127
Other (fuel oil, Minerec, Thiocarbanilide)	112,341	.071
Total:		
Pounds	1,010,396	.203
Value	$283,280	$0.057
Frother:		
Aerofroth 65, Aerofroth 77	9,076	0.028
Aerofroth 71	37,415	.065
Barrett oil, cresylic acid	32,373	.043
Dowfroth	49,264	.062
Methyl isobutyl carbinol	405,106	.104
Pine oil	68,027	.081
Total:		
Pounds	601,261	.121
Value	$106,977	$0.022

See footnote at end of table.

Table 27.—Froth flotation of lead-zinc-silver ores in 1965—Continued

CONSUMPTION OF FLOTATION REAGENTS [1]

Function and name	Total	Per ton
Flocculant:		
Separan	7,641	0.005
Superfloc	1,173	.002
Total:		
Pounds	8,814	.005
Value	$10,806	$0.006
Total reagents:		
Pounds	14,740,748	2.963
Value	$1,252,619	$0.252

[1] Based on 19 operations accounting for 96 percent of total ore.

Table 28.—Froth flotation of zinc ores in 1965

OPERATING DATA

Plants:		Rod consumption, pounds:	
Number	10	Total	1,160,972
Capacity, short tons per day	15,000	Per ton	0.318
Ore treated:		Ball consumption, pounds:	
Short tons	3,740,500	Total	659,942
Zinc, percent	4.98	Per ton	0.203
Energy used, kilowatt-hours:		Liner consumption, pounds:	
Total, million	61.5	Total	137,303
Per ton	16.4	Per ton	0.063
Water used, gallons:			
Total, million	1,585.9		
Per ton	425		

CONCENTRATES PRODUCED

Quantity, short tons	289,232
Zinc, percent	61.14
Recovery, percent	95

CONSUMPTION OF FLOTATION REAGENTS

Function and name	Total	Per ton
Modifier: Lime: Total:		
Pounds	718,880	3.536
Value	$9.467	$0.047
Activator: Copper sulfate: Total:		
Pounds	2,016,773	0.539
Value	$267,748	$0.072
Depressant: Calcium cyanide, sodium cyanide: Total:		
Pounds	47,792	0.034
Value	$4,711	$0.003
Collector:		
Aerofloat 211	105,798	0.072
Sodium Aerofloat	162,297	.078
Sodium ethyl xanthate, sodium isopropyl xanthate	17,459	.082
Total:		
Pounds	285,554	.076
Value	$74,689	$0.020
Frother:		
Aerofroth 65	247,450	0.106
Aerofroth 77, Dowfroth 250	214,654	.142
Barrett oil, cresylic acid	148,282	.233
Methyl isobutyl carbinol	7,322	.128
Pine oil	186,924	.239
Total:		
Pounds	804,632	.215
Value	$147,844	$0.040
Flocculant: Separan, Superfloc: Total:		
Pounds	939	0.002
Value	$1,421	$0.003
Total reagents:		
Pounds	3,874,570	1.036
Value	$505,880	$0.135

Table 29.—Froth flotation of feldspar, mica, and quartz ores in 1965

OPERATING DATA

Plants:		Rod consumption, pounds:	
Number	18	Total	973,635
Capacity, short tons per day	10,200	Per ton	0.984
Ore treated, short tons	2,211,000	Liner consumption, pounds:	
Energy used, kilowatt-hours:		Total	76,092
Total, million	35.8	Per ton	0.155
Per ton	16.2		
Water used, gallons:			
Total, million	5,552.8		
Per ton	2,510.0		

CONCENTRATES PRODUCED, SHORT TONS

Feldspar	451,362
Mica	51,364
Quartz	598,976
Other	168,158

CONSUMPTION OF FLOTATION REAGENTS [1]

Function and name	Total	Per ton
Modifier:		
Hydrofluoric acid	1,429,430	1.138
Lime	59,200	.375
Sodium carbonate	43,040	.356
Sodium hydroxide	503,980	1.407
Sulfuric acid	2,373,716	1.369
Other	24,751	.162
Total:		
Pounds	4,434,117	2.325
Value	$283,245	$0.149
Depressant:		
Lignin sulfonate	56,300	0.456
Other	299,880	.900
Total:		
Pounds	356,180	.780
Value	$38,433	$0.084
Collector:		
Aero Promoter 801, 825	394,900	1.374
Amines	686,257	.505
Fatty acids	526,700	1.160
Fuel oil	1,445,577	1.384
Petroleum sulfonate	428,911	.761
Other	332,073	.812
Total:		
Pounds	3,814,418	2.000
Value	$405,237	$0.213
Frother:		
Aerofroth 65	8,420	0.053
Methyl isobutyl carbinol	109,660	.271
Pine oil	825,597	1.204
Total:		
Pounds	943,677	.769
Value	$141,165	$0.115
Flocculant: Total:		
Pounds	433,561	1.074
Value	$13,967	$0.035
Total reagents:		
Pounds	9,981,953	5.234
Value	$882,047	$0.463

[1] Based on 16 operations accounting for 86 percent of total ore.

cost of reagents per ton of ore treated occurred in 1965 compared with similar data in 1960. This resulted from less consumption of modifiers and collectors.

Florida continued as the leader in phosphate flotation with 16 plants with Montana and Wyoming each having 1 flotation plant. A new flotation plant for treating

Table 30.—Froth flotation of fluorspar ores in 1965

OPERATING DATA

Plants:		Water used, gallons:	
Number	6	Total, million	905.1
Capacity, short tons per day	2,000	Per ton	1,290
Ore treated:		Ball consumption:	
Short tons	516,200	Total, pounds	533,356
Fluorspar, percent	41.24	Per ton	1.033
Energy used, kilowatt-hours:		Liner consumption:	
Total, million	30.9	Total, pounds	160,434
Per ton	44.1	Per ton	0.311

CONCENTRATES PRODUCED

Fluorspar			Lead		Zinc	
Quantity, short tons	Grade, percent	Recovery, percent	Quantity, short tons	Grade, percent	Quantity, short tons	Grade, percent
201,889	95.82	92	5,303	71.54	25,689	61.99

CONSUMPTION OF FLOTATION REAGENTS

Function and name	Total	Per ton
Modifier:		
Salt	3,376,783	7.915
Soda ash	1,652,849	3.202
Other (Nalco, sodium hydroxide, sodium pyrophosphate, sodium silicate)	265,762	.848
Total:		
Pounds	5,295,394	10.259
Value	$72,831	$0.141
Activator: Copper sulfate: Total:		
Pounds	511,677	1.038
Value	$83,117	$0.169
Depressant:		
Quebracho	595,756	1.209
Zinc hydrosulfite	70,506	.255
Other (Aero Depressant 633, sodium cyanide, starch)	455,085	1.289
Total:		
Pounds	1,121,347	2.275
Value	$148,062	$0.300
Collector:		
Fatty acids	396,552	0.768
Potassium ethyl xanthate	62,481	.178
Other (Aerofloat 31, Aerofloat 211, Sodium Aerofloat)	77,720	.220
Total:		
Pounds	536,753	1.040
Value	$93,529	$0.181
Frother:		
Methyl isobutyl carbinol	153,048	0.359
Other (Pentasol, pine oil)	10,334	.050
Total:		
Pounds	163,382	.332
Value	$25,276	$0.051
Flocculant: Alum, Separan, Superfloc: Total:		
Pounds	28,606	0.055
Value	$11,164	$0.022
Total reagents:		
Pounds	7,657,159	14.834
Value	$433,979	$0.841

phosphate rock was under construction in North Carolina and was scheduled for operation in early 1966.

Potash.—In 1965, nine flotation plants having a total daily capacity of 50,000 tons treated potash ores compared with seven plants and 39,800 tons in 1960. Increases in 1965 totaled 4,100,000 tons in ore treated, 1,110,000 tons in concentrate produced, and 1 percent in K_2O recovery. At the same time, the average grade of ore treated dropped from 18.54 to 17.28 percent K_2O and that of the concentrate produced dipped from 60.95 to 57.25 percent K_2O.

Table 31.—Froth flotation of iron ores in 1965

OPERATING DATA

Plants:		Rod consumption, pounds:	
Number	6	Total	15,103,731
Capacity, short tons per day	40,000	Per ton	1.075
Ore treated:		Ball consumption, pounds:	
Short tons	14,046,600	Total	17,624,712
Iron, percent	34.8	Per ton	1.267
Energy used, kilowatt-hours:		Liner consumption, pounds:	
Total, million	318.5	Total	1,017,939
Per ton	22.7	Per ton	0.123
Water used, gallons:			
Total, million	25,871.1		
Per ton	1,840		

CONCENTRATES PRODUCED

Type	Quantity, short tons	Iron, percent	Recovery, percent
Iron	5,987,581	58.8	72
Other	68,282	----	--

CONSUMPTION OF FLOTATION REAGENTS

Function and name	Total	Per ton
Modifier:		
Sulfuric acid	6,296,916	1.760
Sodium silicate	3,870,726	1.126
Total:		
Pounds	10,167,642	2.842
Value	$152,019	$0.042
Depressant: Sodium fluoride: Total:		
Pounds	59,407	0.513
Value	$10,099	$0.087
Collector:		
Aero Promoter 899	2,866,278	0.979
Fatty acids	14,805,668	1.056
Fuel oil	2,604,814	.753
Other	67,906	.122
Total:		
Pounds	20,344,666	1.448
Value	$1,436,936	$0.102
Frother: Methyl isobutyl carbinol-pine oil: Total:		
Pounds	749,254	0.087
Value	$101,561	$0.012
Flocculant: Total:		
Pounds	4,802	0.009
Value	$5,042	$0.009
Total reagents:		
Pounds	31,325,771	2.230
Value	$1,705,657	$0.121

Total reagent consumption and cost per ton of potash ore treated fell from 1.085 pounds and 16.7 cents in 1960 to 0.959 pound and 13.6 cents in 1965. Again New Mexico and Utah were the only potash producers with seven of the plants in the former and two in the latter State.

Anthracite.—Five flotation plants—all in Pennsylvania—treated anthracite in 1965, the same number as in 1960. There was a small decrease of 55,400 tons in the quantity of raw coal treated and of 18,000 tons in clean coal produced. At the same time, reagent consumption and cost per ton of raw coal rose 0.469 pound and 1.5 cents, respectively. The principal functions of the flotation were to recover fine-sized coal and to prepare a low-ash coal for power plant fuel.

Bituminous Coal.—The number of flotation plants treating bituminous coal increased from 26 in 1960 to 64 in 1965. Corresponding increases of 20,500 tons in plant capacity, 5,443,600 tons in raw coal treated, and 4,255,500 tons of clean coal produced were recorded. Although there was a de-

Table 32.—Froth flotation of limestone-magnesite ores in 1965

OPERATING DATA		
Plants:		
Number		5
Capacity	short tons per day	4,500
Ore treated	short tons	1,064,200
Concentrate produced	do	795,918
CONSUMPTION OF FLOTATION REAGENTS[1]		
Function and name	Total	Per ton
Collector:		
Fatty acids	1,230,287	1.297
Fuel oil	401,085	.451
Other	37,875	.625
Total:		
Pounds	1,669,247	1.654
Value	$115,192	$0.114
Frother: Total:		
Pounds	18,347	0.152
Value	$3,855	$0.032
Flocculant: Separan, Superfloc: Total:		
Pounds	10,994	0.013
Value	$11,904	$0.014
Total reagents:		
Pounds	1,698,588	1.683
Value	$130,951	$0.130

[1] Based on 4 operations accounting for 95 percent of total ore.

Table 33.—Froth flotation of phosphate ores in 1965

OPERATING DATA

Plants:		Water used, gallons:	
Number	18	Total, million	145,299.6
Capacity, short tons per day	122,400	Per ton	4,475
Ore treated:		Ball consumption, pounds:	
Short tons	32,477,500	Total	890,577
Percent P_2O_5	14.7	Per ton	0.154
Energy used, kilowatt-hours:			
Total, million	268.2		
Per ton	8.3		

CONCENTRATES PRODUCED		
Quantity, short tons		11,221,018
P_2O_5 content, percent		34.3
Recovery, percent		80.0
CONSUMPTION OF FLOTATION REAGENTS[1]		
Function and name	Total	Per ton
Modifier:		
Caustic soda	17,139,475	0.653
Sodium hydroxide	5,739,133	1.081
Sulfuric acid	18,896,321	1.013
Other	1,206,085	3.590
Total:		
Pounds	42,981,014	1.362
Value	$1,092,795	$0.035
Collector:		
Amine	1,026,890	0.040
Fatty acids	56,170,977	1.780
Fuel oil	112,306,488	3.621
Kerosine	4,284,443	.212
Total:		
Pounds	173,788,798	5.508
Value	$3,158,422	$0.100
Frother: Pine oil: Total:		
Pounds	2,113,052	0.442
Value	$289,503	$0.061
Flocculant: Total:		
Pounds	88,356	0.263
Value	$10,631	$0.032
Total reagents:		
Pounds	218,971,220	6.940
Value	$4,551,351	$0.144

[1] Based on 16 operations accounting for 97 percent of total ore.

Table 34.—Froth flotation of potash ores in 1965

OPERATING DATA

Plants		Ore treated		Energy used, kilowatt-hours		Water used, gallons	
Number	Capacity, short tons/day	Quantity, short tons	K_2O, percent	Total, million	Per ton	Total, million	Per ton
9	50,000	16,083,000	17.28	306.2	19.0	4,271.4	265

CONCENTRATES PRODUCED

Quantity, short tons	4,226,180
K_2O, percent	57.25
K_2O recovery, percent	87

CONSUMPTION OF FLOTATION REAGENTS[1]

Function and name	Total	Per ton
Modifier:		
Sulfuric acid	139,664	0.043
Phosphate, sodium hydroxide, hydrochloric acid	1,034,990	.121
Total:		
Pounds	1,174,654	.137
Value	$55,201	$0.006
Depressant:		
Starch	1,813,827	0.365
Other	752,971	.204
Total:		
Pounds	2,566,798	.296
Value	$413,173	$0.048
Collector:		
Amine	2,914,499	0.190
Fuel oil	3,841,573	.795
Total:		
Pounds	6,756,072	.440
Value	$831,085	$0.054
Frother:		
Barrett oil	680,215	0.079
Methyl isobutyl carbinol-pentasol	936,720	.061
Total:		
Pounds	1,616,935	.105
Value	$157,569	$0.010
Flocculant:		
Guar	639,826	0.084
Separan	64,214	.009
Aerofloc 550, Superfloc, Nalco, starch	1,921,782	.197
Total:		
Pounds	2,625,822	.171
Value	$629,645	$0.041
Total reagents:		
Pounds	14,740,281	0.959
Value	$2,086,673	$0.136

[1] Based on 7 operations accounting for 96 percent of total ore.

crease in total reagents used per ton of raw coal from 2.7 pounds in 1960 to 0.7 pound in 1965, reagent costs rose from 9 to 12 cents per ton.

Like that for anthracite, froth flotation of bituminous coal is principally used to recover fine-sized material containing little ash. The data include information on one plant used to reduce ash content of gilsonite. Of the 64 plants, 38 were in West Virginia, 14 in Pennsylvania, 5 in Alabama, 2 each in Colorado and Kentucky, and 1 each in New Mexico, Utah, and Virginia.

Miscellaneous.—Data for some flotation operations are not shown separately to avoid disclosing confidential information. Also, because of dissimilarity of the data for the various plants, it would be inappropriate to combine the data to overcome the confidentiality problem. However, the data have been included in the totals in order to present complete information on flotation in the mineral industry.

Table 35.—Froth flotation of anthracite in 1965

OPERATING DATA

Plants:	
Number	5
Capacity ____ short tons per day	5,000
Raw coal treated ____ short tons	744,600
Clean coal produced ____ do	407,000

CONSUMPTION OF FLOTATION REAGENTS

Function and name	Total	Per ton
Collector: Fuel oil, kerosine: Total:		
Pounds	1,772,224	2.380
Value	$30,193	$0.041
Frother: Aerofroth 65, pine oil: Total:		
Pounds	211,021	0.283
Value	$36,574	$0.049
Total reagents:		
Pounds	1,983,245	2.663
Value	$66,767	$0.090

Flotation plants for which data have been handled in this manner include:

Antimony ....1 in Nevada
Barite ....2 in Arkansas
Do ....1 in Georgia
Do ....1 in South Carolina
Bastnaesite ....1 in California
Garnet ....1 in New York
Ilmenite ....1 in New York
Do ....1 in Virginia
Kyanite ....2 in Virginia
Do ....1 in Georgia
Do ....1 in South Carolina
Mercury ....1 in Oregon
Molybdenum ....1 in Colorado
Talc ....1 in Alabama
Do ....1 in New York
Tungsten ....1 in California
Vermiculite ....1 in Montana

Table 36.—Froth flotation of bituminous coal in 1965

OPERATING DATA

Plants:	
Number	64
Capacity ____ short tons per day	42,000
Raw coal treated ____ short tons	8,755,600
Clean coal produced ____ do	6,625,500

CONSUMPTION OF FLOTATION REAGENTS

Function and name	Total	Per ton
Modifier: Sulfuric acid: Total:		
Pounds	298,274	1.922
Value	$3,231	$0.021
Collector:		
Fuel oil	969,991	2.153
Kerosine	1,313,091	1.553
Total:		
Pounds	2,283,082	1.762
Value	$41,582	$0.032
Frother:		
Aerofroth 71	42,006	0.263
Aerofroth 77	217,757	.152
Methyl isobutyl carbinol	1,077,307	.155
Pine oil	6,710	.100
Total:		
Pounds	1,343,780	.156
Value	$230,951	$0.027
Flocculant:		
Aerofloc 550	60,391	0.071
Nalco	133,032	.082
Separan	36,017	.051
Starch	926,777	.431
Superfloc	108,402	.079
Other	1,036,382	.687
Total:		
Pounds	2,301,001	.365
Value	$763,978	$0.121
Total reagents:		
Pounds	6,226,137	0.711
Value	$1,039,742	$0.119

Statistical Summary

By Kathleen J. D'Amico [1]

Contents

This summary appears in Minerals Yearbook volumes I and III, which cover mineral production in the United States, its island possessions, the Canal Zone, and the Commonwealth of Puerto Rico, as well as the principal minerals imported into and exported from the United States. The several commodity and area chapters contain further details on production. A summary table comparing world and U.S. mineral production also is included.

Mineral production may be measured at any of several stages of extraction and processing. The stage of measurement used in the chapter is normally what is termed "mine output." It usually refers to minerals in the form in which they are first extracted from the ground, but customarily includes for some minerals the product of auxiliary processing operations at or near mines.

Because of inadequacies in the statistics available, some series deviate from the foregoing definition. The quantities of gold, silver, copper, lead, zinc, and tin are recorded on a mine basis (as the recoverable content of ore sold or treated). The values assigned to these quantities, however, are based on the average selling price of refined metal, not the mine value. Mercury is measured as recovered metal and valued at the average New York price for metal.

The weight or volume units shown are those customary in the particular industries producing the respective commodities. No adjustment has been made in dollar values for changes in purchasing power of the dollar.

[1] Statistical officer, Division of Minerals.

Table 1.—Value of mineral production [1] in the United States [2] by mineral groups [3]

(Millions)

Year	Mineral fuels	Nonmetals (except fuels)	Metals	Total	Year	Mineral fuels	Nonmetals (except fuels)	Metals	Total
1925	$2,910	$1,187	$715	$4,812	1946	$5,090	$1,243	$729	$7,062
1926	3,371	1,219	721	5,311	1947	7,188	1,338	1,084	9,610
1927	2,875	1,201	622	4,698	1948	9,502	1,552	1,219	12,273
1928	2,666	1,163	655	4,484	1949	7,920	1,559	1,101	10,580
1929	2,940	1,166	802	4,908	1950	8,689	1,822	1,351	11,862
1930	2,500	973	507	3,980	1951	9,779	2,079	1,671	13,529
1931	1,620	671	287	2,578	1952	9,616	2,163	1,617	13,396
1932	1,460	412	128	2,000	1953	10,257	2,350	1,811	14,418
1933	1,413	432	205	2,050	1954	9,919	2,733	1,518	14,170
1934	1,947	520	277	2,744	1955	10,780	3,076	2,055	15,911
1935	2,013	564	365	2,942	1956	11,741	3,391	2,358	17,490
1936	2,405	685	516	3,606	1957	12,709	3,387	2,137	18,233
1937	2,798	711	756	4,265	1958	11,589	3,466	1,594	16,649
1938	2,436	622	460	3,518	1959	11,950	3,861	1,570	17,381
1939	2,423	754	631	3,808	1960	12,142	3,868	2,022	18,032
1940	2,662	784	752	4,198	1961	12,357	3,946	1,927	18,230
1941	3,228	989	890	5,107	1962	12,784	4,117	1,937	18,838
1942	3,568	1,056	999	5,623	1963	13,295	4,318	2,002	19,615
1943	4,028	916	987	5,931	1964 r	13,623	4,623	2,261	20,507
1944	4,574	836	900	6,310	1965	14,045	4,916	2,472	21,433
1945	4,569	888	774	6,231					

r Revised.

[1] Production as measured by mine shipments, sales, or marketable production (including consumption by producers).

[2] Excludes Alaska and Hawaii, 1925–53.

[3] Data for 1925–46 are not strictly comparable with those for subsequent years, since for earlier years value of heavy clay products has not been replaced by value of raw clays used for such products.

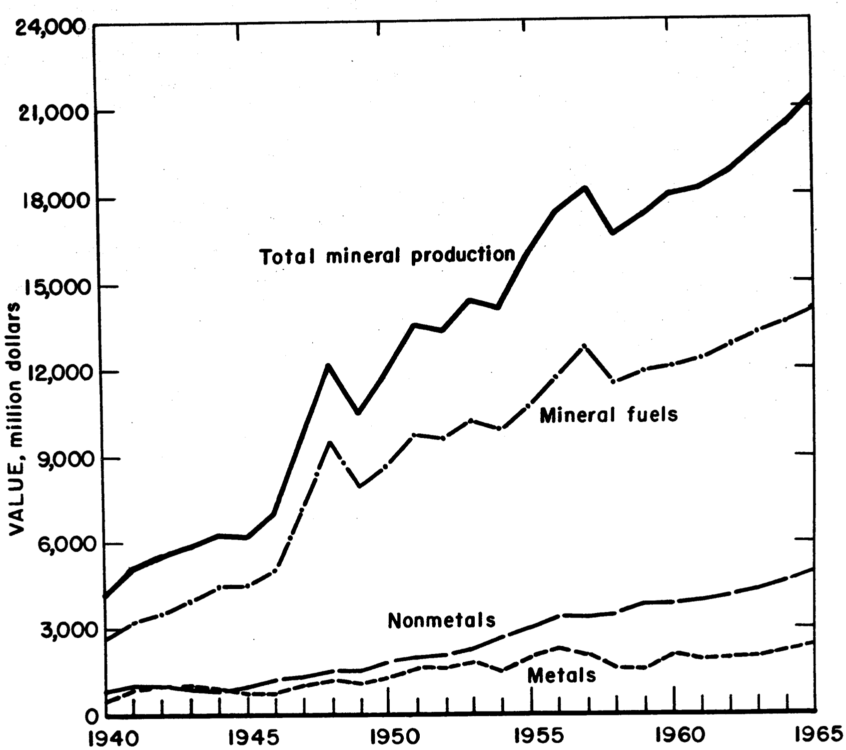

Figure 1.—Value of mineral production in the United States.

Table 2.—Mineral production[1] in the United States

Mineral	1962 Quantity	1962 Value (thousands)	1963 Quantity	1963 Value (thousands)	1964 Quantity	1964 Value (thousands)	1965 Quantity	1965 Value (thousands)
Mineral fuels:								
Asphalt and related bitumens (native): Bituminous limestone and sandstone and gilsonite____short tons__	1,647,063	$14,601	1,632,645	$8,383	1,935,344	$10,038	1,911,664	$9,461
Carbon dioxide, natural (estimate)__thousand cubic feet__	1,144,107	146	1,295,545	178	1,232,816	166	1,173,676	152
Coal:								
Bituminous and lignite[2]____thousand short tons__	422,149	1,891,553	458,928	2,013,309	486,998	2,165,582	512,088	2,276,022
Pennsylvania anthracite____do____	16,894	134,094	18,267	153,503	17,184	148,648	14,866	122,021
Helium[3]____thousand cubic feet__	599,519	20,905	627,344	21,957	r 4,027,497	r 61,245	4,365,068	66,687
Natural gas____million cubic feet__	13,876,622	2,145,301	14,746,663	2,328,030	r 15,462,138	2,387,689	16,039,753	2,494,542
Natural gas liquids:								
Natural gasoline and cycle products thousand gallons__	6,244,522	444,817	6,534,967	439,173	7,000,181	463,600	7,288,070	494,354
LP gases____do____	9,409,083	353,334	10,302,250	359,770	10,743,591	362,792	11,257,267	417,249
Peat____short tons__	566,441	5,186	546,621	5,423	639,690	r 6,198	603,746	6,080
Petroleum (crude)____thousand 42-gallon barrels__	2,676,189	7,774,051	2,752,723	7,965,743	2,786,822	8,017,078	[4] 2,848,462	[4] 8,158,150
Total mineral fuels____	XX	12,784,000	XX	13,295,000	XX	r 13,623,000	XX	14,045,000
Nonmetals (except fuels):								
Abrasive stone[5]____short tons__	2,653	260	2,693	255	3,186	292	3,603	432
Aplite____long tons__	125,156	912	(6)	(6)	(6)	(6)	(6)	(6)
Asbestos____short tons__	53,190	4,677	66,396	5,108	101,092	8,143	118,275	10,162
Barite____thousand short tons__	860	9,820	824	9,402	830	9,796	852	10,192
Boron minerals____short tons__	646,613	49,336	700,183	54,981	776,000	60,871	807,000	64,180
Bromine____thousand pounds__	190,747	46,617	203,333	48,558	r 283,530	r 66,064	328,115	77,259
Calcite (optical grade)____pounds____	----------	----------	----------	----------	4	2	(6)	(6)
Cement:								
Portland____thousand 376-pound barrels__	325,476	1,070,371	342,036	1,095,884	358,378	1,145,108	366,802	1,154,448
Masonry____thousand 280-pound barrels__	19,998	57,405	20,997	59,599	22,397	63,305	23,260	65,979
Natural and slag____thousand 376-pound barrels__	402	1,611	352	1,407	283	1,057	279	1,027
Clays____thousand short tons__	47,797	163,012	50,135	180,810	r 52,947	r 192,631	55,089	203,772
Emery____short tons__	4,316	71	6,732	119	9,214	172	10,720	204
Feldspar____long tons__	492,476	5,076	548,954	5,525	r 587,194	r 5,389	624,598	6,263
Fluorspar____short tons__	206,026	9,166	199,948	9,001	217,137	9,723	240,932	10,889
Garnet (abrasive)____do____	14,166	1,172	14,626	1,412	16,123	1,622	19,330	1,717
Gem stones (estimate)____	NA	1,296	NA	1,421	NA	1,474	NA	2,218
Gypsum____thousand short tons__	9,969	36,343	10,388	38,138	10,684	38,874	10,035	37,423
Lime____do____	13,752	186,754	14,521	199,389	16,089	r 223,149	16,794	232,939
Magnesium compounds from sea water and brine (except for metals) short tons, MgO equivalent____	408,129	28,742	520,699	39,323	599,698	42,177	644,021	47,555
Mica:								
Scrap____short tons__	107,702	2,639	109,323	2,776	114,729	3,353	120,255	3,468
Sheet____pounds__	363,016	1,299	102,961	13	242,662	58	716,086	185
Perlite____short tons__	320,330	2,663	325,132	2,727	349,867	3,073	392,384	3,352
Phosphate rock____thousand long tons__	19,382	134,304	19,855	139,861	22,960	161,067	26,440	194,552
Potassium salt____thousand short tons, K_2O equivalent__	2,452	94,859	2,864	110,164	2,897	r 114,095	3,140	129,767
Pumice____thousand short tons__	2,271	6,301	2,618	6,578	2,776	6,443	3,483	6,640
Pyrites____thousand long tons__	916	6,809	825	5,698	847	5,471	875	5,333

Table 2.—Mineral production [1] in the United States—Continued

Mineral	1962		1963		1964		1965	
	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)
Nonmetals (except fuels)—Continued								
Salt thousand short tons	28,807	$174,841	30,641	$184,589	31,623	$200,706	34,687	$215,699
Sand and gravel do	776,701	794,725	821,850	847,272	r 868,208	r 893,375	[4] 908,049	[4] 957,416
Sodium carbonate (natural) short tons	977,584	24,330	1,119,081	27,616	1,274,745	30,451	1,494,105	34,717
Sodium sulfate (natural) do	457,881	9,092	435,257	8,392	575,033	10,989	619,752	11,024
Stone [7] thousand short tons	656,954	1,025,697	688,366	1,068,108	r 725,583	r 1,134,564	780,072	1,203,618
Sulfur:								
Frasch process mines thousand long tons	4,917	107,069	4,995	99,014	r 6,035	r 120,776	7,251	146,921
Other mines long tons	150,550	1,439	1,371	15	794	8	2,852	11
Talc, soapstone, and pyrophyllite short tons	771,728	5,278	804,358	5,505	889,949	6,218	862,875	6,343
Tripoli do	61,732	244	66,635	266	64,613	268	71,138	381
Vermiculite thousand short tons	205	3,293	226	3,572	226	3,613	249	4,460
Value of items that cannot be disclosed: Brucite, calcium-magnesium chloride, diatomite, epsom salts from epsomite (1961–63), graphite, iodine, kyanite, lithium minerals, magnesite, greensand marl, olivine, staurolite, wol lastonite, and values indicated by footnote 6	XX	49,436	XX	54,929	XX	r 58,771	XX	65,028
Total nonmetals	XX	4,117,000	XX	4,318,000	XX	r 4,623,000	XX	4,916,000
Metals:								
Antimony ore and concentrate short tons, antimony content	631	(8)	645	(8)	632	(8)	845	(8)
Bauxite long tons, dried equivalent	1,369,007	15,609	1,524,700	17,234	1,600,722	17,875	1,653,840	18,632
Beryllium concentrate short tons, gross weight	[9] 978	(8)	[9] 751	(8)	(8)	(8)	(8)	(8)
Copper (recoverable content of ores, etc.) short tons	1,228,421	756,707	1,213,166	747,310	1,246,780	812,901	1,351,734	957,028
Gold (recoverable content of ores, etc.) troy ounces	1,542,511	53,990	1,454,010	50,889	1,456,308	50,971	1,705,190	59,682
Iron ore, usable (excluding byproduct iron sinter) thousand long tons, gross weight	69,969	618,242	73,563	678,177	84,300	802,331	84,472	804,498
Lead (recoverable content of ores, etc.) short tons	236,956	43,602	253,369	54,727	286,010	74,935	301,147	93,959
Manganese ore (35 percent or more Mn) short tons, gross weight	24,758	(8)	10,622	(8)	26,058	(8)	29,258	(8)
Manganiferous ore (5 to 35 percent Mn) do	338,501	(8)	543,125	(8)	238,776	(8)	332,763	(8)
Mercury 76-pound flasks	26,277	5,024	19,117	3,623	14,142	4,452	19,582	11,176
Molybdenum (content of concentrate) thousand pounds	50,506	69,390	65,839	91,096	65,097	97,121	77,310	120,801
Nickel (content of ore and concentrate) short tons	13,110	(8)	13,394	(8)	15,420	(8)	16,188	(8)
Silver (recoverable content of ores, etc.) thousand troy ounces	36,798	39,929	35,243	45,076	36,334	46,980	39,808	51,469
Tin long tons	(8)	(8)	(8)	(8)	65	185	47	126
Titanium concentrate:								
Ilmenite short tons, gross weight	809,037	13,974	890,071	16,529	1,003,997	19,178	948,832	18,058
Rutile do	8,033	933	11,311	1,262	10,547	1,016	10,037	759
Tungsten ore and concentrate short tons, 60 percent WO_3 basis	8,429	11,639	5,657	7,202	9,244	11,251	7,949	13,028
Uranium ore short tons	7,052,870	138,294	5,645,921	115,821	r 5,674,631	[4] 111,707	4,362,614	83,915

Vanadium (recoverable in ore and concentrate)----do----	5,211	18,605	3,862	13,788	4,362	13,061	5,226	18,284
Zinc (recoverable content of ores, etc.)-----------do----	505,491	116,413	529,254	122,533	574,858	156,308	611,153	178,284
Value of items that cannot be disclosed: Cobalt, magnesium chloride for magnesium metal, manganiferous residuum, platinum-group metals (crude), rare-earth metal concentrates, zirconium concentrate, and values indicated by footnote 8----------------------------	XX	35,071	XX	36,827	XX	r 40,183	XX	42,641
Total metals------------------------------------	XX	1,937,000	XX	2,002,000	XX	r 2,261,000	XX	2,472,000
Grand total mineral production---------------------	XX	18,838,000	XX	19,615,000	XX	r 20,507,000	XX	21,433,000

r Revised. NA Not available. XX Not applicable.
1 Production as measured by mine shipments, sales, or marketable production (including consumption by producers).
2 Includes small quantity of anthracite mined in States other than Pennsylvania.
3 Refined only, 1962–63; crude and refined, 1964–65.
4 Final figure; superseded figure given in commodity chapter.
5 Grindstones, pulpstones, millstones (weight not recorded), grinding pebbles, sharpening stones, and tube-mill liners.
6 Figure withheld to avoid disclosing individual company confidential data; value included with "Value of items (nonmetal) that cannot be disclosed."
7 Excludes abrasive stone, bituminous limestone, bituminous sandstone, and ground soapstone, all included elsewhere in table.
8 Figure withheld to avoid disclosing individual company confidential data; value included with "Value of items (metal) that cannot be disclosed."
9 Includes low-grade beryllium ore as follows: 760 tons in 1962, and 750 tons in 1963.

Table 3.—Minerals produced in the United States and principal producing States in 1965

Mineral	Principal producing States in order of quantity	Other producing States
Antimony	Idaho, Nev., Alaska	
Aplite	Va	
Asbestos	Calif., Vt., Ariz., N.C	
Asphalt	Tex., Utah, Ala., Mo	
Barite	Mo., Ark., Ga., Nev	Calif., Mont., N. Mex., S.C., Tenn., Tex., Wash.
Bauxite	Ark., Ala., Ga	
Beryllium	S. Dak	Colo., Wyo.
Boron	Calif	
Bromine	Tex., Mich., Ark., Calif	
Calcium-magnesium chloride	Mich., Calif., W. Va	
Carbon dioxide	N. Mex., Colo., Utah, Calif	Wash.
Cement	Calif., Pa., Tex., N. Y	Ala., Ariz., Ark., Colo., Fla., Ga., Hawaii, Idaho, Ill., Ind., Iowa, Kans., Ky., La., Maine, Md., Mich., Minn., Miss., Mo., Mont., Nebr., Nev., N. Mex., N.C., Ohio, Okla., Oreg., S.C., S. Dak., Tenn., Utah, Va., Wash., W. Va., Wis., Wyo.
Clays	Ohio, Ga., Tex., Pa	All other States except Alaska and R.I.
Coal	W. Va., Pa., Ky., Ill	Ala., Alaska, Ark., Colo., Ind., Iowa, Kans., Md., Mo., Mont., N. Mex., N. Dak., Ohio, Okla., S. Dak., Tenn., Utah, Va., Wash., Wyo.
Cobalt	Pa	
Copper	Ariz., Utah, Mont., N. Mex	Alaska, Calif., Colo., Idaho, Mich., Mo., Nev., Okla., Oreg., Pa., Tenn., Wash., Wyo.
Diatomite	Calif., Nev., Wash., Ariz	Oreg.
Emery	N.Y	
Feldspar	N.C., Calif., Conn., S. Dak	Ariz., Colo., Ga., Maine, N.H., S.C., Va., Wyo.
Fluorspar	Ill., Ky., Mont., Nev	Colo., Utah.
Garnet, abrasive	N.Y., Idaho	
Gold	S. Dak., Utah, Nev., Ariz	Alaska, Calif., Colo., Idaho, Mont., N. Mex., Oreg., Pa., Tenn., Wash., Wyo.
Graphite	Tex	
Gypsum	Calif., Mich., Iowa, Tex	Ariz., Ark., Colo., Ind., Kans., La., Mont., Nev., N. Mex., N.Y., Ohio, Okla., S. Dak., Utah, Va., Wyo.
Helium	Kans., Tex., Okla., Ariz	N. Mex.
Iodine	Mich., Calif	
Iron ore	Minn., Mich., Calif., N.Y	Ala., Ariz., Ark., Colo., Ga., Idaho, Miss., Mo., Mont., Nev., N.J., N. Mex., Oreg., Pa., Tex., Utah, Wis., Wyo.
Kyanite	Va., S.C., Ga	
Lead	Mo., Idaho, Utah, Colo	Ariz., Ark., Calif., Ill., Kans., Ky., Mont., Nev., N. Mex., N.Y., Okla., Oreg., Va., Wash.
Lime	Ohio, Pa., Mo., Tex	Ala., Ariz., Ark., Calif., Colo., Conn., Fla., Hawaii, Idaho, Ill., Iowa, La., Md., Mass., Mich., Minn., Miss., Mont., Nebr., Nev., N.J., N. Mex., N.Y., N. Dak., Okla., Oreg., S. Dak., Tenn., Utah, Vt., Va., Wash., W. Va., Wis., Wyo.
Lithium	N.C., Calif., S. Dak	
Magnesite	Nev., Wash	
Magnesium chloride	Tex	
Magnesium compounds	Mich., Calif., Tex., N.J	Fla., Miss.
Manganese ore	Mont., N. Mex	
Manganiferous ore	Minn., N. Mex., Mont	
Marl	N.J., Md	
Mercury	Calif., Nev., Oreg., Idaho	Alaska, Ariz., Tex., Wash.
Mica:		
Scrap	N.C., Ala., Ga., S.C	Ariz., Calif., Conn., N. Mex., Pa., S. Dak.
Sheet	N.C., Ga	
Molybdenum	Colo., Utah, Ariz., N. Mex	Calif., Nev., N. Dak., S. Dak.
Natural gas	Tex., La., Okla., N. Mex	Ala., Alaska, Ariz., Ark., Calif., Colo., Fla., Ill., Ind., Kans., Ky., Md., Mich., Miss., Mo., Mont., Nebr., N.Y., N. Dak., Ohio, Pa., Tenn., Utah, Va., W. Va., Wyo.

Table 3.—Minerals produced in the United States and principal producing States in 1965—Continued

Mineral	Principal producing States in order of quantity	Other producing States
Natural gas liquids	Tex., La., Okla., N. Mex	Ark., Calif., Colo., Fla., Ill., Kans., Ky., Mich., Miss., Mont., Nebr., N. Dak., Pa., Utah, W. Va., Wyo.
Nickel	Oreg	
Olivine	Wash., N.C	
Peat	Mich., Ind., Pa., N.J	Alaska, Calif., Colo., Conn., Fla., Ga., Idaho, Ill., Iowa, Maine, Md., Mass., Minn., Mont., Nev., N.Y., N. Dak., Ohio, S.C., Vt., Wash., Wis.
Perlite	N. Mex., Ariz., Nev., Calif	Colo., Idaho, Tex., Utah.
Petroleum	Tex., La., Calif., Okla	Ala., Alaska, Ariz., Ark., Colo., Fla., Ill., Ind., Kans., Ky., Mich., Miss., Mo., Mont., Nebr., Nev., N. Mex., N.Y., N. Dak., Ohio, Pa., S. Dak., Tenn., Utah, Va., W. Va., Wyo.
Phosphate rock	Fla., Idaho, Tenn., Mont	Ark., Utah, Wyo.
Platinum-group metals	Alaska, Calif	
Potassium salts	N. Mex., Calif., Utah	Md., Mich.
Pumice	Ariz., Calif., Oreg., Hawaii	Colo., Idaho, Nebr., Nev., Okla., Tex., Utah, Wash.
Pyrites	Tenn., Pa., Ariz., Colo	S.C.
Rare-earth metals	Calif., Fla	
Salt	La., Tex., Ohio, N.Y	Calif., Colo., Hawaii, Kans., Mich., Nev., N. Mex., N. Dak., Okla., Utah, Va., W. Va.
Sand and gravel	Calif., Mich., Ohio, N.Y	All other States.
Silver	Idaho, Ariz., Utah, Mont	Alaska, Calif., Colo., La., Mich., Mo., Nev., N. Mex., N.Y., Okla., Oreg., Pa., S. Dak., Tenn., Wash., Wyo.
Sodium carbonate	Wyo., Calif	
Sodium sulfate	Calif., Tex., Wyo	
Staurolite	Fla	
Stone	Pa., Ill., Calif., Ohio	All other States.
Sulfur (Frasch)	Tex., La	
Sulfur, ore	Utah, Calif., Nev	
Talc	N.Y., Calif., N.C., Vt	Ala., Ark., Ga., Md., Mont., Nev., Pa., Tex., Va., Wash.
Tin	Colo., Alaska, Calif., N. Mex	
Titanium	N.Y., Fla., N.J., Va	Ga., Idaho.
Tripoli	Ill., Okla., Ark., Mo	Ala., Pa.
Tungsten	Calif., Colo., Wash	Ariz., Nev.
Uranium	N. Mex., Wyo., Colo., Utah	Alaska, Ariz., Calif., Nev., N. Dak., S. Dak., Tex., Wash.
Vanadium	Colo., Utah, Ariz., Idaho	N. Mex., N. Dak., S. Dak., Wyo.
Vermiculite	Mont., S.C	
Wollastonite	N.Y., Calif	
Zinc	Tenn., N.Y., Idaho, Colo	Ariz., Calif., Ill., Kans., Ky., Mo., Mont., Nev., N.J., N. Mex., Okla., Oreg., Pa., Utah, Va., Wash., Wis.
Zirconium	Fla., Ga	

Table 4.—Value of mineral production in the United States, and principal minerals produced in 1965

(Thousands)

State	Value	Rank	Percent of U.S. total	Principal minerals in order of value
Alabama	$246,264	21	1.15	Coal, cement, stone, petroleum.
Alaska	83,455	35	.39	Sand and gravel, petroleum, coal, stone.
Arizona	580,182	9	2.70	Copper, sand and gravel, molybdenum, cement.
Arkansas	179,110	27	.83	Petroleum, stone, bauxite, sand and gravel.
California	1,599,388	3	7.46	Petroleum, natural gas, cement, sand and gravel.
Colorado	331,216	17	1.54	Petroleum, molybdenum, coal, sand and gravel.
Connecticut	21,234	45	.10	Stone, sand and gravel, lime, feldspar.
Delaware	1,903	50	.01	Sand and gravel, stone, clays, gem stones.
Florida	249,320	20	1.16	Phosphate rock, stone, cement, clays.
Georgia	135,182	28	.63	Clays, stone, cement, sand and gravel.
Hawaii	20,835	46	.10	Stone, cement, sand and gravel, pumice.
Idaho	105,085	30	.49	Silver, lead, zinc, phosphate rock.
Illinois	593,025	8	2.77	Coal, petroleum, stone, sand and gravel.
Indiana	218,567	24	1.02	Coal, cement, stone, petroleum.
Iowa	112,783	29	.53	Cement, stone, sand and gravel, gypsum.
Kansas	553,491	11	2.58	Petroleum, natural gas, helium, natural gas liquids.
Kentucky	466,381	14	2.17	Coal, petroleum, stone, natural gas.
Louisiana	2,978,855	2	13.90	Petroleum, natural gas, natural gas liquids, sulfur.
Maine	17,741	47	.08	Sand and gravel, cement, stone, clays.
Maryland	77,995	38	.36	Stone, cement, sand and gravel, coal.
Massachusetts	36,198	43	.17	Stone, sand and gravel, lime, clays.
Michigan	565,560	10	2.69	Iron ore, cement, copper, sand and gravel.
Minnesota	507,760	12	2.37	Iron ore, sand and gravel, stone, cement.
Mississippi	208,972	25	.97	Petroleum, natural gas, sand and gravel, cement.
Missouri	225,568	23	1.05	Stone, cement, lead, iron ore.
Montana	229,392	22	1.07	Copper, petroleum, sand and gravel, phosphate rock.
Nebraska	83,791	34	.39	Petroleum, cement, sand and gravel, stone, natural gas.
Nevada	99,916	31	.47	Copper, sand and gravel, gold, iron ore.
New Hampshire	7,665	48	.03	Sand and gravel, stone, feldspar, clays.
New Jersey	80,158	37	.37	Sand and gravel, stone, zinc, magnesium compounds.
New Mexico	773,274	7	3.61	Petroleum, potassium salts, natural gas, copper.
New York	290,057	18	1.35	Cement, stone, sand and gravel, salt.
North Carolina	60,383	40	.28	Stone, sand and gravel, cement, feldspar.
North Dakota	92,878	32	.43	Petroleum, sand and gravel, coal, natural gas.
Ohio	464,252	15	2.17	Coal, stone, lime, cement.
Oklahoma	907,914	5	4.24	Petroleum, natural gas, natural gas liquids, cement.
Oregon	82,966	36	.39	Sand and gravel, stone, cement, nickel.
Pennsylvania	913,823	4	4.26	Coal, cement, stone, iron ore.
Rhode Island	2,931	49	.01	Sand and gravel, stone.
South Carolina	41,261	42	.19	Cement, stone, clays, sand and gravel.
South Dakota	50,175	41	.23	Gold, sand and gravel, stone, cement.
Tennessee	182,941	26	.85	Stone, zinc, cement, phosphate rock.
Texas	4,708,709	1	21.97	Petroleum, natural gas, natural gas liquids, cement.
Utah	431,378	16	2.01	Copper, petroleum, coal, molybdenum.
Vermont	27,392	44	.13	Stone, asbestos, sand and gravel, talc.
Virginia	267,977	19	1.25	Coal, stone, cement, sand and gravel.
Washington	86,172	33	.40	Sand and gravel, cement, stone, zinc.
West Virginia	859,604	6	4.01	Coal, natural gas, natural gas liquids, stone.
Wisconsin	72,999	39	.34	Sand and gravel, stone, cement, zinc.
Wyoming	498,552	13	2.33	Petroleum, natural gas, iron ore, sodium salts.
Total	21,433,000	--	100.00	Petroleum, natural gas, coal, cement.

Table 5.—Mineral production[1] in the United States, by States

Mineral	1962 Quantity	1962 Value (thousands)	1963 Quantity	1963 Value (thousands)	1964 Quantity	1964 Value (thousands)	1965 Quantity	1965 Value (thousands)
ALABAMA								
Cement:[2]								
Portland .... thousand 376-pound barrels..	12,482	$40,164	12,218	$38,417	12,870	$40,108	13,765	$42,604
Masonry .... thousand 280-pound barrels..	2,187	6,521	2,386	7,242	2,574	7,794	2,598	7,853
Clays[3] .... thousand short tons..	1,632	1,947	1,607	3,003	1,991	4,060	2,220	4,888
Coal (bituminous) .... do....	12,880	95,149	12,359	91,243	14,435	102,267	14,832	106,249
Gem stones	----------	----------	NA	2	----------	----------	----------	----------
Iron ore (usable) .... thousand long tons, gross weight..	2,962	17,838	2,126	11,806	2,106	11,812	1,495	8,241
Lime .... thousand short tons..	522	6,298	596	6,974	599	7,118	653	7,905
Natural gas .... million cubic feet..	128	13	177	21	r 165	18	203	26
Petroleum (crude) .... thousand 42-gallon barrels..	7,473	19,355	9,175	23,763	8,498	22,095	8,064	21,047
Sand and gravel .... thousand short tons..	4,655	4,486	5,363	5,778	5,840	6,191	6,422	7,195
Stone[4] .... do....	12,680	19,667	13,684	22,206	15,852	24,976	17,987	30,810
Value of items that cannot be disclosed: Native asphalt, bauxite, slag cement, clays (kaolin, bentonite 1964–65), scrap mica, sheet mica (1962), salt, stone (dimension limestone, dimension marble 1964–65, shell 1963–65, crushed sandstone 1965), talc, and tripoli (1965)	XX	8,347	XX	5,415	XX	9,251	XX	9,446
Total	XX	219,785	XX	215,870	XX	235,690	XX	246,264
ALASKA								
Antimony ore and concentrate. short tons, antimony content..	----------	----------	----------	----------	14	$18	1	$1
Coal (bituminous) .... thousand short tons..	871	$6,409	853	$5,910	745	5,008	893	6,095
Copper (recoverable content of ores, etc.) .... short tons..	----------	----------	----------	----------	11	7	32	23
Gold (recoverable content of ores, etc.) .... troy ounces..	165,259	5,784	99,573	3,485	58,416	2,045	42,249	1,479
Lead (recoverable content of ores, etc.) .... short tons..	----------	----------	5	1	----------	----------	9	3
Mercury .... 76-pound flasks..	3,719	711	400	76	303	95	W	W
Natural gas .... million cubic feet..	2,184	467	4,498	1,111	r 6,238	1,719	7,255	1,799
Peat .... short tons..	64	W	----------	----------	2,350	19	1,967	16
Petroleum (crude) .... thousand 42-gallon barrels..	10,259	31,187	10,740	32,650	11,059	33,627	11,128	34,073
Sand and gravel .... thousand short tons..	5,731	5,355	16,926	22,005	26,089	18,488	30,266	34,467
Silver (recoverable content of ores, etc.) thousand troy ounces..	22	24	14	18	7	9	8	10
Value of items that cannot be disclosed: Gem stones, platinum-group metals, stone, tin (1964-65), uranium ore, and values indicated by symbol W	XX	4,255	XX	2,584	XX	4,912	XX	5,489
Total	XX	54,192	XX	67,840	XX	65,947	XX	83,455

Table 5.—Mineral production [1] in the United States, by States—Continued

Mineral	1962 Quantity	1962 Value (thousands)	1963 Quantity	1963 Value (thousands)	1964 Quantity	1964 Value (thousands)	1965 Quantity	1965 Value (thousands)
ARIZONA								
Asbestos..........short tons..	W	W	W	W	W	W	3,469	$441
Beryllium concentrate..........short tons, gross weight..	1	([4])	----------	----------	----------	----------	----------	----------
Clays [3]..........thousand short tons..	139	$184	163	$203	168	$213	129	164
Copper (recoverable content of ores, etc.)..........short tons..	644,242	396,853	660,977	407,162	690,988	450,524	703,377	497,991
Diatomite..........do....	W	W	W	W	450	16	295	8
Gem stones..........	NA	120	NA	120	NA	120	NA	120
Gold (recoverable content of ores, etc.)..........troy ounces..	137,207	4,802	140,030	4,901	153,676	5,379	150,431	5,265
Gypsum..........thousand short tons..	W	W	W	W	147	770	103	540
Helium, refined..........thousand cubic feet..	W	W	W	W	46,000	1,610	58,000	2,030
Iron ore (usable)..........thousand long tons, gross weight..	W	W	W	W	4	32	8	51
Lead (recoverable content of ores, etc.)..........short tons..	6,966	1,282	5,815	1,256	6,147	1,611	5,913	1,845
Lime..........thousand short tons..	174	2,914	181	3,048	177	2,920	204	3,543
Mercury..........76-pound flasks..	W	W	W	W	77	24	158	90
Molybdenum (content of concentrate)..........thousand pounds..	4,412	5,864	5,553	7,584	6,296	9,532	9,399	15,880
Natural gas..........million cubic feet..	230	27	1,334	161	r 2,014	241	3,106	376
Petroleum (crude)..........thousand 42-gallon barrels..	39	W	68	W	64	W	97	W
Pumice..........thousand short tons..	756	1,640	800	1,877	880	1,685	1,273	1,605
Sand and gravel..........do....	15,579	17,404	15,037	14,466	18,116	20,868	14,918	16,621
Silver (recoverable content of ores, etc.) thousand troy ounces..	5,454	5,917	5,373	6,873	5,811	7,513	6,095	7,881
Stone..........thousand short tons..	4,333	6,616	3,257	5,069	3,759	6,283	2,474	4,171
Tungsten ore and concentrate short tons, 60-percent WO_3 basis..	15	14	----------	----------	16	17	3	5
Uranium ore..........short tons..	143,196	3,047	150,584	4,844	102,258	3,253	117,898	3,918
Vanadium (recoverable in ore and concentrate)..........do....	632	W	222	W	W	575	W	381
Zinc (recoverable content of ores, etc.)..........do....	32,888	7,564	25,419	5,846	24,690	6,716	21,757	6,353
Value of items that cannot be disclosed: Cement, clays (bentonite, fire clay 1962–64), feldspar, scrap mica, perlite, pyrites, and values indicated by symbol W..........	XX	19,883	XX	17,705	XX	r 14,501	XX	10,903
Total..........	XX	474,131	XX	481,115	XX	r 534,353	XX	580,182
ARKANSAS								
Barite..........thousand short tons..	259	$2,232	236	$2,161	233	$2,202	249	$2,379
Bauxite..........long tons, dried equivalent..	1,270,124	14,606	1,478,047	16,701	1,561,984	17,431	1,593,085	17,974
Bromine and bromine in compounds..........thousand pounds..	W	W	W	W	W	W	32,254	7,171
Clays..........thousand short tons..	654	1,693	769	1,763	892	2,152	866	1,890
Coal (bituminous)..........do....	256	1,809	221	1,505	212	1,503	226	1,643
Gem stones..........	NA	15	NA	42	NA	33	NA	31
Gypsum..........thousand short tons..	83	261	W	W	W	W	W	W
Iron ore (usable)..........thousand long tons, gross weight..	43	296	W	W	W	W	W	W
Lime..........thousand short tons..	350	4,542	167	2,237	189	2,814	192	2,776
Natural gas..........million cubic feet..	66,213	9,866	76,101	11,796	r 75,753	11,806	82,831	12,922
Natural gas liquids:								
Natural gasoline and cycle products..........thousand gallons..	29,415	1,673	26,219	1,466	30,082	1,678	27,787	1,578

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LP gases ....do	69,452	2,432	66,377	2,497	61,616	2,460	69,752	3,139
Petroleum (crude) ....thousand 42-gallon barrels	27,649	73,546	27,406	72,900	26,737	71,120	25,930	68,974
Sand and gravel ....thousand short tons	10,847	10,006	12,099	13,589	11,794	14,836	12,806	15,836
Stone ....do	20,611	19,866	18,913	22,727	20,241	26,172	21,241	26,778
Zinc (recoverable content of ores, etc.) ....short tons	211	49	----------	----------	----------	----------	----------	----------
Value of items that cannot be disclosed: Abrasive stones, cement, phosphate rock (1963–65), soapstone, tripoli (1965), and values indicated by symbol W	XX	11,063	XX	17,900	XX	r 20,611	XX	16,019
Total	XX	153,955	XX	167,284	XX	r 174,818	XX	179,110
CALIFORNIA								
Asbestos ....short tons	W	W	19,591	$1,547	55,041	$4,419	74,587	$6,177
Barite ....thousand short tons	7	$133	5	31	6	45	4	21
Boron minerals ....short tons	646,613	49,336	700,183	54,981	776,000	60,871	807,000	64,180
Calcite (optical grade) ....pounds	----------	----------	----------	----------	4	2	W	W
Cement ....thousand 376-pound barrels	43,667	139,151	46,278	147,656	47,204	149,933	45,352	144,852
Clays ....thousand short tons	3,137	7,349	3,395	8,031	r 3,685	r 8,433	3,207	7,226
Copper (recoverable content of ores, etc.) ....short tons	1,162	716	916	564	1,035	675	1,165	825
Feldspar ....long tons	W	W	75,516	W	102,264	W	95,975	W
Gem stones	NA	200	NA	200	NA	200	NA	200
Gold (recoverable content of ores, etc.) ....troy ounces	106,272	3,720	86,867	3,040	71,028	2,486	62,885	2,201
Gypsum ....thousand short tons	1,747	4,113	1,756	4,222	1,893	4,539	1,611	3,881
Lead (recoverable content of ores, etc.) ....short tons	455	84	823	178	1,546	405	1,810	565
Lime ....thousand short tons	470	8,454	487	8,932	577	r 10,294	602	11,073
Magnesium compounds from sea water and bitterns (partly estimated) short tons, MgO equivalent	76,445	6,077	82,397	6,135	94,739	7,143	101,563	8,302
Mercury ....76-pound flasks	15,951	3,050	13,592	2,575	10,291	3,240	13,404	7,650
Mica, scrap ....short tons	W	W	977	14	W	W	W	W
Natural gas ....million cubic feet	564,220	163,624	646,486	189,420	r 660,444	198,551	660,384	204,059
Natural gas liquids:								
Natural gasoline and cycle products ....thousand gallons	716,904	54,460	715,303	54,188	720,373	54,088	655,780	49,850
LP gases ....do	407,378	19,294	393,503	17,329	352,614	15,893	339,082	15,467
Peat ....short tons	33,901	331	39,873	450	35,391	443	30,905	434
Petroleum (crude) ....thousand 42-gallon barrels	296,590	741,475	300,908	746,252	300,009	729,022	316,428	753,099
Pumice ....thousand short tons	573	2,615	460	2,017	443	1,937	676	1,744
Salt ....do	1,643	W	1,716	W	1,525	W	1,638	W
Sand and gravel ....do	107,660	124,922	112,185	128,178	112,995	129,333	118,310	136,227
Silver (recoverable content of ores, etc.) thousand troy ounces	133	144	157	200	172	222	197	254
Stone ....thousand short tons	34,776	54,722	37,977	58,253	45,805	63,566	42,575	59,668
Sulfure ore ....long tons	W	W	785	4	520	3	360	2
Talc, soapstone, and pyrophyllite ....short tons	117,912	1,339	120,452	1,427	132,601	1,631	141,074	1,725
Wollastonite ....do	W	W	3,000	28	3,625	36	W	W
Zinc (recoverable content of ores, etc.) ....do	322	74	101	23	143	39	225	66
Value of items that cannot be disclosed: Bromine, calcium-magnesium chloride, carbon dioxide, coal (lignite), diatomite, iodine, iron ore, lithium minerals, manganiferous ore (1962), molybdenum, perlite, platinum-group metals (crude), potassium salts, pyrites (1962), rare-earth metal concentrates, sodium carbonates and sulfates, tin (1963–65), tungsten concentrate, uranium ore (1963–65), and values indicated by symbol W	XX	81,957	XX	90,366	XX	r 113,043	XX	119,640
Total	XX	1,467,340	XX	1,526,241	XX	r 1,560,492	XX	1,599,388

Table 5.—Mineral production [1] in the United States, by States—Continued

Mineral	1962 Quantity	1962 Value (thousands)	1963 Quantity	1963 Value (thousands)	1964 Quantity	1964 Value (thousands)	1965 Quantity	1965 Value (thousands)
COLORADO								
Beryllium concentrate______short tons, gross weight__	[6] 782	W	[6] 751	W	W	W	W	W
Carbon dioxide, natural______thousand cubic feet__	148,940	$15	224,856	$38	211,830	$36	155,668	$26
Clays______thousand short tons__	802	1,573	686	1,334	558	1,275	631	1,446
Coal (bituminous)______do____	3,379	19,999	3,690	21,888	4,355	23,427	4,790	24,431
Copper (recoverable content of ores, etc.)______short tons__	4,534	2,793	4,169	2,568	4,653	3,034	3,828	2,710
Feldspar______long tons__	W	W	W	W	W	W	521	3
Gem stones______	NA	45	NA	63	NA	80	NA	80
Gold (recoverable content of ores, etc.)______troy ounces__	48,882	1,711	33,605	1,176	42,122	1,474	37,228	1,303
Gypsum______thousand short tons__	108	383	99	346	100	398	102	427
Iron ore (usable)______thousand long tons, gross weight__	W	W	W	W	35	231	114	787
Lead (recoverable content of ores, etc.)______short tons__	17,411	3,204	19,918	4,302	20,563	5,388	22,495	7,018
Lime______thousand short tons__	93	1,518	128	2,104	138	2,193	118	2,074
Mica, scrap______short tons__	142	2	440	7	------	------	------	------
Molybdenum (content of concentrate)______thousand pounds__	32,412	45,376	47,977	67,168	46,378	69,207	[7] 50,715	[7] 78,609
Natural gas______million cubic feet__	101,826	11,812	105,705	12,367	[r] 113,691	13,489	126,381	16,303
Natural gas liquids:								
Natural gasoline______thousand gallons__	60,558	3,826	56,869	3,191	52,400	2,845	54,180	3,034
LP gases______do____	100,787	4,411	91,309	4,171	88,916	3,894	91,399	3,930
Peat______short tons__	12,351	68	13,774	98	27,931	188	31,179	236
Petroleum (crude)______thousand 42-gallon barrels__	42,477	122,334	38,283	110,255	34,755	100,094	33,511	96,512
Pumice______thousand short tons__	76	82	60	87	61	114	56	134
Pyrites______thousand long tons__	W	W	W	W	W	W	30	90
Sand and gravel______thousand short tons__	19,313	18,926	20,385	20,929	20,746	22,227	20,810	22,041
Silver (recoverable content of ores, etc.) thousand troy ounces__	2,088	2,265	2,307	2,951	2,626	3,396	2,051	2,652
Stone______thousand short tons__	2,353	5,597	2,510	5,693	3,217	6,805	4,789	8,638
Tin______long tons__	W	W	W	W	29	103	32	76
Tungsten______short tons__	W	W	W	W	W	W	1,176	1,985
Uranium ore______do____	1,135,440	18,044	1,014,206	15,864	833,282	13,389	574,795	10,651
Vanadium (recoverable in ore and concentrate)______do____	3,742	W	3,047	W	3,312	9,916	4,017	14,056
Vermiculite______thousand short tons__	W	W	(5)	1	(5)	1	------	------
Zinc (recoverable content of ores, etc.)______short tons__	43,351	9,971	48,109	11,065	53,682	14,602	53,870	15,730
Value of items that cannot be disclosed: Cement, fluorspar, molybdenum (1965), perlite, salt, and values indicated by symbol W______	XX	34,209	XX	29,478	XX	[r] 18,205	XX	16,234
Total______	XX	308,164	XX	317,144	XX	316,011	XX	331,216
CONNECTICUT								
Beryllium concentrate______short tons, gross weight__	7	$4	------	------	------	------	------	------
Clays______thousand short tons__	[3] 179	[3] 287	189	$339	212	$262	237	$322
Gem stones______	NA	8	NA	8	NA	8	NA	8
Lime______thousand short tons__	35	635	35	666	39	689	W	W
Sand and gravel______do____	10,208	9,244	10,503	9,343	10,088	9,437	9,940	9,106
Stone______do____	5,090	8,816	5,318	9,612	5,864	10,764	5,871	10,444

Value of items that cannot be disclosed: Clays (kaolin 1962), feldspar, scrap mica, sheet mica (1962), peat, and values indicated by symbol W	XX	760	XX	646	XX	690	XX	1,354
Total	XX	19,754	XX	20,614	XX	21,850	XX	21,234
DELAWARE								
Clays ---- thousand short tons	W	W	13	$13	11	$11	11	$11
Gem stones	NA	W	NA	1	NA	1	NA	1
Sand and gravel ---- thousand short tons	1,755	$1,445	1,094	1,136	1,282	1,280	1,545	1,441
Stone ---- do	W	W	W	W	180	450	180	450
Value of items that cannot be disclosed: Other nonmetals and values indicated by symbol W	XX	86	XX	191	XX	----------	XX	----------
Total	XX	1,531	XX	1,341	XX	1,742	XX	1,903
FLORIDA								
Clays ---- thousand short tons	487	$6,741	538	$7,777	627	$8,405	651	$9,752
Lime ---- do	W	W	126	1,996	117	1,814	101	1,558
Natural gas ---- million cubic feet	29	6	35	7	40	5	107	14
Peat ---- short tons	20,595	139	21,049	129	19,813	102	19,253	109
Petroleum (crude) ---- thousand 42-gallon barrels	419	W	464	W	620	W	1,464	W
Phosphate rock ---- thousand long tons	13,949	94,595	14,592	101,050	17,108	119,667	19,253	141,258
Sand and gravel ---- thousand short tons	5,924	5,179	7,542	5,823	7,420	6,427	7,298	6,377
Stone ---- do	27,279	32,608	31,900	38,173	33,157	38,362	35,730	41,148
Value of items that cannot be disclosed: Cement, gem stones (1963), magnesium compounds, natural gas liquids, rare-earth metals concentrates, staurolite, titanium concentrate, zirconium concentrate, and values indicated by symbol W	XX	46,432	XX	46,665	XX	48,627	XX	49,104
Total	XX	185,700	XX	201,620	XX	223,409	XX	249,320
GEORGIA								
Barite ---- thousand short tons	109	$1,987	117	$2,013	109	$2,022	W	W
Clays ---- do	3,801	47,462	4,208	54,024	4,365	58,899	4,607	$63,158
Coal (bituminous) ---- do	8	28	5	16	4	15	----------	----------
Feldspar ---- long tons	35,692	795	W	W	W	W	W	W
Gem stones	NA	W	NA	1	----------	----------	----------	----------
Iron ore (usable) ---- thousand long tons, gross weight	215	1,118	260	1,304	354	1,752	424	2,170
Mica:								
Scrap ---- short tons	W	W	W	W	W	W	13,065	W
Sheet ---- pounds	60	1	----------	----------	----------	----------	2,793	[5]
Sand and gravel ---- thousand short tons	3,429	3,365	3,817	3,922	r 3,588	r 3,594	3,675	3,588
Stone ---- do	19,555	42,037	19,582	46,044	r 22,822	r 46,428	23,421	48,265
Talc ---- short tons	45,940	96	42,000	93	40,400	135	44,800	313
Value of items that cannot be disclosed: Bauxite, cement, kyanite (1963–65), manganiferous ore (1962), peat, titanium concentrate (1965), zirconium concentrate (1965), and values indicated by symbol W	XX	10,816	XX	12,059	XX	14,292	XX	17,688
Total	XX	107,705	XX	119,476	XX	r 127,137	XX	135,182

Table 5.—Mineral production [1] in the United States, by States—Continued

Mineral	1962 Quantity	1962 Value (thousands)	1963 Quantity	1963 Value (thousands)	1964 Quantity	1964 Value (thousands)	1965 Quantity	1965 Value (thousands)
HAWAII								
Cement thousand 376-pound barrels	1,128	$6,055	1,483	$7,125	1,717	$8,877	1,564	$8,297
Clays thousand short tons	W	W	W	W	3	W	W	W
Gem stones	NA	W	NA	36	NA	W	NA	W
Lime thousand short tons	15	386	12	428	9	321	9	305
Pumice do	232	380	274	469	365	603	380	624
Sand and gravel do	700	1,122	304	764	407	979	751	2,237
Stone do	4,071	6,883	3,844	6,480	5,282	8,765	5,172	9,353
Value of items that cannot be disclosed: Other nonmetals and values indicated by symbol W	XX	18	XX	5	XX	60	XX	19
Total	XX	14,844	XX	15,307	XX	19,605	XX	20,835
IDAHO								
Antimony ore and concentrate short tons, antimony content	631	W	645	W	585	W	818	W
Clays thousand short tons	35	$70	[3] 31	[3] $15	[3] 29	[3] $25	[3] 47	[3] $33
Copper (recoverable content of ores, etc.) short tons	3,861	2,378	4,172	2,570	4,666	3,042	5,140	3,639
Gold (recoverable content of ores, etc.) troy ounces	5,845	205	5,477	192	5,677	199	5,078	178
Iron ore (usable) thousand long tons, gross weight	5	35	6	40	4	33	9	84
Lead (recoverable content of ores, etc.) short tons	84,058	15,467	75,759	16,364	71,312	18,684	66,606	20,781
Lime thousand short tons	68	801	60	874	W	W	W	W
Mercury 76-pound flasks	----------	----------	W	W	83	26	1,119	639
Peat short tons	W	W	W	W	900	8	W	W
Phosphate rock thousand long tons	1,912	10,635	1,700	10,589	W	W	W	W
Pumice thousand short tons	67	103	161	275	59	100	46	79
Sand and gravel do	14,321	13,029	12,433	10,615	9,582	8,691	12,151	13,198
Silver (recoverable content of ores, etc.) thousand troy ounces	17,772	19,283	16,711	21,375	16,483	21,313	18,457	23,865
Stone thousand short tons	1,381	2,698	1,168	2,217	1,144	2,773	1,831	3,440
Tungsten concentrate short tons, 60-percent WO_3 basis	----------	----------	----------	----------	11	8	----------	----------
Vanadium (recoverable in ore and concentrate) short tons	W	W	23	W	W	W	W	W
Zinc (recoverable content of ores, etc.) do	62,865	14,459	63,267	14,551	59,298	16,129	58,034	16,946
Value of items that cannot be disclosed: Barite (1962–64), cement, clays (fire clay 1963–65, bentonite 1963–65, kaolin 1963–65), abrasive garnet, gem stones, scrap mica (1963–64), sheet mica (1962), perlite, titanium concentrate, uranium (1962), and values indicated by symbol W	XX	3,451	XX	3,110	XX	15,231	XX	22,203
Total	XX	82,614	XX	82,787	XX	86,262	XX	105,085
ILLINOIS								
Cement:								
Portland thousand 376-pound barrels	9,145	$30,205	9,281	$30,577	9,790	$32,191	9,358	$30,622
Masonry thousand 280-pound barrels	440	1,320	472	1,440	596	2,038	615	1,907

Clays ____ thousand short tons__	1,929	4,151	1,949	4,368	[3] 2,007	[3] 4,358	[3] 2,169	[3] 4,601
Coal (bituminous) ____ do____	48,487	186,986	51,736	196,518	55,023	208,448	58,483	218,972
Fluorspar ____ short tons__	132,830	6,392	132,060	6,547	127,454	6,452	159,140	7,861
Lead (recoverable content of ores, etc.) ____ do____	3,610	664	2,901	627	2,180	571	3,005	938
Natural gas ____ million cubic feet__	10,650	1,523	9,459	1,220	[r] 7,824	905	7,396	865
Natural gas liquids:								
Natural gasoline and cycle products ____ thousand gallons__	13,315	1,023	14,939	1,077	14,109	1,030	W	W
LP gases ____ do____	327,616	13,812	337,278	14,714	312,173	13,758	W	W
Peat ____ short tons__	W	W	W	W	W	W	36,774	453
Petroleum (crude) ____ thousand 42-gallon barrels__	78,796	234,812	74,796	222,892	70,168	205,592	63,708	186,664
Sand and gravel ____ thousand short tons__	34,122	38,981	31,746	36,431	34,880	39,966	36,228	40,480
Stone ____ do____	41,293	54,411	40,293	52,217	42,987	56,553	47,066	61,294
Zinc (recoverable content of ores, etc.) ____ short tons__	27,413	6,305	20,337	4,678	13,800	3,754	18,314	5,348
Value of items that cannot be disclosed: Clay (fuller's earth 1964–65), gem stones, lime, tripoli, and values indicated by symbol W ____	XX	12,133	XX	13,656	XX	15,520	XX	33,020
Total ____	XX	592,718	XX	586,962	XX	591,136	XX	593,025

INDIANA

Abrasive stones ____ short tons__	5	$15	5	$16	5	$16	5	$15
Cement [2] ____ thousand 376-pound barrels__	12,878	42,572	13,165	43,216	15,038	48,695	14,925	48,797
Clays ____ thousand short tons__	1,450	2,255	1,546	2,347	1,545	2,264	1,459	2,160
Coal (bituminous) ____ do____	15,709	60,079	15,100	57,120	15,075	57,246	15,565	59,927
Natural gas ____ million cubic feet__	284	60	286	67	[r] 199	47	239	56
Peat ____ short tons__	47,430	272	47,695	412	66,568	543	53,873	511
Petroleum (crude) ____ thousand 42-gallon barrels__	12,077	35,989	11,902	35,230	11,283	32,157	[3] 11,429	[3] 32,458
Sand and gravel ____ thousand short tons__	21,261	18,692	22,840	20,683	24,416	21,811	24,867	22,220
Stone ____ do____	18,709	34,653	19,667	35,616	22,318	39,978	24,574	42,124
Value of items that cannot be disclosed: Cement (masonry 1963–64), gem stones (1962–63), and gypsum ____	XX	8,839	XX	9,259	XX	9,026	XX	10,299
Total ____	XX	203,426	XX	203,966	XX	211,783	XX	218,567

IOWA

Cement:								
Portland ____ thousand 376-pound barrels__	12,261	$42,417	12,495	$42,891	13,607	$46,398	13,643	$46,273
Masonry ____ thousand 280-pound barrels__	568	1,786	551	1,754	585	1,847	608	1,867
Clays ____ thousand short tons__	1,039	1,427	1,064	1,405	1,008	1,254	1,085	1,347
Coal (bituminous) ____ do____	1,130	4,026	1,213	4,244	973	3,447	1,043	3,694
Gypsum ____ do____	1,256	5,318	1,282	5,667	1,287	5,821	1,254	5,554
Sand and gravel ____ do____	13,797	12,474	14,168	12,845	13,890	13,546	18,205	17,152
Stone ____ do____	21,618	28,244	20,904	27,788	23,935	33,038	25,891	35,468
Value of items that cannot be disclosed: Gem stones, lime, peat, and petroleum (1962–64) ____	XX	869	XX	1,076	XX	1,279	XX	1,428
Total ____	XX	96,561	XX	97,670	XX	106,630	XX	112,783

Table 5.—Mineral production [1] in the United States, by States—Continued

Mineral	1962 Quantity	1962 Value (thousands)	1963 Quantity	1963 Value (thousands)	1964 Quantity	1964 Value (thousands)	1965 Quantity	1965 Value (thousands)
KANSAS								
Cement:								
Portland thousand 376-pound barrels	8,058	$25,134	8,201	$25,372	8,483	$25,959	8,801	$26,972
Masonry thousand 280-pound barrels	392	1,156	387	1,183	384	1,173	404	1,178
Clays thousand short tons	895	1,091	893	1,104	785	935	789	953
Coal (bituminous) do	915	4,249	1,169	5,311	1,263	5,749	1,310	6,072
Helium [9] thousand cubic feet	42,305	1,478	46,177	1,616	[r] 2,215,338	[r] 26,598	2,570,889	30,422
Lead (recoverable content of ores, etc.) short tons	970	178	1,027	222	1,185	310	1,644	513
Lime thousand short tons	5	59	----------	----------	----------	----------	----------	----------
Natural gas million cubic feet	694,352	86,100	732,946	97,482	[r] 764,073	96,031	793,379	105,519
Natural gas liquids:								
Natural gasoline thousand gallons	151,360	7,696	165,370	9,811	162,725	8,713	153,485	7,791
LP gases do	166,769	6,295	395,877	15,481	512,747	18,121	587,416	22,322
Petroleum (crude) thousand 42-gallon barrels	112,076	326,141	109,107	317,501	106,252	310,256	104,733	305,820
Salt [10] thousand short tons	944	11,654	924	11,993	930	11,799	1,053	12,376
Sand and gravel do	11,552	8,039	12,062	8,676	12,968	9,108	12,544	8,473
Stone do	[4] 13,527	[4] 17,274	13,558	18,483	14,138	18,912	15,270	20,538
Zinc (recoverable content of ores, etc.) short tons	3,943	907	3,508	807	4,665	1,269	6,508	1,900
Value of items that cannot be disclosed: Natural cement, gypsum, pumice, salt (brine), and stone (crushed sandstone 1962)	XX	3,625	XX	3,260	XX	3,277	XX	2,642
Total	XX	501,076	XX	518,302	XX	[r] 538,210	XX	553,491
KENTUCKY								
Barite thousand short tons	4	$36	6	$85	6	$96	----------	----------
Clays [3] do	936	2,158	984	2,397	920	1,801	1,059	$2,580
Coal (bituminous) do	69,212	270,875	77,350	295,743	82,747	309,896	85,766	324,523
Fluorspar short tons	33,830	1,492	35,072	1,537	38,214	1,693	31,992	1,485
Lead (recoverable content of ores, etc.) do	743	137	831	179	858	225	756	236
Natural gas million cubic feet	70,241	17,419	74,634	17,838	[r] 76,940	18,257	78,976	18,638
Petroleum (crude) thousand 42-gallon barrels	17,789	52,478	18,344	53,564	19,772	56,746	19,386	55,638
Sand and gravel thousand short tons	6,137	5,378	6,480	6,071	6,560	6,297	6,742	6,332
Silver (recoverable content of ores, etc.) thousand troy ounces	1	2	2	2	2	2	2	2
Stone thousand short tons	19,472	27,682	24,689	34,571	[4] 21,868	[4] 29,594	26,029	34,533
Zinc (recoverable content of ores, etc.) short tons	1,172	270	1,461	336	2,063	561	5,654	1,651
Value of items that cannot be disclosed: Cement, ball clay, gem stones (1962–63), natural gas liquids, and stone (dimension sandstone 1964)	XX	20,609	XX	20,370	XX	19,211	XX	20,763
Total	XX	398,536	XX	432,693	XX	444,379	XX	466,381
LOUISIANA								
Clays thousand short tons	638	$641	655	$655	780	$797	909	$936
Lime do	624	6,519	657	6,862	725	8,312	842	9,980

Natural gas ---- million cubic feet	3,525,456	694,515	3,928,427	777,829	[r]4,152,731	793,328	4,466,786	812,955
Natural gas liquids:								
Natural gasoline and cycle products ---- thousand gallons	1,010,137	74,726	1,143,707	81,332	1,352,980	91,931	1,431,836	102,731
LP gases ---- do	862,772	29,037	1,113,670	41,043	1,247,484	45,935	1,300,038	46,101
Petroleum (crude) ---- thousand 42-gallon barrels	477,153	1,502,568	515,057	1,608,120	549,698	1,709,622	594,853	1,841,714
Salt ---- thousand short tons	5,248	27,407	6,199	30,450	6,401	36,056	8,126	41,812
Sand and gravel ---- do	12,040	14,817	12,500	14,701	13,594	15,253	14,298	16,405
Stone [4] ---- do	5,711	8,067	5,408	7,961	5,459	7,228	7,452	10,905
Sulfur (Frasch process) ---- thousand long tons	2,262	49,772	2,445	48,905	2,733	54,996	3,577	71,966
Value of items that cannot be disclosed: Cement, gypsum, and stone (crushed miscellaneous)	XX	18,554	XX	20,531	XX	21,549	XX	23,350
Total	XX	2,426,623	XX	2,638,389	XX	2,785,007	XX	2,978,855
MAINE								
Beryllium concentrate ---- short tons, gross weight	W	W	----	----	----	----	----	----
Clays ---- thousand short tons	48	$63	42	$55	45	$58	49	$63
Gem stones	NA	25	NA	25	NA	35	NA	35
Mica:								
Scrap ---- short tons	15	[5]	----	----	----	----	----	----
Sheet ---- pounds	2,017	16	----	----	----	----	----	----
Peat ---- short tons	1,250	47	W	W	6,350	171	1,275	56
Sand and gravel ---- thousand short tons	10,014	4,013	11,195	4,673	13,552	6,463	17,294	7,831
Stone ---- do	1,127	4,249	947	3,581	1,414	4,506	1,100	3,409
Value of items that cannot be disclosed: Cement, feldspar, and values indicated by symbol W	XX	6,534	XX	5,770	XX	6,341	XX	6,347
Total	XX	14,947	XX	14,104	XX	17,574	XX	17,741
MARYLAND								
Clays ---- thousand short tons	593	$899	580	$897	[3]635	[3]$798	[3]914	[3]$1,088
Coal (bituminous) ---- do	821	3,168	1,162	4,330	1,136	4,511	1,210	4,389
Gem stones	NA	3	NA	3	NA	3	NA	3
Lime ---- thousand short tons	W	W	W	W	W	W	37	481
Natural gas ---- million cubic feet	2,472	667	1,633	439	[r]1,373	366	408	103
Sand and gravel ---- thousand short tons	12,762	16,816	13,310	16,063	15,041	18,071	16,200	21,188
Stone ---- do	11,610	22,595	13,012	26,407	13,348	26,715	14,553	28,432
Value of items that cannot be disclosed: Cement, ball clay (1964–65), diatomite (1962–63), greensand marl, peat, potassium salts, talc and soapstone, and values indicated by symbol W	XX	22,481	XX	22,111	XX	23,429	XX	22,311
Total	XX	66,629	XX	70,250	XX	73,893	XX	77,995
MASSACHUSETTS								
Clays ---- thousand short tons	125	$96	157	$213	138	$174	181	$238
Gem stones	NA	2	NA	2	NA	2	NA	2
Lime ---- thousand short tons	148	2,337	145	2,426	171	2,703	170	2,779
Sand and gravel ---- do	17,566	15,026	19,905	15,592	21,341	16,794	22,141	16,172
Stone ---- do	4,985	12,541	5,570	14,396	6,519	16,663	6,168	16,980
Value of items that cannot be disclosed: Nonmetals	XX	33	XX	32	XX	31	XX	27
Total	XX	30,035	XX	32,661	XX	36,367	XX	36,198

Table 5.—Mineral production [1] in the United States, by States—Continued

Mineral	1962		1963		1964		1965	
	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)
MICHIGAN								
Cement:								
Portland thousand 376-pound barrels	22,682	$73,267	25,016	$76,944	26,745	$84,316	27,565	$86,996
Masonry thousand 280-pound barrels	1,517	4,335	1,684	4,519	1,865	4,954	2,108	5,373
Clays thousand short tons	1,751	1,917	1,958	2,149	2,385	2,592	2,402	2,580
Copper (recoverable content of ores, etc.) short tons	74,099	45,645	75,262	46,361	69,040	45,014	71,749	50,798
Gypsum thousand short tons	1,278	4,791	1,315	4,938	1,421	5,263	1,338	5,027
Iron ore (usable) thousand long tons, gross weight	9,422	85,597	10,789	107,201	13,871	143,979	13,527	145,482
Lime thousand short tons	1,153	15,371	1,371	18,431	1,430	19,246	1,095	13,057
Magnesium compounds from sea water and brine (except for metal) short tons, MgO equivalent	W	W	266,740	23,062	306,494	23,385	319,389	26,143
Manganiferous ore (5 to 35 percent Mn) short tons, gross weight	----------	----------	152,957	W	----------	----------	----------	----------
Natural gas million cubic feet	28,987	6,174	32,850	8,902	r 31,388	7,984	34,558	8,674
Natural gas liquids:								
Natural gasoline thousand gallons	----------	----------	----------	----------	----------	----------	9,054	607
LP gases do	----------	----------	----------	----------	----------	----------	76,299	3,815
Peat short tons	257,693	2,277	251,809	2,413	269,074	2,412	230,950	2,134
Petroleum (crude) thousand 42-gallon barrels	17,114	48,775	15,972	45,520	15,601	43,839	14,728	41,091
Salt thousand short tons	4,274	33,343	4,244	33,656	4,345	35,711	4,171	36,087
Sand and gravel do	47,563	42,029	50,458	43,433	51,921	44,405	53,168	47,176
Silver (recoverable content of ores, etc.) thousand troy ounces	401	436	339	434	349	452	458	592
Stone thousand short tons	28,440	29,055	30,316	32,065	34,650	37,002	34,713	36,438
Value of items that cannot be disclosed: Bromine, calcium-magnesium chloride, gem stones, iodine, potassium salts, and values indicated by symbol W	XX	53,500	XX	42,001	XX	r 54,278	XX	53,490
Total	XX	446,512	XX	492,029	XX	r 554,832	XX	565,560
MINNESOTA								
Clays thousand short tons	203	$291	[3] 199	[3] $298	[3] 213	[3] $319	[3] 207	[3] $311
Iron ore (usable) thousand long tons, gross weight	44,295	385,997	45,435	408,486	49,626	449,289	50,873	459,290
Manganiferous ore (5 to 35 percent Mn) short tons, gross weight	292,779	W	347,336	W	188,481	W	280,705	W
Peat short tons	14,386	307	8,110	294	19,188	405	7,346	123
Sand and gravel thousand short tons	29,399	22,656	30,462	23,318	35,817	25,907	37,545	27,296
Stone do	3,803	10,360	3,898	11,027	3,588	12,297	4,371	11,680
Value of items that cannot be disclosed: Abrasive stones, cement, fire clay (1963–65), gem stones, lime, and values indicated by symbol W	XX	9,325	XX	10,120	XX	9,278	XX	9,060
Total	XX	428,936	XX	453,543	XX	497,495	XX	507,760

MISSISSIPPI

Clays____thousand short tons__	1,129	$5,742	1,235	$5,968	1,331	$6,130	1,502	$5,925
Natural gas____million cubic feet__	170,271	32,351	176,807	31,825	r 180,428	31,385	166,825	28,861
Natural gas liquids:								
Natural gasoline and cycle products___thousand gallons__	25,891	1,616	28,757	1,755	27,485	1,644	26,582	1,606
LP gases____do____	20,401	732	24,541	956	23,277	780	22,150	975
Petroleum (crude)____thousand 42-gallon barrels__	55,713	154,882	58,619	161,788	56,777	151,595	56,183	148,437
Sand and gravel____thousand short tons__	7,001	7,262	6,825	7,056	7,825	8,569	8,447	8,717
Stone____do____	1,199	1,266	1,267	1,267	1,553	1,557	[4] 2,357	[4] 2,358
Value of items that cannot be disclosed: Cement, iron ore (1965), lime magnesium compounds, and stone (dimension sandstone 1965)____	XX	9,030	XX	9,579	XX	10,533	XX	12,093
Total____	XX	212,881	XX	220,194	XX	212,193	XX	208,972

MISSOURI

Asphalt, native____short tons__	W	W	1,779	$15	1,522	$13	W	W
Barite____thousand short tons__	304	$3,994	287	3,680	267	3,451	329	$4,219
Cement:								
Portland____thousand 376-pound barrels__	12,739	44,004	12,402	41,640	12,378	42,618	13,334	46,034
Masonry____thousand 280-pound barrels__	455	1,457	417	1,345	334	1,046	377	1,173
Clays____thousand short tons__	2,053	5,033	1,746	4,467	1,966	4,874	2,226	5,439
Coal (bituminous)____do____	2,896	12,057	3,174	13,196	3,254	13,285	3,564	14,779
Copper (recoverable content of ores, etc.)____short tons__	2,752	1,695	1,816	1,119	2,059	1,343	2,331	1,650
Iron ore (usable)____thousand long tons, gross weight__	346	3,188	345	3,085	1,116	14,907	1,784	24,607
Lead (recoverable content of ores, etc.)____short tons__	60,982	11,221	79,844	17,246	120,148	31,479	133,521	41,659
Lime____thousand short tons__	1,176	13,703	1,240	14,386	1,219	14,328	1,442	16,782
Natural gas____million cubic feet__	92	23	100	27	r 107	26	84	21
Petroleum (crude)____thousand 42-gallon barrels__	55	W	53	150	65	163	73	W
Sand and gravel____thousand short tons____	10,304	11,572	10,653	12,260	11,483	13,380	12,068	13,735
Silver (recoverable content of ores, etc.) thousand troy ounces__	491	533	132	168	----------	----------	300	387
Stone____thousand short tons__	28,876	44,006	30,885	46,130	31,487	47,984	36,247	53,574
Zinc (recoverable content of ores, etc.)____short tons__	2,792	642	321	74	1,501	408	4,312	1,259
Value of items that cannot be disclosed: Gem stones (1962), tripoli (1965), and values indicated by symbol W____	XX	179	XX	----------	XX	----------	XX	250
Total____	XX	153,307	XX	158,988	XX	189,305	XX	225,568

MONTANA

Clays [3]____thousand short tons__	56	$77	38	$45	49	$59	76	$98
Coal (bituminous and lignite)____do____	382	1,140	343	967	346	925	364	1,050
Copper (recoverable content of ores, etc.)____short tons__	94,021	57,917	79,762	49,133	103,806	67,682	115,489	81,766
Gold (recoverable content of ores, etc.)____troy ounces__	24,387	854	18,520	648	29,115	1,019	22,772	797
Iron ore (usable)____thousand long tons, gross weight__	9	62	13	89	15	99	9	71
Lead (recoverable content of ores, etc.)____short tons__	6,121	1,126	5,000	1,080	4,538	1,189	6,981	2,178
Lime____thousand short tons__	104	1,049	114	1,290	136	1,385	159	1,512
Manganese ore (35 percent or more Mn) short tons, gross weight__	24,758	W	5,260	W	20,264	W	23,621	W
Manganiferous ore (5 to 35 percent Mn)____do____	2,264	29	1,688	W	3,638	W	1,968	W

Table 5.—Mineral production [1] in the United States, by States—Continued

Mineral	1962 Quantity	1962 Value (thousands)	1963 Quantity	1963 Value (thousands)	1964 Quantity	1964 Value (thousands)	1965 Quantity	1965 Value (thousands)
MONTANA—Continued								
Natural gas—million cubic feet	29,955	$2,217	30,026	$2,253	[r]25,051	$1,965	28,105	$2,305
Petroleum (crude)—thousand 42-gallon barrels	31,648	76,690	30,870	75,323	30,647	74,621	32,778	79,624
Sand and gravel—thousand short tons	18,473	17,642	14,319	13,756	16,017	17,840	12,048	13,587
Silver (recoverable content of ores, etc.) thousand troy ounces	4,561	4,948	4,242	5,426	5,290	6,840	5,207	6,733
Stone—thousand short tons	996	1,708	6,109	7,081	7,345	8,477	5,512	5,971
Zinc (recoverable content of ores, etc.)—short tons	37,678	8,666	32,941	7,576	29,059	7,904	33,786	9,866
Value of items that cannot be disclosed: Barite, cement, clays (fire clay 1962–64, bentonite 1964–65), fluorspar, gem stones, gypsum, sheet mica (1962), natural gas liquids, peat, phosphate rock, pumice (1964), rare-earth metal concentrates (1962), talc, tungsten (1962), uranium ore (1962–64), vermiculite, and values indicated by symbol W	XX	16,531	XX	17,351	XX	[r]21,447	XX	23,834
Total	XX	190,656	XX	182,018	XX	[r]211,452	XX	229,392
NEBRASKA								
Clays—thousand short tons	142	$142	148	$148	143	$143	106	$106
Gem stones	NA	5	NA	5	NA	5	NA	5
Natural gas—million cubic feet	14,880	2,708	13,051	2,454	[r]11,094	1,707	10,720	1,565
Natural gas liquids:								
Natural gasoline—thousand gallons	12,239	809	10,119	687	9,587	627	7,822	516
LP gases—do	28,718	1,329	25,931	1,207	24,556	1,092	16,946	847
Petroleum (crude)—thousand 42-gallon barrels	24,894	70,450	21,846	61,824	19,113	51,605	17,216	45,796
Sand and gravel—thousand short tons	12,853	9,797	11,166	10,680	14,641	15,748	11,993	13,697
Stone—do	3,670	6,626	3,700	6,192	3,779	6,417	4,198	6,637
Value of items that cannot be disclosed: Cement, lime, and pumice	XX	16,507	XX	15,710	XX	14,615	XX	14,622
Total	XX	108,373	XX	98,907	XX	91,959	XX	83,791
NEVADA								
Antimony ore and concentrate short tons, antimony content	----------	----------	----------	----------	33	$20	26	$19
Barite—thousand short tons	138	$954	120	$760	149	1,261	91	583
Copper (recoverable content of ores, etc.)—short tons	82,602	50,883	81,738	50,351	67,272	43,861	71,332	50,503
Gem stones	NA	100	NA	100	NA	100	NA	100
Gold (recoverable content of ores, etc.)—troy ounces	62,863	2,200	98,879	3,461	90,469	3,166	229,050	8,017
Gypsum—thousand short tons	817	2,952	890	3,216	799	2,894	710	2,518
Iron ore (usable)—thousand long tons, gross weight	617	3,238	772	3,921	911	5,048	1,141	5,330
Lead (recoverable content of ores, etc.)—short tons	771	142	1,126	243	809	212	2,277	710
Mercury—76-pound flasks	6,573	1,257	4,944	937	3,262	1,027	3,333	1,902
Perlite—short tons	25,067	205	22,910	192	15,603	135	13,780	121
Petroleum (crude)—thousand 42-gallon barrels	141	W	118	W	255	W	209	W
Pumice—thousand short tons	W	W	W	W	W	W	68	187
Sand and gravel—do	7,850	9,655	9,688	10,513	14,142	14,427	9,455	11,796

Silver (recoverable content of ores, etc.) thousand troy ounces	245	266	215	275	172	223	507	656
Stone thousand short tons	722	1,220	639	1,101	788	1,396	1,248	2,247
Sulfur ore long tons	W	W	586	11	274	5	336	6
Talc and soapstone short tons	6,157	55	4,243	50	5,322	58	3,592	31
Tungsten ore and concentrate short tons, 60-percent WO_3 basis	156	234	W	W	W	W	W	W
Zinc (recoverable content of ores, etc.) short tons	281	65	571	131	582	158	3,858	1,127
Value of items that cannot be disclosed: Brucite (1965), cement (1965), clays, diatomite, fluorspar, lime, magnesite, molybdenum, peat (1964–65), salt, uranium ore (1963–65), and values indicated by symbol W	XX	9,648	XX	10,215	XX	11,146	XX	14,063
Total	XX	83,074	XX	85,477	XX	85,137	XX	99,916
NEW HAMPSHIRE								
Beryllium concentrate short tons, gross weight	7	$4	----------	----------	----------	----------	----------	----------
Clays thousand short tons	37	37	47	$40	46	$40	53	$47
Mica:								
Sheet pounds	37,508	396	----------	----------	----------	----------	----------	----------
Scrap short tons	411	11	----------	----------	----------	----------	----------	----------
Sand and gravel thousand short tons	8,260	4,119	7,581	4,376	8,768	4,996	10,584	5,559
Stone do	154	1,368	137	1,566	202	2,138	153	1,932
Value of items that cannot be disclosed: Other nonmetals	XX	97	XX	109	XX	128	XX	127
Total	XX	6,032	XX	6,091	XX	7,302	XX	7,665
NEW JERSEY								
Clays thousand short tons	584	$1,476	498	$1,392	500	$1,441	506	$1,388
Gem stones	NA	9	NA	9	NA	10	NA	10
Peat short tons	29,099	247	23,685	241	W	W	40,480	431
Sand and gravel thousand short tons	13,728	21,230	16,672	25,245	17,661	27,079	17,389	28,646
Stone do	14,214	28,979	11,229	25,654	12,326	28,461	12,232	27,247
Zinc (recoverable content of ores, etc.) [11] short tons	15,309	3,559	32,738	7,855	32,926	8,935	38,297	11,106
Value of items that cannot be disclosed: Iron ore, lime, magnesium compounds, manganiferous residuum, greensand marl, titanium concentrate, and values indicated by symbol W	XX	10,186	XX	12,880	XX	12,246	XX	11,330
Total	XX	65,686	XX	73,276	XX	78,172	XX	80,158
NEW MEXICO								
Barite thousand short tons	([5])	$4	1	$6	W	W	([5])	$2
Beryllium concentrate short tons, gross weight	34	19	----------	----------	----------	----------	----------	----------
Carbon dioxide, natural thousand cubic feet	826,810	74	854,339	63	816,168	$61	833,819	62
Clays thousand short tons	52	156	W	140	[3] 104	[3] 167	60	101
Coal (bituminous) do	677	2,595	1,945	5,629	2,969	9,763	3,212	10,710
Copper (recoverable content of ores, etc.) short tons	82,683	50,933	83,037	51,151	86,104	56,140	98,658	69,850
Fluorspar do	----------	----------	----------	----------	137	3	----------	----------
Gem stones	NA	45	NA	45	NA	45	NA	45
Gold (recoverable content of ores, etc.) troy ounces	7,529	264	7,805	273	6,110	214	9,641	337
Gypsum thousand short tons	151	564	179	656	W	W	W	W

Table 5.—Mineral production[1] in the United States, by States—Continued

Mineral	1962 Quantity	1962 Value (thousands)	1963 Quantity	1963 Value (thousands)	1964 Quantity	1964 Value (thousands)	1965 Quantity	1965 Value (thousands)
NEW MEXICO—Continued								
Helium, refined......thousand cubic feet..	27,377	$958	79,624	$2,787	[r]82,105	$2,958	80,583	$2,975
Iron ore (usable)......thousand long tons, gross weight..	9	121	W	W	W	W	W	W
Lead (recoverable content of ores, etc.)......short tons..	1,134	209	1,014	219	1,626	426	3,387	1,057
Lime......thousand short tons..	29	403	27	377	25	352	33	465
Manganese ore (35 percent or more Mn) short tons, gross weight..	W	W	5,362	137	5,794	149	5,637	156
Manganiferous ore (5 to 35 percent Mn)......do....	W	W	41,144	W	46,657	300	50,090	328
Mica: Scrap......short tons..	5,731	140	W	W	6,922	105	4,263	45
Natural gas......million cubic feet..	804,612	92,530	808,377	96,197	[r]873,947	101,932	937,205	110,590
Natural gas liquids:								
Natural gasoline and cycle products...thousand gallons..	273,969	16,775	291,388	17,555	356,047	21,570	358,487	20,824
LP gases......do....	661,330	20,359	728,200	21,801	739,190	21,641	759,311	25,817
Perlite......short tons..	258,164	2,143	259,113	2,212	286,329	2,568	331,011	2,905
Petroleum (crude)......thousand 42-gallon barrels..	109,328	314,883	109,941	316,574	113,863	326,565	119,166	334,977
Potassium salts......thousand short tons, K_2O equivalent..	2,208	85,124	2,643	101,458	2,675	[r]104,861	2,848	117,771
Pumice......thousand short tons..	308	741	322	850	260	760	264	915
Salt......do....	43	334	54	472	62	559	64	572
Sand and gravel......do....	6,889	8,021	8,402	12,843	8,781	10,160	11,763	12,130
Silver (recoverable content of ores, etc.) thousand troy ounces..	302	327	256	328	242	313	288	372
Stone......thousand short tons..	2,004	2,782	2,509	4,236	2,760	4,244	1,911	3,020
Uranium ore......short tons..	3,478,238	63,504	2,304,577	41,372	2,093,350	38,203	2,013,861	38,311
Vanadium (recoverable in ore and concentrate)......do....	W	W	23	W	W	154	W	221
Zinc (recoverable content of ores, etc.)......do....	22,015	5,063	12,938	2,976	29,833	8,115	36,460	10,646
Value of items that cannot be disclosed: Cement, fire clay (1964), molybdenum, sheet mica (1962), tin (1964–65), and values indicated by symbol W......	XX	6,743	XX	8,249	XX	[r]7,802	XX	8,070
Total......	XX	675,814	XX	688,606	XX	[r]720,130	XX	773,274
NEW YORK								
Clays......thousand short tons..	1,397	$1,618	1,598	$2,186	1,499	$1,993	1,354	$1,717
Emery......short tons..	4,316	71	6,732	119	9,214	172	10,720	204
Gem stones......	NA	10	NA	10	NA	10	NA	10
Gypsum......thousand short tons..	601	3,122	647	3,339	653	3,321	662	3,511
Iron ore (usable)......thousand long tons, gross weight..	2,099	24,953	W	W	W	W	W	W
Lead (recoverable content of ores, etc.)......short tons..	1,063	196	1,009	218	732	192	601	188
Natural gas......million cubic feet..	4,262	1,198	3,962	1,169	[r]3,108	963	3,340	1,029
Peat......short tons..	14,400	113	21,358	178	32,574	261	25,098	232
Petroleum (crude)......thousand 42-gallon barrels..	1,589	7,309	1,679	7,707	1,874	8,321	1,632	7,246
Salt......thousand short tons..	4,456	32,236	4,782	34,228	4,816	34,216	5,002	35,771
Sand and gravel......do....	29,447	31,346	37,381	37,274	39,282	38,583	39,225	40,370
Silver (recoverable content of ores, etc.) thousand troy ounces..	19	21	20	25	13	17	11	15
Stone......thousand short tons..	27,589	47,256	26,611	44,549	29,141	46,669	30,801	48,675
Zinc (recoverable content of ores, etc.)......short tons..	53,654	12,340	53,495	12,304	60,754	16,525	69,880	20,405

Value of items that cannot be disclosed: Cement, abrasive garnet, lime, talc, titanium concentrate, wollastonite, and values indicated by symbol W	XX	79,183	XX	115,768	XX	137,202	XX	130,684
Total	XX	240,972	XX	259,074	XX	288,445	XX	290,057
NORTH CAROLINA								
Abrasive stones (millstones)	NA	$2	NA	$2	----------	----------	----------	----------
Clays [3] ... thousand short tons	2,731	1,782	2,735	1,761	3,199	$2,064	3,383	$2,162
Feldspar ... long tons	244,708	2,373	267,654	2,821	r 281,449	r 2,342	278,990	3,153
Gem stones	NA	2	NA	14	NA	15	NA	15
Gold (recoverable content of ores, etc.) ... troy ounces	460	16	33	1	----------	----------	----------	----------
Iron ore (usable) ... thousand long tons	1	13	1	10	----------	----------	----------	----------
Lead (recoverable content of ores, etc.) ... short tons	219	40	62	13	----------	----------	----------	----------
Mica:								
Scrap ... do	61,983	1,384	61,598	1,497	64,010	2,027	72,199	1,987
Sheet ... pounds	320,305	867	92,961	13	242,662	58	713,293	185
Phosphate rock ... thousand long tons	----------	----------	----------	----------	6	41	----------	----------
Sand and gravel ... thousand short tons	12,516	11,457	11,028	10,132	11,150	10,404	10,499	10,076
Silver (recoverable content of ores, etc.) thousand troy ounces	100	109	27	34	----------	----------	----------	----------
Stone ... thousand short tons	19,308	29,533	15,701	25,683	[4] 17,943	[4] 30,378	[4] 18,835	[4] 30,920
Talc and pyrophyllite ... short tons	100,298	433	106,652	446	106,035	495	109,721	556
Zinc (recoverable content of ores, etc.) ... do	----------	----------	13	3	----------	----------	----------	----------
Value of items that cannot be disclosed: Asbestos, cement (1963–65), clay (kaolin), copper (1962–63), lithium minerals, olivine, stone (crushed and dimension marble and dimension slate 1964–65), and tungsten concentrate (1962–64)	XX	6,586	XX	2,095	XX	7,903	XX	11,329
Total	XX	54,597	XX	44,525	XX	r 55,727	XX	60,383
NORTH DAKOTA								
Clays ... thousand short tons	98	$124	[3] 5	[3] $10	85	$119	81	$114
Coal (lignite) ... do	2,733	6,135	2,399	5,250	2,637	5,659	2,732	5,848
Gem stones	NA	1	NA	1	NA	1	NA	1
Natural gas ... million cubic feet	25,155	3,446	32,798	6,264	r 34,512	7,634	35,652	5,704
Natural gas liquids:								
Natural gasoline ... thousand gallons	16,872	1,085	20,511	1,339	21,368	1,338	21,059	1,263
LP gases ... do	68,881	2,665	79,653	3,166	84,338	2,960	85,174	3,066
Petroleum (crude) ... thousand 42-gallon barrels	25,181	69,248	25,030	68,332	25,731	63,813	26,350	65,875
Sand and gravel ... thousand short tons	9,615	7,122	9,529	9,193	10,520	10,142	7,574	7,895
Stone ... do	19	19	132	132	31	56	356	624
Uranium ore ... short tons	W	W	5,567	141	W	W	44,558	1,359
Value of items that cannot be disclosed: Clays (bentonite 1963, miscellaneous clay 1963), lime (1965), molybdenum (1964–65), peat (1963–65), salt, vanadium (1965), and values indicated by symbol W	XX	774	XX	875	XX	1,144	XX	1,129
Total	XX	90,619	XX	94,703	XX	92,866	XX	92,878

Table 5.—Mineral production[1] in the United States, by States—Continued

Mineral	1962		1963		1964		1965	
	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)
OHIO								
Cement:								
Portland—thousand 376-pound barrels	15,353	$51,006	16,218	$53,244	15,553	$50,647	14,786	$47,499
Masonry—thousand 280-pound barrels	946	2,793	1,023	3,084	1,068	3,127	1,050	3,004
Clays—thousand short tons	4,751	12,979	4,841	13,959	5,005	14,426	5,070	14,816
Coal (bituminous)—do	34,125	127,051	36,790	136,113	37,310	137,776	39,390	146,028
Gem stones	NA	3	NA	3	NA	3	NA	3
Lime—thousand short tons	3,102	43,792	3,207	45,957	3,664	53,308	3,831	53,208
Natural gas—million cubic feet	36,747	9,407	36,817	8,909	[r]37,106	8,880	35,684	8,421
Peat—short tons	7,383	106	6,910	109	6,363	83	5,352	80
Petroleum (crude)—thousand 42-gallon barrels	5,835	18,089	6,039	19,023	15,859	46,420	12,908	37,940
Salt—thousand short tons	4,187	28,706	4,245	29,682	4,537	31,092	5,026	34,816
Sand and gravel—do	35,204	43,333	37,790	44,368	37,771	45,567	40,852	49,305
Stone—do	34,470	57,202	37,537	62,787	[4]37,715	[4]61,814	42,263	66,969
Value of items that cannot be disclosed: Abrasive stone, gypsum, stone (calcareous marl 1964)	XX	1,588	XX	1,742	XX	1,794	XX	2,163
Total	XX	396,055	XX	418,980	XX	454,937	XX	464,252
OKLAHOMA								
Clays[3]—thousand short tons	737	$756	898	$911	835	$854	794	$806
Coal (bituminous)—do	1,048	6,978	1,008	5,667	1,028	5,474	974	5,520
Gypsum—do	509	1,668	531	1,462	694	1,899	761	2,343
Helium, refined—thousand cubic feet	284,214	9,917	237,201	8,302	[r]298,803	[r]8,591	300,992	9,532
Lead (recoverable content of ores, etc.)—short tons	2,710	499	3,192	689	2,781	729	2,813	878
Natural gas—million cubic feet	1,060,717	135,772	1,233,883	160,405	[r]1,316,201	166,747	1,320,995	182,297
Natural gas liquids:								
Natural gasoline and cycle products—thousand gallons	552,795	35,764	555,467	35,131	554,053	34,011	570,129	34,561
LP gases—do	838,903	25,223	810,894	28,981	880,804	28,055	894,665	32,208
Petroleum (crude)—thousand 42-gallon barrels	202,732	591,977	201,962	587,709	202,524	587,320	203,441	587,944
Salt—thousand short tons	5	25	4	26	6	41	9	65
Sand and gravel—do	4,436	4,736	5,420	6,116	6,680	7,003	5,218	6,023
Stone—do	14,666	18,819	13,817	16,160	13,987	15,087	16,417	18,071
Zinc (recoverable content of ores, etc.)—short tons	10,013	2,303	13,245	3,046	12,159	3,307	12,715	3,713
Value of items that cannot be disclosed: Clay (bentonite), cement, copper (1965), gem stones (1962), lime, pumice, silver (1965) and tripoli	XX	20,853	XX	22,929	XX	22,670	XX	23,953
Total	XX	855,290	XX	877,534	XX	[r]881,788	XX	907,914
OREGON								
Clays—thousand short tons	249	$305	279	$330	[r]290	[r]$356	291	$359
Copper (recoverable content of ores, etc.)—short tons	W	W	W	W	15	10	W	W

Diatomite do	50	2	150	3	W	W	W	W
Gold (recoverable content of ores, etc.) troy ounces	822	29	1,809	63	661	23	499	17
Lime thousand short tons	78	1,514	87	1,835	95	1,918	98	1,853
Mercury 76-pound flasks	W	W	W	W	126	40	1,364	779
Nickel (content of ore and concentrate) short tons	13,110	W	13,394	W	15,420	W	16,188	W
Perlite do	3	(5)	----------	----------	5	(5)	----------	----------
Pumice thousand short tons	W	W	422	664	566	909	657	1,181
Sand and gravel do	14,869	14,556	15,715	18,850	18,253	25,158	21,800	32,849
Silver (recoverable content of ores, etc.) thousand troy ounces	6	7	58	74	14	19	9	11
Stone thousand short tons	18,258	20,977	19,692	24,197	16,120	19,296	21,212	27,301
Tungsten concentrate short tons, 60-percent WO_3 basis	----------	----------	----------	----------	1	1	----------	----------
Uranium ore short tons	2,722	112	1,763	45	27	2	----------	----------
Zinc (recoverable content of ores, etc.) do	----------	----------	3	1	W	W	W	W
Value of items that cannot be disclosed: Cement, gem stones, iron ore (pigment material 1963, 1965), lead (1963–65), vanadium (1964), and values indicated by symbol W	XX	14,956	XX	16,630	XX	16,631	XX	18,616
Total	XX	52,458	XX	62,692	XX	r 64,363	XX	82,966
PENNSYLVANIA								
Cement:								
Portland thousand 376-pound barrels	38,463	$127,969	38,316	$118,203	37,663	$113,409	40,153	$116,925
Masonry thousand 280-pound barrels	2,565	7,105	2,510	6,611	2,818	7,594	3,006	7,991
Clays [3] thousand short tons	2,893	12,815	3,191	14,717	3,187	15,814	3,394	17,697
Coal:								
Anthracite do	16,894	134,094	18,267	153,503	17,184	148,648	14,866	122,021
Bituminous do	65,315	331,298	71,501	350,085	76,531	388,218	80,308	407,267
Copper (recoverable content of ores, etc.) short tons	W	W	4,434	2,731	3,614	2,356	4,354	3,083
Gem stones	NA	4	NA	4	NA	4	NA	4
Lime thousand short tons	1,104	16,647	1,188	17,548	1,440	20,656	1,568	22,496
Natural gas million cubic feet	90,053	24,494	92,657	24,091	r 81,720	22,349	84,461	22,551
Natural gas liquids:								
Natural gasoline thousand gallons	1,350	75	1,311	78	1,138	64	1,022	55
LP gases do	1,521	112	1,721	118	1,481	100	1,683	109
Peat short tons	32,936	369	33,952	339	39,500	397	45,600	527
Petroleum (crude) thousand 42-gallon barrels	5,302	24,230	5,083	23,178	5,113	22,088	4,922	21,263
Sand and gravel thousand short tons	14,419	23,587	14,066	23,539	16,199	26,414	18,502	29,606
Stone do	48,144	82,087	49,536	83,450	52,829	91,075	56,806	99,627
Zinc (recoverable content of ores, etc.) [11] short tons	24,308	5,652	27,389	6,572	30,754	8,345	27,635	8,014
Value of items that cannot be disclosed: Clay (kaolin), cobalt, gold, iron ore, scrap mica, pyrites, pyrophyllite, silver, tripoli, and values indicated by symbol W	XX	32,966	XX	32,644	XX	34,519	XX	34,587
Total	XX	823,504	XX	857,411	XX	902,050	XX	913,823
RHODE ISLAND								
Gem stones	NA	W	NA	$1	NA	W	NA	W
Sand and gravel thousand short tons	2,346	$1,890	1,750	1,838	1,647	$1,613	1,681	$1,811
Stone do	[4] 304	[4] 483	442	968	450	935	437	1,119
Value of items that cannot be disclosed: Nonmetals and values indicated by symbol W	XX	621	XX	----------	XX	1	XX	1
Total	XX	2,994	XX	2,807	XX	2,549	XX	2,931

Table 5.—Mineral production [1] in the United States, by States—Continued

Mineral	1962 Quantity	1962 Value (thousands)	1963 Quantity	1963 Value (thousands)	1964 Quantity	1964 Value (thousands)	1965 Quantity	1965 Value (thousands)
SOUTH CAROLINA								
Clays ____ thousand short tons__	1,518	$7,165	1,491	$7,589	1,743	$8,309	1,837	$8,539
Sand and gravel ____ do____	3,318	3,670	4,051	4,750	4,622	5,262	5,248	6,688
Stone ____ do____	6,382	10,066	7,262	10,926	[4] 6,109	[4] 9,176	[4] 5,948	[4] 8,447
Value of items that cannot be disclosed: Barite, cement, feldspar, gem stones (1962–63), kyanite, scrap mica, peat, pyrites, stone (crushed limestone 1964–65 and dimension granite 1965), and vermiculite ____	XX	13,000	XX	13,214	XX	15,966	XX	17,587
Total ____	XX	33,901	XX	36,479	XX	38,713	XX	41,261
SOUTH DAKOTA								
Beryllium concentrate ____ short tons, gross weight__	144	$77	(5)	(5)	W	W	W	W
Cement:								
Portland ____ thousand 376-pound barrels__	2,316	7,369	1,869	$5,909	2,001	$6,873	1,575	$5,127
Masonry ____ thousand 280-pound barrels__	60	197	60	198	57	200	55	180
Clays ____ thousand short tons__	249	690	240	960	245	1,076	223	1,220
Coal (lignite) ____ do____	18	77	16	62	13	63	10	49
Copper (recoverable content of ores, etc.) ____ short tons__	----	----	1	(5)	----	----	----	----
Feldspar ____ long tons__	29,697	191	25,590	157	26,980	180	51,560	346
Gem stones ____	NA	20	NA	20	NA	20	NA	20
Gold (recoverable content of ores, etc.) ____ troy ounces__	577,232	20,203	576,726	20,185	616,913	21,592	628,259	21,989
Gypsum ____ thousand short tons__	23	93	24	97	19	76	7	27
Iron ore (usable) ____ thousand long tons__	34	113	----	----	----	----	----	----
Lead (recoverable content of ores, etc.) ____ short tons__	3	1	4	1	----	----	----	----
Lithium minerals ____ do____	W	W	W	W	W	W	150	[e] 5
Mica:								
Scrap ____ do____	210	6	W	W	996	32	W	W
Sheet ____ pounds__	2,085	12	10,000	(5)	----	----	----	----
Petroleum (crude) ____ thousand 42-gallon barrels__	169	W	215	428	247	495	219	438
Sand and gravel ____ thousand short tons__	15,371	9,207	20,806	16,313	13,770	13,641	13,998	14,155
Silver (recoverable content of ores, etc.) thousand troy ounces__	113	123	117	150	133	172	129	167
Stone ____ thousand short tons__	2,852	6,533	2,794	7,339	2,118	6,245	1,554	5,387
Uranium ore ____ short tons__	29,452	370	72,088	1,931	110,147	1,551	44,738	303
Value of items that cannot be disclosed: Lime, molybdenum (1964–65), vanadium, and values indicated by symbol W___	XX	505	XX	366	XX	608	XX	762
Total ____	XX	45,787	XX	54,116	XX	52,824	XX	50,175
TENNESSEE								
Barite ____ thousand short tons__	14	$229	24	$404	39	$519	31	$442
Cement:								
Portland ____ thousand 376-pound barrels__	8,509	27,741	8,283	26,760	8,343	26,791	8,724	27,535
Masonry ____ thousand 280-pound barrels__	1,089	2,931	1,161	3,079	1,212	3,228	1,185	3,140

Clays thousand short tons	[3] 1,037	[3] 4,597	[3] 1,238	[3] 5,248	[3] 1,310	[3] 5,576	1,495	6,103
Coal (bituminous) do	6,214	22,555	6,121	22,689	5,990	22,674	5,865	20,930
Copper (recoverable content of ores, etc.) short tons	14,298	8,808	13,717	8,450	13,889	9,056	14,823	10,495
Gem stones	NA	1	NA	(5)	----------	----------	----------	----------
Gold (recoverable content of ores, etc.) troy ounces	158	6	137	5	133	5	122	4
Lead (recoverable content of ores, etc.) short tons	51	9	----------	----------	----------	----------	----------	----------
Natural gas million cubic feet	75	14	90	17	77	15	85	16
Petroleum (crude) thousand 42-gallon barrels	14	W	16	W	10	W	11	W
Phosphate rock thousand long tons	2,418	19,868	2,352	17,876	2,441	18,971	2,637	22,296
Sand and gravel thousand short tons	6,075	8,018	7,613	9,443	7,972	10,245	8,193	10,690
Silver (recoverable content of ores, etc.) thousand troy ounces	112	122	108	138	91	117	94	122
Stone thousand short tons	24,398	35,614	26,825	38,113	[4] 26,497	[4] 38,239	[4] 28,888	[4] 38,859
Zinc (recoverable content of ores, etc.) short tons	71,548	16,456	95,847	22,045	115,943	31,536	122,387	35,737
Value of items that cannot be disclosed: Clay (fuller's earth 1962–64), iron ore (1962–63), lime, pyrites, stone (crushed sandstone 1964–65), and values indicated by symbol W	XX	7,050	XX	6,458	XX	6,993	XX	6,572
Total	XX	154,019	XX	160,725	XX	173,965	XX	182,941

TEXAS

Cement:								
Portland thousand 376-pound barrels	26,204	$83,162	29,104	$92,734	30,030	$94,492	30,820	$97,598
Masonry thousand 280-pound barrels	926	2,774	930	2,858	930	2,805	968	3,011
Clays thousand short tons	[3] 3,744	[3] 5,634	[3] 4,199	[3] 6,849	[3] 4,156	[3] 6,695	4,469	6,865
Gem stones	NA	150	NA	150	NA	140	NA	150
Gypsum thousand short tons	1,120	3,956	1,099	3,999	1,131	4,049	1,045	3,794
Helium [9] thousand cubic feet	245,623	8,552	264,342	9,252	r 1,385,251	r 21,488	1,354,704	21,728
Lime thousand short tons	1,046	11,999	1,131	13,026	1,350	17,201	1,338	19,663
Natural gas million cubic feet	6,080,210	747,866	6,205,034	775,629	r 6,490,202	809,180	6,636,555	858,396
Natural gas liquids:								
Natural gasoline and cycle products thousand gallons	3,205,517	233,345	3,320,416	218,975	3,512,460	232,245	3,772,471	256,959
LP gases do	5,012,291	189,382	5,366,831	169,695	5,521,236	167,492	5,847,601	204,666
Perlite short tons	----------	----------	----------	----------	300	3	1,000	8
Petroleum (crude) thousand 42-gallon barrels	943,328	2,818,709	977,835	2,908,380	989,525	2,928,994	1,000,749	2,962,119
Salt thousand short tons	5,553	19,485	5,965	22,355	6,410	28,797	6,964	30,771
Sand and gravel do	30,076	33,097	33,256	36,311	29,155	33,394	32,649	36,075
Stone do	38,067	48,988	43,142	54,007	40,240	52,070	39,520	53,659
Sulfur (Frasch process) thousand long tons	2,655	57,297	2,550	50,109	r 3,302	r 65,780	3,674	74,955
Talc and soapstone short tons	73,635	387	72,658	368	89,334	395	64,211	204
Values of items that cannot be disclosed: Native asphalt, barite, bromine, clays (fuller's earth, kaolin 1964), coal (lignite), graphite, iron ore, magnesium chloride (for metal), magnesium compounds (except for metal), mercury (1965), pumice, sodium sulfate, and uranium ore	XX	58,774	XX	62,777	XX	r 83,604	XX	78,088
Total	XX	4,323,557	XX	4,427,474	XX	r 4,548,824	XX	4,708,709

UTAH

Carbon dioxide, natural thousand cubic feet	81,920	$6	100,895	$7	96,432	$7	86,201	$6
Clays thousand short tons	174	1,403	[3] 125	[3] 470	127	[3] 330	[3] 149	[3] 332
Coal (bituminous) do	4,297	23,209	4,360	22,755	4,720	33,184	4,992	31,811
Copper (recoverable content of ores, etc.) short tons	218,018	134,299	203,095	125,107	199,588	130,131	259,138	183,470

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Table 5.—Mineral production [1] in the United States, by States—Continued

Mineral	1962 Quantity	1962 Value (thousands)	1963 Quantity	1963 Value (thousands)	1964 Quantity	1964 Value (thousands)	1965 Quantity	1965 Value (thousands)
UTAH—Continued								
Fluorspar short tons	399	$12	247	$7	W	W	W	W
Gem stones	NA	75	NA	75	NA	$75	NA	$75
Gold (recoverable content of ores, etc.) troy ounces	311,924	10,917	285,907	10,007	287,674	10,069	426,299	14,921
Iron ore (usable) thousand long tons, gross weight	2,630	18,242	1,881	12,900	2,082	14,306	2,139	14,229
Lead (recoverable content of ores, etc.) short tons	38,199	7,029	45,028	9,726	40,249	10,545	37,700	11,762
Lime thousand short tons	163	2,759	156	2,668	163	2,917	189	3,470
Natural gas million cubic feet	74,128	12,454	77,122	14,036	[r] 79,739	10,904	71,616	8,952
Perlite short tons	929	3	1,313	7	2,003	12	W	W
Petroleum (crude) thousand 42-gallon barrels	31,029	85,019	33,435	90,943	28,575	74,867	25,298	66,045
Pumice thousand short tons	28	46	28	46	W	W	W	W
Salt do	311	3,349	325	3,462	371	3,848	384	3,591
Sand and gravel do	19,941	20,954	11,709	10,408	10,218	10,405	[8] 10,032	[8] 10,464
Silver (recoverable content of ores, etc.) thousand troy ounces	4,628	5,022	4,791	6,128	4,552	5,886	5,636	7,287
Stone thousand short tons	2,118	3,865	2,346	4,040	3,105	6,930	2,158	4,552
Sulfur ore long tons, gross weight	---	---	---	---	---	---	2,156	3
Uranium ore short tons	781,955	23,653	743,792	23,852	761,180	26,385	377,989	9,014
Vanadium (recoverable in ore and concentrate) do	525	W	382	W	405	1,214	387	1,353
Zinc (recoverable content of ores, etc.) do	34,313	7,892	36,179	8,321	31,428	8,548	27,747	8,102
Value of items that cannot be disclosed: Asphalt (gilsonite), barite (1962), beryllium (1963), cement, clays (fire clay 1963–65, kaolin 1965), gypsum, molybdenum, natural gas liquids, phosphate rock, potassium salts, and values indicated by symbol W	XX	50,382	XX	40,458	XX	40,867	XX	51,939
Total	XX	410,590	XX	385,423	XX	391,430	XX	431,378
VERMONT								
Gem stones	NA	$2	NA	W	NA	W	NA	W
Peat short tons	---	---	---	---	286	$4	780	$3
Sand and gravel thousand short tons	1,430	1,076	2,375	$1,410	1,764	$1,494	2,084	1,670
Stone do	1,715	19,815	2,159	19,193	2,070	20,652	2,591	21,564
Value of items that cannot be disclosed: Asbestos, clays, lime, talc, and values indicated by symbol W	XX	4,237	XX	3,788	XX	3,977	XX	4,155
Total	XX	25,130	XX	24,391	XX	26,127	XX	27,392
VIRGINIA								
Aplite long tons	125,156	$912	W	W	W	W	W	W
Clays thousand short tons	1,464	1,444	1,410	$1,558	1,440	$1,614	1,415	$1,657
Coal (bituminous) do	29,474	117,560	30,531	120,972	31,654	123,123	34,053	139,291
Gem stones	NA	6	NA	6	NA	6	NA	7
Lead (recoverable content of ores, etc.) short tons	4,059	747	3,500	756	3,857	1,010	3,651	1,139
Lime thousand short tons	615	7,668	639	8,058	780	9,781	847	10,584
Natural gas million cubic feet	2,499	677	2,085	488	[r] 1,600	479	3,152	942

Petroleum (crude)____thousand 42-gallon barrels__	3	W	3	W	6	W	4	W
Sand and gravel____thousand short tons__	9,745	16,375	10,400	17,752	10,588	13,722	15,322	18,019
Soapstone____short tons__	W	W	3,696	9	3,775	9	3,549	9
Stone____thousand short tons__	25,766	43,121	27,653	45,529	30,407	52,153	36,350	59,397
Zinc (recoverable content of ores, etc.) [11]____short tons__	26,479	6,141	23,988	5,725	21,004	5,700	20,491	5,942
Value of items that cannot be disclosed: Cement, feldspar, gypsum, iron ore (pigment materials), kyanite, pyrites (1962), salt, titanium concentrate, and values indicated by symbol W____	XX	27,843	XX	28,211	XX	29,818	XX	30,990
Total____	XX	222,494	XX	229,064	XX	237,415	XX	267,977
WASHINGTON								
Barite____thousand short tons__	W	W	----------	----------	----------	----------	([5])	$1
Carbon dioxide____thousand cubic feet__	W	W	W	W	W	W	11,848	3
Cement:								
Portland____thousand 376-pound barrels__	W	W	W	W	W	W	6,258	22,351
Masonry____thousand 280-pound barrels__	W	W	W	W	W	W	62	201
Clay[3]____thousand short tons__	103	$100	134	$123	128	$119	162	211
Coal (bituminous)____do____	235	1,630	190	1,380	68	575	55	497
Copper (recoverable content of ores, etc.)____short tons__	41	25	W	W	35	23	30	21
Lead (recoverable content of ores, etc.)____do____	6,033	1,110	5,374	1,161	5,731	1,502	6,328	1,974
Peat____do____	41,962	288	37,248	188	35,609	170	29,729	131
Pumice____thousand short tons__	10	130	W	W	W	W	W	W
Sand and gravel____do____	19,580	18,145	22,760	20,490	31,920	25,971	31,301	27,234
Stone____do____	12,749	18,180	12,934	16,846	[r] 10,498	[r] 15,204	12,461	17,446
Talc and soapstone____short tons__	2,835	11	2,969	18	2,680	18	2,861	17
Uranium ore____do____	110,948	2,050	117,286	2,545	147,005	3,601	73,495	1,871
Zinc (recoverable content of ores, etc.)____do____	21,644	4,978	22,270	5,122	24,296	6,609	22,230	6,491
Value of items that cannot be disclosed: Abrasive stones (1962–63), clays (fire clay, bentonite 1965), diatomite, epsom salts (1962–63), gem stones, gold, gypsum (1962), lime (1963–65), magnesite, mercury (1965), olivine, silver, tungsten (1965), and values indicated by symbol W____	XX	21,827	XX	24,057	XX	27,518	XX	7,723
Total____	XX	68,474	XX	71,430	XX	[r] 81,310	XX	86,172
WEST VIRGINIA								
Clays____thousand short tons__	447	$2,086	414	$2,044	[3] 261	[3] $309	[3] 289	[3] $328
Coal (bituminous)____do____	118,499	578,293	132,568	634,794	141,409	693,572	149,191	726,096
Natural gas____million cubic feet__	210,698	57,942	210,223	55,919	[r] 202,765	50,968	207,416	48,743
Natural gas liquids:								
Natural gasoline____thousand gallons__	32,921	2,216	W	W	W	W	W	W
LP gases____do____	344,969	17,475	W	W	W	W	W	W
Petroleum (crude)____thousand 42-gallon barrels__	3,470	13,880	3,350	13,367	3,370	12,975	3,530	13,591
Salt____thousand short tons__	1,042	4,635	W	W	1,033	3,666	1,153	5,539
Sand and gravel____do____	5,202	10,942	4,808	10,578	5,472	11,555	5,253	11,480
Stone [4]____do____	7,506	13,242	9,452	14,489	7,481	13,105	8,482	14,587
Value of items that cannot be disclosed: Calcium-magnesium chloride, cement, clay (fire clay 1964–65), gem stones, lime, stone (dimension sandstone) and values indicated by symbol W____	XX	14,753	XX	37,051	XX	36,541	XX	39,240
Total____	XX	715,464	XX	768,242	XX	822,691	XX	859,604

Table 5.—Mineral production [1] in the United States, by States—Continued

Mineral	1962 Quantity	1962 Value (thousands)	1963 Quantity	1963 Value (thousands)	1964 Quantity	1964 Value (thousands)	1965 Quantity	1965 Value (thousands)
WISCONSIN								
Abrasive stones ______ short tons	[12] 569	[12] $17	[13] 561	[13] $21	W	W	W	W
Clays ______ thousand short tons	137	156	111	140	119	$147	119	$147
Iron ore (usable) ______ thousand long tons, gross weight	1,045	W	938	W	524	W	141	W
Lead (recoverable content of ores, etc.) ______ short tons	1,394	256	1,116	241	1,742	456	1,645	513
Lime ______ thousand short tons	W	W	W	W	W	W	197	3,076
Peat ______ short tons	W	W	2,667	136	3,261	136	3,090	122
Sand and gravel ______ thousand short tons	33,649	24,408	35,363	24,863	34,348	24,695	38,751	27,707
Stone ______ do	13,392	19,709	13,583	18,744	13,901	20,232	15,344	21,924
Zinc (recoverable content of ores, etc.) ______ short tons	13,292	3,057	15,114	3,476	26,278	7,148	26,993	7,882
Value of items that cannot be disclosed: Abrasive stones (tube-mill liners, 1963), cement, gem stones, and values indicated by symbol W	XX	20,686	XX	19,220	XX	17,193	XX	11,628
Total	XX	68,289	XX	66,841	XX	70,007	XX	72,999
WYOMING								
Beryllium concentrate ______ short tons, gross weight	1	(5)	(5)	(5)	W	W	W	W
Clays ______ thousand short tons	1,141	$11,138	1,187	$12,385	1,271	$12,816	1,352	$13,633
Coal (bituminous) ______ do	2,569	8,198	3,124	9,922	3,101	9,774	3,260	10,150
Copper (recoverable content of ores, etc.) ______ short tons	----	----	----	----	5	3	6	4
Gem stones	NA	85	NA	110	NA	120	NA	120
Gold (recoverable content of ores, etc.) ______ troy ounces	----	----	4	(5)	6	(5)	3	(5)
Iron ore (usable) ______ thousand long tons, gross weight	739	6,441	1,604	17,504	2,056	24,543	2,087	25,198
Natural gas ______ million cubic feet	204,996	29,929	209,060	29,687	[r] 281,613	29,808	285,849	31,840
Natural gas liquids:								
Natural gasoline ______ thousand gallons	78,780	4,935	86,014	5,523	86,803	5,607	95,093	6,195
LP gases ______ do	149,438	5,762	150,437	6,203	152,982	6,438	148,331	6,020
Petroleum (crude) ______ thousand 42-gallon barrels	135,847	338,259	144,407	361,018	138,752	351,043	138,314	345,785
Pumice ______ thousand short tons	42	41	W	W	W	W	----	----
Sand and gravel ______ do	7,769	8,104	7,901	7,874	5,632	5,936	7,996	8,373
Stone ______ do	1,755	3,054	1,940	2,991	2,154	3,671	1,594	2,791
Uranium ore ______ short tons	1,301,784	25,715	1,173,420	23,849	[3] 1,183,754	[3] 23,321	1,048,176	17,758
Vanadium (recoverable in ore and concentrate) ______ do	W	442	W	435	W	359	W	444
Value of items that cannot be disclosed: Cement, feldspar (1965), gypsum, lime, phosphate rock, silver (1964–65), sodium carbonates and sulfates, vermiculite (1962–63), and values indicated by symbol W	XX	20,467	XX	24,736	XX	26,822	XX	30,241
Total	XX	462,570	XX	502,237	XX	[3] 500,256	XX	498,552

[e] Estimate. [r] Revised. NA Not available. W Withheld to avoid disclosing individual company confidential data; included with "Value of items that cannot be disclosed." XX Not applicable.

[1] Production as measured by mine shipments, sales, or marketable production (including consumption by producers).

[2] Excludes certain cement, included with "Value of items that cannot be disclosed."

[3] Excludes certain clays, included with "Value of items that cannot be disclosed."

[4] Excludes certain stone, included with "Value of items that cannot be disclosed."

[5] Less than ½ unit.

[6] Includes 760 tons of low-grade beryllium ore in 1962, and 750 tons in 1963.
[7] Excludes shipments from Nye Metals, Inc., included with "Value of items that cannot be disclosed."
[8] Final figure, supersedes figure given in commodity chapter.
[9] Refined only, 1962–63; crude and refined, 1964–65.
[10] Excludes salt in brine, included with "Value of items that cannot be disclosed."
[11] Recoverable zinc valued at the yearly average price of Prime Western slab zinc, East St. Louis market. Represents value established after transportation, smelting and manufacturing charges have been added to the value of ore at mine.
[12] Grinding pebbles and tube-mill liners.
[13] Grinding pebbles; tube-mill liners included with "Value of items that cannot be disclosed."

Table 6.—Mineral production[1] in the Canal Zone and islands administered by the United States[2]

Mineral	1962		1963		1964		1965	
	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)
American Samoa:								
Pumice .... thousand short tons..	50	$108						
Sand and gravel .... do....	3	4	77	$193	22	$20	60	$55
Stone .... do....	1,103	1,788	944	2,351	157	234	60	60
Total	XX	1,900	XX	2,544	XX	254	XX	115
Canal Zone:								
Sand and gravel .... thousand short tons..	70	77	84	87	84	82	83	85
Stone (crushed) .... do....	207	359	162	281	153	349	153	366
Total	XX	436	XX	368	XX	431	XX	451
Canton: Stone (crushed) .... thousand short tons..	(3)	(3)	2	6				
Guam: Stone .... do....	82	123	307	439	469	868	483	925
Virgin Islands: Stone (crushed) .... do....	21	82	66	329	69	342	68	302
Wake: Stone (crushed) .... do....	5	41	9	51	2	5	1	4

XX Not applicable.
[1] Production as measured by mine shipments, sales, or marketable production (including consumption by producers).
[2] Production data for Canton and Wake furnished by U.S. Department of Commerce, Civil Aeronautics Administration; Guam, by the Government of Guam; American Samoa, by the Government of American Samoa.
[3] Less than ½ unit.

Table 7.—Mineral production [1] in the Commonwealth of Puerto Rico

Mineral	1962		1963		1964		1965	
	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)
Cement..........thousand 376-pound barrels..	6,347	$20,018	7,217	$22,090	7,926	$23,879	7,284	$23,415
Clays..........thousand short tons..	219	131	200	158	341	271	357	288
Lime..........do....	1	14	4	103	18	574	27	867
Salt..........do....	----------	----------	8	181	5	74	8	138
Sand and gravel..........do....	7,378	9,793	7,616	10,407	7,816	11,492	8,147	12,405
Stone..........do....	5,589	8,551	5,334	8,237	5,504	8,586	5,344	9,111
Total..........	XX	38,507	XX	41,126	XX	44,876	XX	46,224

XX Not applicable.

[1] Production as measured by mine shipments, sales, or marketable production (including consumption by producers).

Table 8.—U.S. exports of principal minerals and products

Mineral	1964 Quantity	1964 Value (thousands)	1965 Quantity	1965 Value (thousands)
Metals:				
Aluminum:				
Ingots, slabs, crude .... short tons..	208,622	$92,227	203,642	$92,533
Scrap .... do....	68,615	21,476	38,547	12,452
Plates, sheets, bars, etc .... do....	69,761	50,982	65,172	51,323
Castings and forgings .... do....	1,832	4,671	2,256	6,669
Antimony: Metals and alloys, crude .... do....	401	223	14	18
Arsenic: Calcium arsenate .... pounds..	1,537,484	96	NA	NA
Bauxite, including bauxite concentrates long tons..	[r] 278,812	[r] 22,211	146,830	10,736
Aluminum sulfate .... short tons..	16,511	531	15,641	501
Other aluminum compounds .... do....	240,581	23,334	386,590	31,430
Beryllium .... pounds..	170,699	630	119,761	624
Bismuth: Metals and alloys .... do....	[r] 61,299	[r] 102	341,868	940
Cadmium .... thousand pounds..	1,439	4,033	[1] 73	[1] 195
Calcium chloride .... short tons..	39,893	1,513	NA	NA
Chrome:				
Ore and concentrate:				
Exports .... do....	6,366	241	7,047	285
Reexports .... do....	32,116	1,256	94,963	3,719
Chromic acid .... do....	891	523	999	574
Ferrochrome .... do....	10,032	2,504	12,002	3,021
Cobalt .... pounds..	1,453,107	2,002	1,441,187	2,097
Columbium metals, alloys, and other forms ... do....	348,107	610	4,217	177
Copper:				
Ore, concentrate, composition metal, and unrefined copper (copper content) short tons..	5,395	2,971	15,510	8,369
Refined copper and semimanufactures ... do....	381,432	262,741	379,498	317,338
Other copper manufactures .... do....	4,470	3,668	5,805	5,436
Copper sulfate or blue vitriol .... do....	1,087	275	2,135	1,288
Copper base alloys .... do....	80,613	56,705	80,049	70,116
Ferroalloys:				
Ferrosilicon .... do....	5,785	1,232	4,585	1,755
Ferrophosphorus .... pounds..	326,332,849	4,938	159,820,667	2,914
Gold:				
Ore and base bullion .... troy ounces..	21,566	755	49,836	1,744
Bullion, refined .... do....	12,056,841	421,989	36,667,207	1,283,352
Iron ore .... thousand long tons..	6,963	79,670	7,085	80,418
Iron and steel:				
Pig iron .... short tons..	176,056	10,275	28,225	1,665
Iron and steel products (major):				
Semimanufactures .... do....	[r] 2,800,935	[r] 440,485	1,935,571	351,212
Manufactured steel mill products ... do....	1,264,427	440,549	952,664	397,379
Advanced products .... do....	NA	206,378	NA	201,810
Iron and steel scrap: Ferrous scrap, including rerolling materials .... short tons..	[r] 7,898,473	[r] 243,333	6,248,728	199,744
Lead:				
Ore, matte, base bullion (lead content) ... do....	19	4	NA	NA
Pigs, bars, anodes .... do....	10,175	2,813	7,811	3,714
Scrap .... do....	13,148	2,384	3,793	757
Magnesium:				
Metal and alloys and semimanufactured forms, n.e.c .... short tons..	16,811	10,202	18,320	11,525
Powder .... do....	8	29	NA	NA
Manganese:				
Ore and concentrate .... do....	14,444	1,451	14,150	1,387
Ferromanganese .... do....	3,903	670	3,273	727
Mercury:				
Exports .... 76-pound flasks..	188	52	7,543	5,031
Reexports .... do....	196	50	494	316
Molybdenum:				
Ore and concentrates (molybdenum content) .... pounds..	24,939,780	40,987	24,095,858	44,282
Metals and alloys, crude and scrap ... do....	1,404,502	3,630	110,709	414
Wire .... do....	30,903	500	23,414	631
Semifabricated forms, n.e.c .... do....	34,950	290	66,366	516
Powder .... do....	[r] 302,024	[r] 1,176	602,759	2,095
Ferromolybdenum .... do....	1,745,611	3,328	2,242,275	4,577
Nickel:				
Ore .... short tons..	8	3	NA	NA
Alloys and scrap (including Monel metal), ingots, bars, sheets, etc .... short tons..	66,108	35,412	16,552	26,437
Catalysts .... do....	1,002	2,013	2,547	6,063
Nickel-chrome electric resistance wire ... do....	445	1,929	380	1,914
Semifabricated forms, n.e.c .... do....	939	4,754	1,455	6,114
Platinum:				
Ore, concentrate, metal and alloys in ingots, bars, sheets, anodes, and other forms, including scrap .... troy ounces..	125,139	9,842	72,925	9,838

Table 8.—U.S. exports of principal minerals and products—Continued

Mineral	1964 Quantity	1964 Value (thousands)	1965 Quantity	1965 Value (thousands)
Metals—Continued				
Platinum—Continued				
Palladium, rhodium, iridium, osmiridium, ruthenium, and osmium (metal and alloys including scrap) ---- troy ounces--	21,167	$1,363	30,172	$3,758
Platinum group manufactures, except jewelry-	NA	5,083	NA	2,515
Radium metal (radium content) ---- milligrams--	177	2	NA	NA
Rare earths:				
Cerium ore, metal, and alloys ---- pounds--	1,637,142	400	54,151	221
Lighter flints ---- do----	37,455	139		
Silver:				
Ore and base bullion-thousand troy ounces--	r 649	r 840	537	697
Bullion, refined ---- do----	r 108,746	r 140,557	39,128	50,727
Tantalum:				
Ore, metal, and other forms ---- pounds--	232,282	1,211	304,409	1,656
Powder ---- do----	32,217	574	24,662	757
Tin:				
Ingots, pigs, bars, etc:				
Exports ---- long tons--	2,726	9,241	2,605	10,078
Reexports ---- do----	1,315	6,225	224	880
Tin scrap and other tin-bearing material except tinplate scrap ---- long tons--	4,844	2,151	1,354	1,220
Tin cans, finished or unfinished ---- do----	23,963	14,244	NA	NA
Titanium:				
Ore and concentrate ---- short tons--	2,161	386	1,201	203
Sponge (including iodide titanium) and scrap ---- short tons--	1,817	1,781	2,132	2,070
Intermediate mill shapes ---- do----	790	3,696	605	5,144
Mill products, n.e.c ---- do----	75	1,302		
Ferrotitanium ---- do----	541	392	NA	NA
Dioxide and pigments ---- do----	29,359	8,287	26,896	7,249
Tungsten: Ore and concentrate:				
Exports ---- do----	77	145	11	18
Reexports ---- do----	150	122	261	181
Vanadium ore and concentrate, pentoxide, etc. (vanadium content) ---- pounds--	2,461,193	3,620	1,856,096	3,540
Zinc:				
Ore and concentrate (zinc content) short tons--	39	12	NA	NA
Slabs, pigs, or blocks ---- do----	26,515	7,240	5,939	1,765
Sheets, plates, strips, or other forms, n.e.c short tons--	6,569	3,978	5,120	3,051
Scrap (zinc content) ---- do----	6,448	1,379	5,617	1,153
Dust ---- do----	1,828	542	NA	NA
Semifabricated forms, n.e.c ---- do----	5,666	2,451	2,764	1,931
Zirconium:				
Ore and concentrate ---- do----	2,500	352	1,761	287
Metals and alloys and other forms ---- pounds--	533,449	3,191	213,326	1,933
Nonmetals:				
Abrasives:				
Grindstones ---- short tons--	179	48	NA	NA
Diamond dust and powder ---- carats--	1,892,097	4,097	1,147,838	3,268
Diamond grinding wheels ---- do----	405,328	2,709	382,605	3,053
Other natural and artificial metallic abrasives and products ----	NA	r 36,601	NA	42,754
Asbestos: Unmanufactured:				
Exports ---- short tons--	26,819	3,162	42,995	5,270
Reexports ---- do----	328	37	131	23
Boron: Boric acid, borates, crude and refined pounds--	766,200,586	31,289	348,033,874	16,922
Bromine, bromides, and bromates ---- do----	17,036,442	3,437	NA	NA
Cement ---- 376-pound barrels--	712,678	3,290	748,440	4,288
Clays:				
Kaolin or china clay ---- short tons--	151,725	4,671	192,875	6,244
Fire clay ---- do----	246,796	5,596	182,446	3,667
Other clays ---- do----	449,537	14,706	474,443	15,828
Cryolite ---- do----	3,385	744	NA	NA
Fluorspar ---- do----	3,702	158	9,429	395
Graphite:				
Amorphous ---- do----	1,326	194		
Crystalline flake, lump, or chip ---- do----	229	62	3,196	419
Natural, n.e.c ---- do----	409	77		
Gypsum:				
Crude, crushed or calcined thousand short tons--	21	829	28	1,112
Manufactures, n.e.c ----	NA	979	NA	920
Iodine, iodide, iodates ---- thousand pounds--	147	343	NA	NA
Kyanite and allied minerals ---- short tons--	6,080	393	10,238	732
Lime ---- do----	29,858	777	40,036	942

Table 8.—U.S. exports of principal minerals and products—Continued

Mineral	1964 Quantity	1964 Value (thousands)	1965 Quantity	1965 Value (thousands)
Nonmetals—Continued				
Mica:				
Unmanufactured ---- pounds --	542,516	$161	7,802,539	$589
Manufactured:				
Ground or pulverized ---- do ----	8,263,497	478		
Other ---- do ----	281,131	946	523,338	1,635
Mineral-earth pigments: Iron oxide, natural and manufactured ---- short tons --	5,097	1,817	4,656	1,380
Nitrogen compounds (major) ---- do ----	1,182,425	67,636	1,637,752	88,421
Phosphate rock ---- long tons --	5,652,573	52,630	6,653,602	65,632
Phosphatic fertilizers (superphosphates) ---- do ----	707,943	33,259	528,137	29,504
Pigments and compounds (lead and zinc):				
Lead pigments ---- short tons --	1,680	608	2,286	890
Zinc pigments ---- do ----	3,619	899	3,269	1,005
Lead compounds ---- do ----	936	278	NA	NA
Potash:				
Fertilizer ---- do ----	1,026,446	32,563	1,052,305	33,809
Chemical ---- do ----	22,033	5,024	46,289	8,685
Quartz crystal (raw) ----	NA	558	NA	848
Radioactive isotopes, etc ---- curie --	388,112	2,919	513,038	2,816
Salt:				
Crude and refined ---- short tons --	594,318	3,373	688,418	4,285
Shipments to noncontiguous Territories do ----	13,966	1,174	16,755	1,263
Sodium and sodium compounds:				
Sodium sulfate ---- do ----	43,545	1,320	12,808	415
Sodium carbonate ---- thousand short tons --	r 276	r 8,535	277	9,030
Stone:				
Limestone, crushed, ground, broken short tons --	1,369,728	2,079	1,165,327	2,905
Marble and other building and monumental cubic feet --	441,312	2,027	517,843	3,290
Stone, crushed, ground, broken -- short tons --	105,504	2,013	73,096	1,955
Manufactures of stone ----	NA	677	NA	1,480
Sulfur:				
Crude ---- long tons --	1,920,392	39,651	2,624,052	64,278
Crushed, ground, flowers of ---- do ----	7,700	1,287	27,683	1,271
Talc:				
Crude and ground ---- short tons --	73,998	3,316	69,597	3,486
Manufactures, n.e.c ---- do ----	128	75	NA	4,045
Powders-talcum (face and compact) ----	NA	1,068		
Fuels:				
Carbon black ---- thousand pounds --	333,907	31,929	274,608	26,658
Coal:				
Anthracite ---- short tons --	1,575,097	22,060	850,630	11,488
Bituminous ---- do ----	47,969,423	441,216	50,181,361	465,314
Briquets ---- do ----	17,857	210	88,506	1,149
Coke ---- do ----	523,695	10,093	833,668	16,307
Petroleum:				
Crude ---- thousand barrels --	1,361	3,806	1,004	2,841
Gasoline ---- do ----	5,295	31,877	3,820	24,371
Jet fuel ---- do ----	169	652	154	621
Naphtha ---- do ----	1,830	18,193	1,545	16,842
Kerosine ---- do ----	160	1,240	166	1,275
Distillate oil ---- do ----	6,507	20,498	5,042	17,576
Residual oil ---- do ----	19,135	41,853	14,997	33,509
Lubricating oil ---- do ----	r 16,177	r 197,420	14,191	165,135
Asphalt ---- do ----	614	4,909	450	2,827
Liquefied petroleum gases ---- do ----	5,365	14,836	7,511	27,231
Wax ---- do ----	1,736	32,849	1,646	30,072
Coke ---- do ----	13,618	45,491	13,263	42,027
Petrochemical feedstocks ---- do ----	716	8,501	1,944	11,700
Miscellaneous ---- do ----	r 1,363	r 22,121	1,333	20,086

r Revised. NA Not available.

[1] Not strictly comparable to preceding years.

[2] Excludes 10,275 pounds of spent catalysts, valued at $12,272 and 171,152 pounds of residues, valued at $17,980.

Table 9.—U.S. imports for consumption of principal minerals and products

Mineral	1964 Quantity	1964 Value (thousands)	1965 Quantity	1965 Value (thousands)
Metals:				
Aluminum:				
Metal____short tons__	394,563	$163,419	527,252	$218,217
Scrap____do____	8,152	2,038	27,029	8,482
Plates, sheets, bars, etc____do____	50,542	r 30,376	66,484	38,993
Antimony:				
Ore (antimony content)____do____	10,676	3,294	10,360	4,310
Needle or liquated____do____	31	21	23	18
Metal____do____	3,307	2,481	2,650	2,112
Oxide____do____	3,131	3,022	2,173	1,798
Arsenic: White (As_2O_3 content)____do____	18,185	1,383	15,525	1,271
Bauxite: Crude____thousand long tons__	r 10,180	128,787	11,400	142,989
Beryllium ore____short tons__	5,425	1,372	7,791	2,056
Bismuth (general imports)____pounds__	1,238,252	2,372	1,378,147	3,506
Boron carbide____do____	4,845	19	13,801	48
Cadmium:				
Metal____thousand pounds__	1,104	2,870	2,121	4,669
Flue dust (cadmium content)____do____	1,272	1,545	1,531	1,521
Calcium:				
Metal____pounds__	42,439	42	28,219	28
Chloride____short tons__	2,718	92	3,658	100
Chromate:				
Ore and concentrate (Cr_2O_3 content)__do____	645,693	22,713	685,497	25,239
Ferrochrome (chromium content)____do____	17,696	5,783	36,961	13,236
Metal____do____	732	1,109	1,010	1,522
Cobalt:				
Metal____thousand pounds__	11,333	16,526	14,846	23,132
Oxide (gross weight)____do____	1,514	1,422	947	1,011
Salts and compounds (gross weight)___do____	94	43	108	149
Columbium ore____pounds__	4,600,800	2,277	4,891,786	2,712
Copper (copper content):				
Ore and concentrate____short tons__	r 33,033	r 17,235	1,441	777
Regulus, black, coarse____do____	r 88	r 47	83	72
Unrefined, black, blister____do____	121,365	73,300	75,122	45,262
Refined in ingots, etc____do____	r 113,018	r 67,468	103,269	70,937
Old and scrap____do____	r 2,011	r 1,372	7,646	6,410
Old and clippings____do____	641	415	1,490	1,151
Ferroalloys: Ferrosilicon (silicon content)__do____	3,044	908	4,558	1,606
Gold:				
Ore and base bullion____troy ounces__	314,674	10,988	292,167	10,199
Bullion____do____	854,211	29,900	2,613,161	91,469
Iron ore:				
Ore____thousand long tons__	42,408	421,288	45,103	443,788
Pyrites cinder____long tons__	8,635	49	1,563	19
Iron and steel:				
Pig iron____short tons__	736,471	31,591	882,095	38,438
Iron and steel products (major):				
Iron products____do____	46,055	11,242	45,038	15,013
Steel products____do____	r 6,583,651	r 784,166	10,645,877	1,232,902
Scrap____do____	r 259,229	r 7,795	193,482	6,999
Tinplate____do____	22,561	472	18,988	451
Lead:				
Ore, flue dust, matte (lead content)___do____	128,067	21,789	128,933	26,923
Base bullion (lead content)____do____	7,043	2,058	566	380
Pigs and bars (lead content)____do____	211,140	45,790	221,519	60,391
Reclaimed, scrap, etc. (lead content)__do____	1,907	350	3,612	793
Sheets, pipe, and shot____do____	1,523	369	880	273
Babbitt metal and solder (lead content) do____	r 1,228	r 5,077	986	8,129
Manufactures____do____	2,276	713	512	329
Magnesium:				
Metallic and scrap____do____	2,227	890	2,551	1,101
Alloys (magnesium content)____do____	474	710	327	760
Sheets, tubing, ribbons, wire and other forms (magnesium content)____do____	40	70	103	128
Manganese:				
Ore (35 percent or more manganese) (manganese content)____short tons__	1,430,431	76,977	1,825,709	109,747
Ferromanganese (manganese content)_do____	162,075	25,811	198,118	31,486
Mercury:				
Compounds____pounds__	8,625	30	47,808	186
Metal____76-pound flasks__	41,153	8,775	16,238	7,614
Minor metals: Selenium and salts____pounds__	292,938	1,289	250,912	1,244
Nickel:				
Ore and matte____short tons__	----------	----------	81	(1)
Pigs, ingots, shot, cathodes____do____	r 105,327	155,973	134,406	205,493
Scrap____do____	1,343	1,256	1,188	898
Oxide____do____	16,862	17,504	13,592	14,979

Table 9.—U.S. imports for consumption of principal minerals and products—Continued

Mineral	1964 Quantity	1964 Value (thousands)	1965 Quantity	1965 Value (thousands)
Metals—Continued				
Platinum group:				
Unrefined materials:				
Grains and nuggets, including crude, dust, and residues ... troy ounces	35,916	$3,341	20,430	$2,275
Sponge and scrap ... do	5,127	487	4	1
Osmiridium ... do	[r]2,548	[r]85	3,988	228
Refined metal:				
Platinum ... do	[r]281,922	[r]24,102	349,280	36,125
Palladium ... do	[r]483,018	[r]13,475	734,881	22,381
Iridium ... do	6,615	489	10,839	943
Osmium ... do	1,399	113	269	88
Rhodium ... do	55,804	7,955	39,768	6,762
Ruthenium ... do	10,356	404	8,198	307
Radium: Radioactive substitutes	NA	1,869	NA	2,816
Rare earths: Ferrocerium and other cerium alloys ... pounds	9,621	48	7,916	36
Silver:				
Ore and base bullion ... thousand troy ounces	43,146	54,235	47,831	56,065
Bullion ... do	8,528	10,159	6,878	6,838
Tantalum: Ore ... pounds	980,702	1,606	1,196,487	2,150
Tin:				
Ore (tin content) ... long tons	5,190	11,539	4,326	13,228
Blocks, pigs, grains, etc ... do	[r]32,132	[r]101,049	40,816	159,506
Dross, skimmings, scrap, residues, and tin alloys, n.s.p.f ... long tons	1,210	714	502	883
Tinfoil, powder, flitters, etc	NA	300	NA	261
Titanium:				
Ilmenite ... short tons	[r]173,219	[r]5,472	166,406	4,770
Rutile ... do	110,981	7,724	151,957	10,116
Metal ... pounds	4,111,285	3,711	6,497,792	6,118
Ferrotitanium ... do	55,450	19	33,919	12
Compounds and mixtures ... do	81,794,801	15,322	99,503,628	18,259
Tungsten: (tungsten content)				
Ore and concentrate ... thousand pounds	3,148	2,008	3,618	3,886
Metal ... pounds	65,418	131	60,213	187
Ferrotungsten ... thousand pounds	195	136	386	404
Other alloys ... pounds	29,048	27	43,890	117
Zinc:				
Ore (zinc content) ... short tons	311,435	35,831	402,936	53,829
Blocks, pigs, and slabs ... do	134,118	31,898	155,489	43,094
Sheets ... do	1,774	527	1,381	453
Old, dross, and skimmings ... do	3,775	652	4,701	1,004
Dust ... do	3,269	797	244	57
Manufactures	NA	[r]1,339	NA	962
Zirconium: Ore, including zirconium sand ... short tons	44,413	1,184	58,873	1,690
Nonmetals:				
Abrasives: Diamond (industrial) ... carats	[r]14,297,911	[r]60,042	12,839,314	55,318
Asbestos ... short tons	739,361	72,973	719,559	70,457
Barite:				
Crude and ground ... do	601,010	4,837	712,713	5,561
Witherite ... do	2,407	98	2,570	112
Chemicals ... do	5,190	529	4,204	565
Bromine ... pounds	897	3	NA	NA
Cement ... 376-pound barrels	3,633,069	9,228	5,504,840	13,523
Clays:				
Raw ... short tons	133,140	2,525	93,045	1,970
Manufactured ... do	3,852	113	4,826	168
Cryolite ... do	24,264	1,765	24,011	2,009
Feldspar: Crude ... long tons	10	1	16	2
Fluorspar ... short tons	687,933	16,882	816,546	19,958
Gem stones:				
Diamond ... carats	2,644,750	258,534	3,159,681	307,285
Emerald ... do	180,069	3,218	189,828	5,397
Other	NA	[r]36,420	NA	40,749
Graphite ... short tons	[r]47,200	1,944	58,056	2,387
Gypsum:				
Crude, ground, calcined ... do	6,259,066	13,358	5,912,624	11,913
Manufactures	NA	1,329	NA	1,415
Iodine, crude ... thousand pounds	2,592	2,369	2,847	2,476
Kyanite ... short tons	2,386	104	4,047	167
Lime:				
Hydrated ... do	843	10	532	10
Other ... do	93,420	1,112	215,816	2,590
Dead-burned dolomite ... do	28,876	1,165	[1]59,519	2,385
Magnesium:				
Magnesite ... do	69,480	3,673	83,922	4,807
Compounds ... do	12,591	556	12,008	546

Table 9.—U.S. imports for consumption of principal minerals and products—Continued

Mineral	1964 Quantity	1964 Value (thousands)	1965 Quantity	1965 Value (thousands)
Nonmetal—Continued				
Mica:				
Uncut sheet and punch ---------- pounds --	2,267,681	$2,434	2,116,113	$2,142
Scrap ---------- short tons --	2,733	71	1,521	71
Manufactures ---------- do ----	4,433	4,566	4,971	6,371
Mineral-earth pigments: Iron oxide pigments:				
Natural ---------- do ----	2,902	136	2,978	155
Synthetic ---------- do ----	8,829	1,426	10,071	1,748
Ocher, crude and refined ---------- do ----	191	18	186	14
Siennas, crude and refined ---------- do ----	726	97	1,025	105
Umber, crude and refined ---------- do ----	3,412	118	3,195	118
Vandyke brown ---------- do ----	259	21	296	25
Nitrogen compounds (major), including urea do ----	1,536,631	65,838	1,511,563	71,743
Phosphate, crude ---------- long tons --	155,819	3,329	132,263	2,980
Phosphatic fertilizers ---------- do ----	70,512	4,010	51,698	3,139
Pigments and salts:				
Lead pigments and compounds -- short tons --	24,250	5,174	24,571	6,183
Zinc pigments and compounds ---------- do ----	12,430	2,389	17,731	3,482
Potash ---------- do ----	r 1,254,026	r 35,797	1,866,750	52,675
Pumice:				
Crude or unmanufactured ---------- do ----	5,499	65	9,457	99
Wholly or partly manufactured ---------- do ----	104,444	356	180,768	509
Manufactures, n.s.p.f ----------	NA	20	NA	27
Quartz crystal (Brazilian pebble) ---------- pounds --	r 834,062	r 645	1,181,753	1,083
Salt ---------- short tons --	2,261,318	5,677	2,410,409	6,505
Sand and gravel:				
Glass sand ---------- do ----	40,308	128	10,830	39
Other sand and gravel ---------- do ----	443,213	558	677,814	840
Sodium sulfate ---------- thousand short tons --	290	5,064	273	4,763
Stone and whiting ----------	NA	23,753	NA	20,414
Strontium: Mineral ---------- short tons --	21,617	506	9,741	221
Sulfur and pyrites:				
Sulfur: Ores and other forms, n.e.s long tons --	1,462,211	26,100	1,465,093	26,759
Pyrites ---------- do ----	10,202	49	13,959	76
Talc: Unmanufactured ---------- short tons --	22,714	917	21,022	833
Fuels:				
Carbon black:				
Acetylene ---------- pounds --	6,878,084	1,184	6,359,080	1,094
Gas black and carbon black ---------- do ----	1,337,683	225	168,068	36
Coal:				
Bituminous, slack, culm, and lignite short tons --	293,059	2,289	184,399	1,564
Briquets ---------- do ----	11,593	182	12,621	205
Coke ---------- do ----	103,286	1,509	89,620	1,379
Peat:				
Fertilizer grade ---------- do ----	265,585	11,997	271,466	11,748
Poultry and stable grade ---------- do ----	4,834	256	3,996	220
Petroleum ---------- thousand barrels --	r 826,736	r 1,962,629	900,744	2,147,936

r Revised. NA Not available.
1 Less than ½ unit.

Table 10.—Comparison of world and United States production of principal metals and minerals

Mineral	1964			1965 [p]		
	World	United States		World	United States	
	Thousand short tons (unless otherwise stated)		Percent of world	Thousand short tons (unless otherwise stated)		Percent of world
Fuels:						
Carbon black thousand pounds	NA	2,223,216	NA	NA	2,353,776	NA
Coal:						
Bituminous	2,008,575	484,048	24	2,064,381	509,045	25
Lignite	[r] 820,387	2,950	(1)	816,185	3,043	(1)
Pennsylvania anthracite	[r] 209,700	17,184	8	208,900	14,866	8
Coke (excluding breeze):						
Gashouse [2]	[r] 48,620	203	(1)	46,260	149	(1)
Oven and beehive	[r] 326,434	62,145	19	340,723	66,854	20
Fuel briquets and packaged fuel	[r] 133,300	368	(1)	128,400	369	(1)
Natural gas (marketable) million cubic feet	NA	[r] 15,462,667	NA	NA	16,039,753	NA
Peat	[r] 185,600	[3] 649	(1)	204,900	[3] 604	(1)
Petroleum (crude) thousand barrels	[r] 10,309,116	[r] 2,786,822	27	11,063,154	2,848,514	26
Nonmetals:						
Asbestos	3,540	101	3	3,570	118	3
Barite	[r] 3,400	817	24	3,790	846	22
Cement [4] thousand barrels	[r] 2,434,019	[r] 385,386	16	2,544,723	388,842	15
China clay	NA	3,331	NA	NA	3,604	NA
Corundum	9	----------	------	11	----------	-------
Diamond thousand carats	[r] 36,815	----------	------	35,513	----------	-------
Diatomite	[r] 1,890	[r] 580	31	1,750	580	33
Feldspar thousand long tons	[r] 1,815	[r] 587	32	1,900	625	33
Fluorspar	[r] 2,730	217	8	3,170	241	8
Graphite	[r] 700	W	W	675	W	W
Gypsum	[r] 51,370	10,684	21	51,610	10,035	19
Lime (sold or used by producers)	NA	16,089	NA	NA	16,794	NA
Magnesite	[r] 10,025	W	W	10,700	W	W
Mica (including scrap) thousand pounds	410,000	229,701	56	435,000	241,226	55
Nitrogen, agricultural [4] [5]	[r] 16,300	[r] 4,422	27	18,200	4,888	27
Phosphate rock thousand long tons	[r] 58,130	22,960	39	64,600	26,440	41
Potash (K_2O equivalent)	[r] 13,200	2,897	22	14,800	3,140	21
Pumice [6]	[r] 16,300	2,776	17	16,560	3,484	21
Pyrites thousand long tons	[r] 20,200	847	4	21,100	875	4
Salt [4]	[r] 109,720	31,628	29	118,590	34,695	29
Strontium [6]	[r] 25	----------	------	9	----------	-------
Sulfur, elemental thousand long tons	[r] 13,870	6,250	45	15,120	7,332	48
Talc, pyrophyllite, and soapstone	[r] 3,840	890	23	3,870	863	22
Vermiculite [6]	[r] 343	226	66	382	249	65
Metals, mine basis:						
Antimony (content of ore and concentrate) short tons	[r] 68,100	632	1	69,100	845	1
Arsenic, white [6]	[r] 65	W	W	68	W	W
Bauxite thousand long tons	[r] 33,230	1,601	5	36,530	1,654	5
Beryllium concentrate short tons	[7] [r] 5,200	W	W	[7] 5,700	W	W
Bismuth thousand pounds	[r] 8,200	W	W	9,400	W	W
Cadmium do	[r] 28,900	10,458	36	27,800	9,671	35
Chromite	[r] 4,705	----------	------	5,400	----------	-------
Cobalt (contained) [6] short tons	[r] 15,500	W	W	17,100	W	W
Columbium-tantalum concentrates [6] thousand pounds	[r] 11,745	----------	------	14,880	----------	-------
Copper (content of ore and concentrate)	[r] 5,340	1,247	23	5,600	1,352	24
Gold thousand troy ounces	46,100	[r] 1,456	3	47,700	1,705	4
Iron ore thousand long tons	[r] 569,336	84,836	15	605,637	87,842	15
Lead (content of ore and concentrate)	[r] 2,835	286	10	2,975	301	10
Manganese ore (35 percent or more Mn)	[r] 17,437	26	(1)	19,406	29	(1)
Mercury thousand 76-pound flasks	[r] 255	14	5	275	20	7
Molybdenum (content of ore and concentrate) thousand pounds	[r] 94,500	65,605	69	115,400	77,372	67
Nickel (content of ore and concentrate)	[r] 423	12	3	472	14	3

Table 10.—Comparison of world and United States production of principal metals and minerals—Continued

Mineral	1964 World Thousand short tons (unless otherwise stated)	1964 United States Thousand short tons (unless otherwise stated)	1964 United States Percent of world	1965 [8] World Thousand short tons (unless otherwise stated)	1965 [8] United States Thousand short tons (unless otherwise stated)	1965 [8] United States Percent of world
Metals, mine basis—Continued						
Platinum groups (Pt, Pd, etc.) thousand troy ounces	r 2,550	40	2	2,960	35	1
Silver do	r 246,400	r 36,334	15	251,000	39,806	16
Tin (content of ore and concentrate) long tons	r 194,500	W	W	199,200	47	(1)
Titanium concentrates:						
Ilmenite [6]	r 2,588	1,001	39	2,728	969	36
Rutile [6]	212	8	4	243	W	W
Tungsten concentrate (60 percent WO_3) short tons	r 64,500	9,244	14	59,800	7,949	13
Vanadium (content of ore and concentrate) [6] short tons	r 7,841	4,362	56	9,150	5,226	57
Zinc (content of ore and concentrate)	r 4,425	575	13	4,750	611	13
Metals, smelter basis:						
Aluminum	r 6,720	2,553	38	7,415	2,754	37
Copper	r 5,730	1,338	23	6,020	1,434	24
Iron, pig (including ferroalloys)	r 351,034	87,922	25	370,065	91,016	25
Lead	r 2,825	449	16	2,905	418	14
Magnesium short tons	r 166,200	79,488	48	174,000	81,361	47
Selenium [6] thousand pounds	r 2,100	929	44	1,740	540	31
Steel ingots and castings	r 482,570	127,076	26	507,540	131,462	26
Tellurium [6] thousand pounds	r 277	145	52	337	195	58
Tin long tons	r 188,900	[8] 5,190	3	194,100	3,098	2
Uranium oxide (U_3O_8) [6] short tons	r 26,700	11,847	44	20,800	10,442	50
Zinc	r 4,110	954	23	4,240	994	23

p Preliminary. r Revised. NA Not avaiable. W Withheld to avoid disclosing individual company confidential data.
[1] Less than ½ unit.
[2] Includes low- and medium-temperature and gashouse coke.
[3] Agricultural use only.
[4] Including Puerto Rico.
[5] Year ended June 30 of year stated (United Nations).
[6] World total exclusive of U.S.S.R.
[7] Not including U.S. output which was very small, but withheld to avoid disclosing individual company confidential data.
[8] U.S. imports of tin concentrates (tin content).

Employment and Injuries in the Metal and Nonmetal Industries

By Forrest T. Moyer [1]

Frequency rates of injuries per million man-hours of exposure were improved during 1965 slightly to moderately over those of 1964 at metal mines, nonferrous reduction and refining plants, nonmetal mills, stone quarries and mills, sand and gravel operations, and slag operations. However, at metal mills and nonmetal mines the rates of occurrence of work injuries were less favorable.

The severity rates of injuries during 1965 were better than in 1964 at metal mines and mills, stone quarries and mills, and slag operations. Conversely, severity rates were worse at nonferrous reduction and refining plants, nonmetal mines and mills, and sand and gravel operations.

The average number of men working daily and man-hours of worktime were greater in 1965 in all the broad industry groups except in the sand and gravel industry.

In addition to the industry classifications included in this chapter, similar employment and injury experience data on mineral fuels industries are presented in volume II. Corresponding data for broad classifications of mineral industry groups are given by States in volume III.

METAL MINES AND MILLS

During 1965 the overall frequency and severity of work-injury rates at metal mines improved slightly. There were 58 fatalities, 3 more than in 1964. The number of nonfatal injuries in 1965 increased slightly to 3,320. At metal mills, the injury-frequency rate in 1965 increased 13 percent because of a substantial rise in the number of nonfatal injuries. However, the count of fatal injuries was three, two less than in 1964. The injury-severity rate for mills was reduced to 851 from 1,090, the rate for 1964.

Activity in the mining and milling of metallic ores was higher in 1965, and the average number of men working and the man-hours of worktime increased over the corresponding data for 1964.

Copper.—The frequency rate of injuries at copper mines in 1965 decreased to 25.41 per million man-hours, a notable drop from 28.82 in 1964. However, the severity rate increased to 4,084 days lost per million man-hours from 3,468 in 1964. The increased severity rate resulted largely from the 20 fatalities that occurred at metal mines during 1965, 7 more than in 1964. In the milling of copper ores, the frequency rate increased slightly, but the severity rate was improved substantially to 379 from 883. No fatalities were reported in 1965 at copper mills. The average number of men working daily and the total worktime increased moderately at copper mines and mills during 1965.

Gold-Silver (Lode and Placer).—Injury experience at gold-silver lode and placer mines worsened substantially during 1965 owing largely to an increased number of nonfatal injuries. No fatalities occurred in gold-silver mills during 1965. There were four fatalities reported for gold-silver mines, the same as in 1964.

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Operating activity at mines declined moderately from that of 1964 as measured by the number of men employed and the man-hours of worktime. However, activity at mills increased moderately.

Iron.—Less favorable injury - frequency rates at iron mines and mills and an increased severity rate at mills during 1965 were offset in part by a significant decrease in the severity rate for iron mines. The improved rate of 1,773 days lost per million man-hours—from 3,309 in 1964—resulted primarily from the sharply reduced number of fatalities. The five fatalities at iron mines in 1965 were seven less than in 1964. This was the lowest annual total in a statistical history extending back to 1911.

Employment and man-hours worked at iron mines and mills were moderately greater than in 1964.

Lead-Zinc.—Injury experience at lead-zinc mines and mills generally was less favorable in 1965. At the mines, the rate of injury-occurrence was slightly less favorable than in 1964. However, owing principally to three fewer fatalities in 1965, the injury-severity rate was improved substantially. At the mills, the frequency and severity rates of injuries were markedly worse than in 1964 because of the larger numbers of fatal and nonfatal injuries.

Operating activity, as measured by man-hours worked, increased moderately at lead-zinc mines and slightly at lead-zinc mills.

Uranium.—Injury experience at uranium mines was affected predominantly by 10 fatalities, an increase of 6 over those of 1964. The severity rate increased to 13,117 from 6,401 in spite of a substantial drop in nonfatal injuries. However, the frequency rate improved slightly over that of 1964. At uranium mills, the injury-frequency rate increased substantially; from 16.85 to 21.51. However, the severity rate was reduced substantially.

The average number of men working daily and man-hours of worktime at uranium mines and mills continued to decline in 1965.

Miscellaneous Metals.—Establishments in the miscellaneous metal group are those mines and mills working antimony, bauxite, manganese, mecury, rare-earth metals, titanium, and other metallic ores not specified earlier in this chapter.

The injury experience at mines and mills in the miscellaneous metal group was improved in 1965. The largest change, from 1,028 to 305, was in the injury-severity rate at mills. No fatalities were reported in mills for 1965, and the count of nonfatal injuries increased only slightly.

The average number of men working daily and man-hours worked at miscellaneous metal mines and mills increased moderately.

Table 1.—Employment and injury experience at metal mines in the United States, by industry groups

Industry and year	Men working daily	Average active mine days	Man-days worked (thousands)	Man-hours worked (thousands)	Number of injuries		Injury rates per million man-hours	
					Fatal	Nonfatal	Frequency	Severity
Copper:								
1956–60 (average)	16,212	278	4,513	36,100	20	1,038	29.31	NA
1961	15,661	285	4,460	35,790	13	893	25.31	3,847
1962	15,629	280	4,377	35,017	15	908	26.36	4,598
1963	14,547	297	4,326	34,611	14	908	26.64	4,199
1964	15,820	288	4,549	36,323	13	1,034	28.82	3,468
1965 p	16,600	302	5,017	39,950	20	995	25.41	4,084
Gold-silver (lode-placer):								
1956–60 (average)	4,949	228	1,127	9,111	6	448	49.83	NA
1961	5,011	213	1,068	8,576	4	365	43.03	5,852
1962	4,361	215	937	7,553	8	268	36.54	7,945
1963	4,823	210	1,015	8,162	6	265	33.20	6,405
1964	4,312	228	983	7,885	4	208	26.89	3,955
1965 p	4,000	235	938	7,500	4	270	36.53	5,155
Iron:								
1956–60 (average)	23,427	224	5,254	42,138	15	573	13.95	NA
1961	17,251	224	3,868	31,027	10	449	14.79	3,014
1962	16,165	234	3,776	30,481	9	453	15.16	2,799
1963	13,353	251	3,357	27,079	10	402	15.21	3,339
1964	14,189	258	3,659	29,443	12	452	15.76	3,309
1965 p	14,400	265	3,820	30,730	5	495	16.27	1,773
Lead-zinc:								
1956–60 (average)	9,384	249	2,334	18,668	16	1,106	60.10	NA
1961	7,510	243	1,829	14,628	7	1,167	80.26	6,441
1962	7,150	243	1,735	13,877	9	935	68.03	7,713
1963	7,443	234	1,738	13,901	6	961	69.56	5,076
1964	8,158	260	2,118	16,969	19	1,038	62.29	10,113
1965 p	8,500	260	2,208	17,670	16	1,100	63.16	8,277
Uranium: [1]								
1960	7,329	233	1,710	13,882	32	862	64.63	16,599
1961	5,965	245	1,461	11,811	11	525	45.38	8,203
1962	5,967	231	1,379	11,175	13	420	38.75	9,059
1963	5,086	199	1,011	8,163	4	348	43.12	4,531
1964	4,772	203	969	7,833	4	349	45.07	6,401
1965 p	4,000	189	757	6,115	10	260	44.15	13,117
Miscellaneous: [2]								
1956–60 (average)	7,660	235	1,799	14,485	14	783	55.02	NA
1961	2,853	256	730	5,846	5	270	47.04	9,157
1962	3,015	239	720	5,764	7	279	49.62	9,279
1963	2,592	251	650	5,196	1	191	36.95	2,613
1964	2,514	286	718	5,750	3	185	32.70	4,755
1965 p	2,800	294	823	6,509	3	200	30.80	4,019
Total: [3]								
1956–60 (average)	63,098	244	15,369	123,268	77	4,121	34.06	NA
1961	54,251	247	13,416	107,678	50	3,669	34.54	4,885
1962	52,287	247	12,924	103,867	61	3,263	32.00	5,469
1963	47,844	253	12,096	97,111	41	3,075	32.09	4,212
1964	49,765	261	12,996	104,204	55	3,266	31.87	4,833
1965 p	50,300	270	13,564	108,555	58	3,320	31.12	4,691

p Preliminary. NA Not available.
[1] Classed as uranium-vanadium and included with miscellaneous prior to 1960.
[2] Includes uranium prior to 1960.
[3] Data may not add to totals shown because of rounding.

Table 2.—Employment and injury experience at metal mills in the United States, by industry groups

Industry and year	Men working daily	Average active mill days	Man-days worked (thousands)	Man-hours worked (thousands)	Number of injuries: Fatal	Number of injuries: Nonfatal	Injury rates per million man-hours: Frequency	Injury rates per million man-hours: Severity
Copper:								
1956-60 (average)	6,215	304	1,886	15,091	2	159	10.67	NA
1961	5,688	317	1,804	14,434	--	106	7.34	286
1962	5,947	325	1,935	15,482	7	127	8.66	2,940
1963	4,839	320	1,550	12,402	1	91	7.42	1,545
1964	5,062	316	1,600	12,800	1	89	7.03	883
1965 p	5,500	338	1,857	14,855	--	105	7.07	379
Gold-silver (lode-placer):								
1956-60 (average)	379	274	104	830	--	18	21.69	NA
1961	343	241	83	659	--	12	18.21	220
1962	347	251	87	702	--	30	42.74	1,845
1963	335	263	88	708	--	25	35.31	768
1964	318	283	90	716	--	13	18.16	362
1965 p	400	253	101	805	--	25	31.06	617
Iron:								
1956-60 (average)	5,785	240	1,386	11,166	1	71	6.45	NA
1961	5,515	266	1,468	11,777	3	65	5.77	1,804
1962	4,868	283	1,376	11,130	3	91	8.45	2,167
1963	4,856	287	1,392	11,189	--	65	5.81	283
1964	5,534	293	1,622	12,944	1	103	8.03	719
1965 p	6,100	296	1,803	14,505	1	130	9.03	781
Lead-zinc:								
1956-60 (average)	2,382	261	621	4,971	--	72	14.48	NA
1961	1,322	241	319	2,554	--	76	29.76	1,688
1962	1,743	254	442	3,539	--	55	15.54	653
1963	1,356	229	310	2,484	2	65	26.97	7,093
1964	1,285	267	343	2,731	1	46	17.21	2,883
1965 p	1,300	272	353	2,835	2	75	27.16	5,040
Uranium: [1]								
1960	2,578	321	826	6,610	1	138	21.03	2,431
1961	2,481	312	775	6,222	--	95	15.27	1,051
1962	2,219	302	670	5,406	2	87	16.46	2,842
1963	1,796	275	494	3,988	--	75	18.81	404
1964	1,441	300	432	3,560	1	59	16.85	2,142
1965 p	1,300	314	408	3,255	--	70	21.51	1,621
Miscellaneous: [2]								
1956-60 (average)	5,214	299	1,558	12,478	2	198	16.03	NA
1961	5,169	336	1,737	13,907	--	104	7.48	310
1962	4,859	332	1,613	12,904	2	92	7.28	1,227
1963	4,834	339	1,638	13,103	2	89	6.94	1,134
1964	4,075	324	1,319	10,565	1	86	8.23	1,028
1965 p	4,600	308	1,417	11,355	--	90	7.93	305
Total: [3]								
1956-60 (average)	20,491	279	5,721	45,859	6	546	12.04	NA
1961	20,518	301	6,186	49,552	3	458	9.30	821
1962	19,983	306	6,123	49,163	14	482	10.09	2,124
1963	18,016	304	5,472	43,874	5	410	9.46	1,298
1964	17,715	305	5,406	43,317	5	396	9.26	1,090
1965 p	19,200	309	5,939	47,610	3	495	10.46	851

p Preliminary. NA Not available.
[1] Classed as uranium-vanadium and included with miscellaneous metals prior to 1960.
[2] Includes uranium prior to 1960.
[3] Data may not add to totals shown because of rounding.

NONFERROUS REDUCTION AND REFINING PLANTS

The overall injury-frequency rate for primary nonferrous reduction plants and refineries improved moderately in 1965 to 8.89 per million man-hours from 10.30 in 1964. This was lower than the corresponding rate for any of the previous 4 years. The overall injury-severity rate was slightly higher in 1965 than in 1964, 1,107 days of lost time per million man-hours worked compared with 1,005 in 1964.

The injury-frequency and severity rates for aluminum plants were lower in 1965 than in 1964. The injury-frequency rates decreased during 1965 at copper, zinc, and miscellaneous metal plants, but these were accompanied by moderately higher severity rates. Frequency and severity rates both were higher in 1965 for lead smelters and refineries.

Gains in the number of men working and in the man-hours worked in all plants indicate that operating activity at the primary nonferrous smelting and refining plants in general was higher in 1965. This was a continuation of an upward trend in operating activity during recent years.

Table 3.—Employment and injury experience at primary nonferrous reduction and refinery plants in the United States, by industry groups

Industry and year	Men working daily	Average active smelter days	Man-days worked (thousands)	Man-hours worked (thousands)	Number of injuries		Injury rates per million man-hours	
					Fatal	Nonfatal	Frequency	Severity
Copper:								
1956–60 (average)	11,566	307	3,552	28,401	4	374	13.31	NA
1961	11,414	329	3,750	29,999	3	420	14.10	1,398
1962	10,954	328	3,590	28,697	5	360	12.72	1,563
1963	10,289	334	3,443	27,579	2	339	12.36	1,020
1964	10,495	323	3,385	27,106	1	355	13.13	751
1965 p	10,900	333	3,635	29,060	3	315	10.95	1,257
Lead:								
1956–60 (average)	3,214	286	918	7,344	2	125	17.29	NA
1961	2,493	300	747	5,973	--	116	19.41	995
1962	2,493	289	720	5,760	2	82	15.58	2,443
1963	2,581	277	715	5,720	1	61	10.84	2,057
1964	2,327	321	746	6,002	1	67	11.33	2,353
1965 p	2,300	305	701	5,610	1	75	13.55	2,896
Zinc:								
1956–60 (average)	8,168	320	2,611	20,852	2	463	22.30	NA
1961	6,518	329	2,138	17,107	2	360	21.16	1,740
1962	6,588	328	2,158	17,246	--	277	16.06	399
1963	6,108	346	2,114	16,909	3	261	15.61	684
1964	6,848	334	2,284	18,074	3	314	17.55	854
1965 p	7,100	342	2,426	18,970	4	285	15.23	1,067
Aluminum [1]								
1960	12,630	346	4,365	34,920	1	214	6.16	389
1961	13,408	326	4,371	34,966	1	331	9.50	790
1962	13,184	336	4,433	35,453	3	269	7.67	1,498
1963 [2]	14,036	358	5,022	40,179	--	269	6.70	1,622
1964	15,794	334	5,278	42,917	3	242	5.71	1,898
1965 p	20,100	341	6,846	53,120	3	285	5.42	622
Miscellaneous: [3]								
1956–60 (average)	13,504	356	4,814	38,351	1	310	8.11	NA
1961	1,714	278	477	3,816	--	20	5.24	215
1962	1,605	297	477	3,819	--	22	5.76	199
1963	1,428	312	446	3,633	1	27	7.71	1,888
1964	1,492	312	465	3,719	--	21	5.65	155
1965 p	1,900	272	517	4,140	--	20	4.83	221
Total: [4]								
1956–60 (average)	38,978	328	12,769	101,934	9	1,316	13.00	NA
1961	35,547	323	11,483	91,862	6	1,247	13.64	1,179
1962	34,824	327	11,378	90,975	10	1,010	11.21	1,147
1963 [2]	34,442	341	11,740	94,020	7	957	10.25	933
1964	36,956	329	12,158	97,807	8	999	10.30	1,005
1965 p	42,300	334	14,126	110,900	11	975	8.89	1,107

p Preliminary. NA Not available.
[1] Aluminum included with miscellaneous prior to 1960.
[2] Revised figures.
[3] Includes aluminum prior to 1960.
[4] Data may not add to total shown because of rounding.

NONMETAL (EXCEPT STONE) MINES AND MILLS

The overall injury experience at nonmetal mines was less favorable in 1965 than in 1964. The injury-frequency and severity rates increased from 25.68 to 28.06 and from 4,389 to 5,009 per million man-hours, respectively. At nonmetal mills, the frequency rate decreased to 19.23 per million man-hours in 1965 from 22.19 in 1964. However, the severity rate increased to 1,884 per million man-hours in 1965 from 1,550 in 1964, due principally to the larger number of fatalities in 1965.

At clay and shale mines, the frequency rate was noticeably higher while the severity rate was reduced principally as a result of fewer fatalities in 1964. At clay and shale mills, the frequency and severity rates were improved in 1965. Gypsum mines reported two fatalities in 1965, causing the severity rate to be markedly higher. The number of nonfatal injuries at gypsum mines was up substantially from 1964. At gypsum mills, frequency and severity rates both were appreciably lower.

At phosphate rock mines, the injury-frequency rate increased slightly, but the severity rate was reduced considerably. Both frequency and severity rates were higher in 1965 at phosphate rock mills, with four fatalities (none were reported in 1964) causing most of the sharp increase in the severity rate. The frequency rates of injuries at potash mines and mills were somewhat higher in 1965, although the severity rates were markedly lower. At salt mines and mills, the injury-frequency rates were lower in 1965. However, three fatalities, two more than in 1964, at salt mines resulted in a noticeably higher severity rate, whereas at salt mills the severity rate was improved. The injury-frequency rate at sulfur mines declined slightly in 1965, but two fatalities (none in 1964) caused a sharp increase in the severity rate. A larger number of fatalities also worsened the severity rate for miscellaneous nonmetal mines in 1965; however, the frequency rate was relatively unchanged. The severity rate at the miscellaneous mills was moderately higher in 1965, but the rate of injury occurrence was improved compared with that of 1964.

Increased numbers of men working at clay-shale, phosphate rock, and salt mines in 1964 more than offset the relatively minor decreases in gypsum, potash, sulfur, and miscellaneous nonmetal mines. Employment increased slightly at mills of most of the nonmetal mineral industries and decreased at clay, salt, and sulfur mills.

Table 4.—Employment and injury experience at nonmetal (except stone) mines in the United States, by industry groups

Industry and year	Men working daily	Average active mine days	Man-days worked (thousands)	Man-hours worked (thousands)	Number of injuries		Injury rates per million man-hours	
					Fatal	Nonfatal	Frequency	Severity
Clay-shale:								
1960	6,209	192	1,193	9,638	5	272	28.74	4,897
1961	5,896	194	1,144	9,220	3	189	20.82	4,533
1962	5,383	185	995	8,031	1	230	28.76	2,464
1963	4,651	199	927	7,490	1	192	25.77	1,659
1964	5,450	212	1,156	9,366	7	254	27.87	6,169
1965 p	5,500	217	1,196	9,690	4	320	33.44	4,064
Gypsum:								
1960	1,178	251	296	2,387	1	33	14.24	3,811
1961	1,100	249	274	2,215	1	27	12.64	3,431
1962	1,105	251	277	2,230	--	19	8.52	2,376
1963	992	256	254	2,051	1	23	11.70	3,841
1964	1,019	255	260	2,091	--	15	7.17	302
1965 p	1,000	248	248	2,000	2	20	11.00	6,432
Phosphate rock:								
1960	2,352	289	679	5,419	--	112	20.67	754
1961	2,373	271	644	5,253	2	73	14.28	3,070
1962	1,974	257	507	4,122	2	70	17.47	4,382
1963	2,012	279	561	4,536	3	72	16.53	5,088
1964	2,124	296	629	5,063	2	92	18.57	3,410
1965 p	2,300	309	711	5,725	2	105	18.69	2,464
Potash:								
1960	1,603	315	506	4,046	1	176	43.75	2,360
1961	1,708	314	537	4,294	5	169	40.52	7,959
1962	1,602	306	491	3,925	5	181	47.38	8,846
1963	1,723	353	608	4,851	19	206	46.38	24,431
1964	2,022	333	673	5,384	4	171	32.50	6,138
1965 p	1,800	334	602	4,815	1	200	41.74	4,542
Salt:								
1960	1,292	261	337	2,771	1	109	39.70	3,300
1961	1,444	255	368	3,067	2	101	33.57	6,666
1962	1,625	267	434	3,635	2	164	45.67	4,289
1963	1,532	270	414	3,443	3	113	33.69	6,214
1964	1,551	273	423	3,487	1	122	35.27	4,335
1965 p	2,000	272	544	4,460	3	135	30.94	6,566
Sulfur:								
1960	1,878	346	650	5,558	5	167	30.95	6,817
1961	1,656	350	580	4,971	--	93	18.71	612
1962	1,468	353	518	4,407	--	72	16.34	748
1963	1,366	361	493	4,247	1	61	14.60	1,816
1964	1,313	363	476	4,106	--	53	12.91	418
1965 p	1,300	365	475	4,290	2	50	12.12	3,184
Miscellaneous:								
1960	4,141	206	853	6,985	6	187	27.63	NA
1961	4,104	195	800	6,496	2	209	32.48	3,222
1962	3,760	201	757	6,133	4	208	34.57	6,858
1963	3,294	223	733	5,921	3	190	32.60	4,117
1964	3,608	223	803	6,479	4	199	31.33	4,993
1965 p	3,300	247	815	6,485	7	195	31.15	8,708
Total: [1]								
1960	18,653	242	4,515	36,805	19	1,056	29.21	4,478
1961	18,281	238	4,347	35,517	15	861	24.66	4,058
1962	16,917	235	3,979	32,484	14	944	29.49	4,275
1963	15,570	256	3,990	32,539	31	857	27.29	6,630
1964	17,087	259	4,420	35,977	18	906	25.68	4,389
1965 p	17,200	267	4,591	37,460	21	1,030	28.06	5,009

p Preliminary. NA Not available.

[1] Data may not add to totals shown because of rounding.

Table 5.—Employment and injury experience at nonmetal (except stone) mills in the United States, by industry groups

Industry and year	Men working daily	Average active mill days	Man-days worked (thousands)	Man-hours worked (thousands)	Number of injuries		Injury rates per million man-hours	
					Fatal	Nonfatal	Frequency	Severity
Clay-shale:								
1960	20,222	247	4,991	40,784	6	1,121	27.63	2,070
1961	20,532	247	5,068	40,593	2	1,107	27.32	1,032
1962	17,142	233	3,987	32,756	3	796	24.39	1,539
1963	15,746	250	3,942	31,762	--	881	27.74	836
1964	15,250	261	3,982	32,058	4	1,011	31.66	2,025
1965 p	15,200	270	4,104	33,025	5	890	27.10	1,974
Gypsum:								
1960	2,464	261	642	5,146	2	18	3.89	2,674
1961	1,691	254	430	3,445	--	19	5.52	1,998
1962	1,690	257	434	3,517	--	21	5.97	289
1963	1,615	289	466	3,731	--	14	3.75	294
1964	1,589	278	442	3,467	--	20	5.77	1,804
1965 p [1]	2,900	294	852	6,555	--	25	3.81	588
Phosphate rock:								
1960	2,188	293	642	5,188	1	61	11.95	1,502
1961	2,523	279	705	5,644	1	50	9.04	2,078
1962	2,381	299	712	5,699	2	53	9.65	2,631
1963	2,297	310	712	5,714	1	29	5.25	1,260
1964	2,163	319	690	5,514	--	38	6.89	1,017
1965 p	2,200	340	749	6,040	4	55	9.77	5,844
Potash:								
1960	978	329	322	2,572	--	118	45.88	900
1961	1,052	331	348	2,786	1	81	29.43	2,887
1962	712	305	217	1,737	--	58	33.39	716
1963	1,020	330	337	2,695	1	25	9.65	2,612
1964	1,003	332	333	2,666	--	45	17.25	2,644
1965 p	1,100	361	397	3,180	1	70	22.01	1,980
Salt:								
1960	5,000	282	1,410	11,304	1	159	14.15	1,066
1961	4,711	286	1,347	10,811	--	174	16.09	453
1962	4,429	269	1,190	10,259	3	196	19.40	2,381
1963	4,539	301	1,368	10,999	--	182	16.55	369
1964	4,870	289	1,405	11,229	--	183	16.30	657
1965 p	4,200	290	1,220	9,755	--	120	12.30	568
Sulfur:								
1960	51	216	11	92	--	8	86.96	1,003
1961	33	182	6	49	--	1	20.41	408
1962	34	265	9	69	--	--	--	--
1963	20	300	6	47	--	1	21.28	553
1964	11	273	3	21	--	--	--	--
1965 p	--	---	--	--	--	--	--	--
Miscellaneous:								
1960	8,665	307	2,661	21,300	3	309	14.65	NA
1961	8,489	303	2,568	20,597	2	248	12.14	1,317
1962	8,512	301	2,563	20,585	1	259	12.63	1,279
1963	8,495	309	2,621	20,996	--	344	16.38	514
1964	7,081	291	2,060	16,506	1	283	17.21	1,185
1965 p	7,200	297	2,136	17,125	1	280	16.41	1,367
Total: [2]								
1960	39,568	270	10,679	86,386	13	1,794	20.92	1,705
1961	39,031	268	10,471	83,925	6	1,680	20.09	1,199
1962	34,900	261	9,112	74,621	9	1,383	18.65	1,587
1963	33,732	280	9,452	75,944	2	1,476	19.45	589
1964	31,967	279	8,914	71,461	6	1,580	22.19	1,550
1965 p	32,800	288	9,459	75,680	10	1,445	19.23	1,844

p Preliminary. NA Not available.

[1] Includes mill data not reported in previous years.

[2] Data may not add to totals shown because of rounding.

STONE QUARRIES AND MILLS

The overall safety record of all stone quarries and mills has been improved slightly in each of the past 3 years. In 1965, the injury-frequency rate was 18.16 injuries per million man-hours compared with 18.20 in 1964 and 18.22 in 1963. The severity rate, 2,426 per million man-hours in 1965, was lower than the 2,752 in 1964 and 2,913 in 1963. There were 49 fatalities reported in 1965, 12 less than in each 1963 and 1964.

The injury-frequency rate was improved compared with that in 1964 for granite, lime, sandstone, and traprock, but was less favorable for cement, limestone, marble, slate, and miscellaneous stone quarries and mills. In spite of the slight increase, cement operations continued to show the lowest rate of occurrence, 5.97 injuries per million man-hours. Marble quarries showed the highest rate of occurrence, 35.65 injuries per million man-hours.

The severity rate was improved for granite, lime, limestone, slate, traprock, and miscellaneous stone quarries and mills. This measure of injury experience was less favorable at cement, marble, and sandstone operations, each of which reported more fatalities.

Operating activity, as measured by the average number of men working daily, registered slight to moderate changes. Increased employment in the granite, lime, limestone, sandstone, and traprock industries was accompanied by corresponding gains in total worktime. Slight increases in man-hours worked were listed for the slate and miscellaneous stone industries, although employment declined slightly. This anomoly results from the increased number of active days at slate and miscellaneous stone operations in 1965.

Table 6.—Employment and injury experience at stone quarries and mills in the United States, by industry groups

Industry and year	Men working daily	Average active days	Man-days worked (thousands)	Man-hours worked (thousands)	Number of injuries: Fatal	Number of injuries: Nonfatal	Injury rates per million man-hours: Frequency	Injury rates per million man-hours: Severity
Cement: [1]								
1956–60 (average)	28,818	NA	NA	72,102	9	313	4.47	NA
1961	27,028	308	8,336	66,732	2	259	3.91	NA
1962	25,564	306	7,817	62,545	8	251	4.14	1,077
1963	24,956	309	7,715	61,727	7	306	5.07	950
1964	23,017	318	7,323	58,592	8	303	5.31	1,017
1965 p	22,700	318	7,218	57,770	10	335	5.97	1,438
Granite:								
1956–60 (average)	7,527	NA	NA	14,941	5	608	41.03	NA
1961	8,329	234	1,949	16,192	4	547	34.03	NA
1962	8,239	229	1,886	15,870	7	425	27.22	5,052
1963	8,131	234	1,900	15,797	13	423	27.60	7,393
1964	8,743	236	2,065	17,076	6	466	27.64	3,753
1965 p	9,000	250	2,246	18,430	6	445	24.47	2,973
Lime: [1]								
1956–60 (average)	8,061	NA	NA	18,940	5	390	20.86	NA
1961	8,485	291	2,466	19,775	3	348	17.75	NA
1962	7,690	289	2,222	17,847	5	312	17.76	2,216
1963	7,439	300	2,230	17,890	3	237	13.42	1,716
1964	7,234	303	2,189	17,595	5	300	17.33	2,237
1965 p	7,700	292	2,250	18,095	4	285	15.97	1,797
Limestone:								
1956–60 (average)	30,026	NA	NA	58,873	20	1,956	33.56	NA
1961	31,923	229	7,322	61,717	15	1,903	31.08	NA
1962	32,931	229	7,538	64,570	33	1,415	22.43	4,830
1963	33,093	230	7,603	64,500	29	1,499	23.69	3,958
1964	31,660	236	7,482	63,476	34	1,424	22.97	4,468
1965 p	32,600	238	7,768	65,875	21	1,555	23.92	3,404
Marble:								
1956–60 (average)	2,995	NA	NA	6,221	1	235	37.94	NA
1961	3,119	245	765	6,257	2	289	46.51	NA
1962	2,919	247	721	5,938	3	260	44.29	4,419
1963	2,792	254	710	5,763	1	168	29.33	3,454
1964	2,602	258	671	5,456	--	174	31.89	581
1965 p	2,500	250	625	5,105	2	180	35.65	3,359
Sandstone:								
1956–60 (average)	3,699	NA	NA	6,444	2	305	47.64	NA
1961	4,370	206	900	7,404	2	327	49.23	NA
1962	5,867	219	1,282	10,802	3	267	25.15	3,444
1963	5,982	222	1,329	11,096	2	334	29.25	2,844
1964	5,427	221	1,197	9,779	4	282	30.28	3,180
1965 p	5,600	221	1,237	10,340	5	255	25.00	3,610
Slate:								
1956–60 (average)	1,371	NA	NA	2,803	--	138	44.44	NA
1961	1,160	251	292	2,359	--	135	57.23	NA
1962	1,224	243	298	2,510	3	77	31.87	7,970
1963	1,270	264	335	2,719	--	103	37.88	1,047
1964	1,402	263	369	2,993	1	86	29.07	3,035
1965 p	1,400	264	370	3,005	--	90	29.95	849
Traprock:								
1956–60 (average)	4,054	NA	NA	7,269	5	340	47.46	NA
1961	4,979	220	1,097	9,079	4	407	45.27	NA
1962	5,734	215	1,235	10,197	4	224	22.36	4,284
1963	6,254	216	1,315	11,146	2	319	28.80	2,014
1964	5,417	208	1,125	9,401	2	240	25.74	2,285
1965 p	6,000	210	1,257	10,440	1	210	20.21	1,120
Miscellaneous: [2]								
1957–61 (average)	1,744	209	364	3,082	1	127	41.53	NA
1962	2,071	190	393	3,173	1	68	21.75	3,865
1963	2,043	186	379	3,046	4	79	27.25	8,524
1964	2,635	199	525	4,200	1	96	23.10	1,799
1965 p	2,500	222	554	4,400	--	105	23.86	1.360
Total: [3]								
1956–60 (average)	87,899	NA	NA	190,037	48	4,399	23.40	NA
1961	91,371	257	23,524	192,705	32	4,280	22.38	NA
1962	92,241	254	23,393	193,453	67	3,299	17.40	3,201
1963	91,960	256	23,553	193,685	61	3,468	18.22	2,913
1964	88,137	260	22,944	188,569	61	3,371	18.20	2,752
1965 p	90,200	261	23,526	193,465	49	3,465	18.16	2,426

p Preliminary. NA Not available.
[1] Includes burning or calcining and other mill operations.
[2] Not compiled separately before 1957.
[3] Data may not add to total shown because of rounding.

SAND AND GRAVEL OPERATIONS

Injury experience at sand and gravel operations was relatively unchanged in 1965. The frequency rate was lowered to 19.15 injuries per million man-hours from 19.73 in 1964. However, the severity rate during 1965 advanced to 3,322 days lost per million man-hours from 3,237 in 1964. A total of 40 fatalities was reported, 6 more than in 1964. The number of nonfatal injuries decreased to 1,870 from 1,957 in 1964.

Activity at sand and gravel operations decreased slightly in 1965, as indicated by the slight declines in employment and worktime. However, the number of active plant days increased to 228 in 1965.

Table 7.—Employment and injury experience at sand and gravel plants in the United States

Year	Men working daily	Average active plant days	Man-days worked (thousands)	Man-hours worked (thousands)	Number of injuries		Injury rates per million man-hours	
					Fatal	Nonfatal	Frequency	Severity
1961	55,726	217	12,117	101,707	21	1,814	18.04	2,331
1962	53,599	218	11,690	97,589	51	2,093	21.97	4,232
1963	52,804	216	11,400	95,786	33	1,894	20.12	3,095
1964	55,886	217	12,129	100,891	34	1,957	19.73	3,237
1965 p	54,700	228	11,979	99,745	40	1,870	19.15	3,322

p Preliminary

SLAG (IRON-BLAST-FURNACE) OPERATIONS

The frequency rate of injuries dropped appreciably in slag operations in 1965 to 14.93 per million man-hours from a high in 1964 of 17.38. The severity rate also was reduced to 3,173 in 1965 from 3,895 in 1964. Operating activity was higher in 1965, both in terms of men employed and man-hours worked.

Table 8.—Employment and injury experience at slag (iron-blast-furnace) plants in the United States

Year	Men working daily	Average active plant days	Man-days worked (thousands)	Man-hours worked (thousands)	Number of injuries		Injury rates per million man-hours	
					Fatal	Nonfatal	Frequency	Severity
1960	1,680	NA	NA	3,613	--	34	9.41	1,050
1961	1,682	246	415	3,361	--	30	8.93	248
1962	1,462	248	362	2,927	--	29	9.91	417
1963	1,421	252	358	2,867	2	35	12.90	4,562
1964	1,472	264	389	3,107	1	53	17.38	3,895
1965	1,537	277	425	3,415	1	50	14.93	3,173

NA Not available.

Abrasive Materials

By Paul M. Ambrose [1]

Contents

Overall the domestic abrasives industry had one of its best years in 1965. Production and value of all commodities increased over that of 1964 which also was a good year. Production of tripoli that was down in the previous year rebounded and production from two new mines was reported. Plant capacities for production of silicon carbide and fused crude aluminum oxide and production from plants in the United States and Canada increased, but demand was high and yearend stocks were less than at the end of 1964.

Foreign Trade.—Increases in value of most imports of abrasive materials in 1965 were offset by a decrease in the value of imported industrial diamond. Production of fused aluminum oxide and silicon carbide in the United States and Canada and imports of these commodities into the United States increased, but combined exports of finished grain of these materials was virtually unchanged from the previous year.

[1] Commodity specialist, Division of Minerals.

Table 1.—Salient abrasive statistics in the United States

Kind	1956–60 (average)	1961	1962	1963	1964	1965
Natural abrasives (domestic) sold or used by producers:						
Tripoli ____ short tons	50,690	54,641	61,732	66,635	64,613	71,138
Value ____ thousands	$209	$225	$244	$266	$268	$381
Special silica-stone products [1] short tons	4,502	2,495	2,653	2,693	3,186	3,603
Value ____ thousands	$342	$238	$260	$255	$292	$432
Garnet ____ short tons	11,396	12,057	14,166	14,626	16,123	19,330
Value ____ thousands	$1,044	$1,036	$1,172	$1,412	$1,622	$1,717
Emery ____ short tons	9,691	6,180	4,316	6,732	9,214	10,720
Value ____ thousands	$155	$106	$71	$119	$172	$204
Artificial abrasives [2] ____ short tons	421,945	372,192	423,412	402,823	459,169	524,305
Value ____ thousands	$59,531	$54,937	$59,854	$56,523	$63,370	$73,102
Foreign trade (natural and artificial abrasives):						
Imports for consumption (value) thousands	$84,369	$96,219	$79,473	$77,500	r $89,299	$88,972
Exports (value) ____ do	$25,311	$29,209	$32,757	$35,774	r $43,455	$49,075
Reexports (value) ____ do	$10,706	$17,814	$11,454	$12,918	$17,142	$13,741

r Revised.
[1] See table 6 for kind of products.
[2] Production of silicon carbide and aluminum oxide (United States and Canada); shipments of metallic abrasives (United States).

Table 2.—U.S. exports of abrasive materials, by kinds

Kind	1964 Quantity	1964 Value	1965 Quantity	1965 Value
Natural abrasives:				
Diamond dust and powder ____________ carats____	1,892,097	$4,097,482	$1,147,838	$3,268,019
Diamond suitable only for industrial use carats____	1,324,195	4,710,488	2,003,218	7,317,265
Grindstones and pulpstones ______ short tons____	179	48,460	(1)	(1)
Whetstones, sticks, etc. (natural) ____ pounds____	271,942	162,950		
Emery powder, grains, and grit (natural) ____ do____	1,360,129	199,025	26,337,618	1,846,775
Corundum grains and grits (natural) _____ do____	308,386	73,666		
Natural abrasives not elsewhere classified pounds____	27,981,930	1,831,076		
Manufactured abrasives:				
Aluminum oxide, fused, crude, and grains pounds____	37,421,869	5,611,540	34,507,958	5,262,361
Silicon carbide, fused, crude, and grains ____ do____	22,430,140	3,863,948	25,518,766	5,774,644
Alumina, unfused ______________________ do____	902,253	143,651	(2)	(2)
Manufactured abrasives, not elsewhere classified pounds____	346,905	113,907		
Abrasive pastes, compounds, and cake (except chemical) _____________________ pounds____	r 944,480	r 301,905		
Diamond-grinding wheels and stones __ carats____	405,328	2,708,712	382,605	3,053,371
Grinding wheels except diamond wheels pounds____	r 3,240,038	4,485,107	4,327,701	6,437,862
Pulpstones of manufactured abrasives ____ do____	3,278,133	871,112	3,271,615	934,373
Whetstones etc. of manufactured abrasives ____ do____	472,847	1,261,764	570,865	1,039,798
Abrasive paper and cloth (natural abrasives) reams____	31,729	645,282	397,202	12,109,950
Abrasive paper and cloth (artificial abrasives) reams____	r 310,495	r 10,920,601		
Metallic abrasives (except steel wool) _ pounds____	17,290,096	1,404,483	22,202,412	1,922,528
Abrasives coated not elsewhere classified ________	-----	-----	-----	3 108,035
Total _________________________________	-----	r 43,455,159	-----	49,074,981

r Revised.
1 No longer separately classified, included in manufactures.
2 No longer separately classified.
3 Class established Jan. 1, 1965, value only.

Table 3.—U.S. reexports of abrasive materials, by kinds

Kind	1964 Quantity	1964 Value	1965 Quantity	1965 Value
Natural abrasives:				
Diamond-grinding wheels, sticks, hones, and laps carats____	950	$5,522	721	$7,632
Diamond dust and powder ______________ do____	185,037	373,269	146,799	409,507
Diamond suitable only for industrial use carats____	2,947,487	16,750,524	2,250,936	13,311,196
Emery powder, grains, and grits (natural) pounds____	10,500	1,155	900	848
Natural abrasives not elsewhere classified ____ do____	86,970	3,792		
Manufactured abrasives:				
Abrasive paper and cloth coated with natural and artificial abrasive materials ________ reams____	-----	-----	5	1,146
Abrasives coated not elsewhere classified __ _____	-----	-----	(1)	206
Aluminum oxide, fused, crude, and grains pounds____	600	286	-----	-----
Grinding wheels, except diamond wheels pounds____	5,436	5,175	2,167	9,115
Whetstones, etc., of manufactured abrasives pounds____	204	1,991	2,139	1,372
Total _________________________________	-----	17,141,714	-----	13,741,022

1 Class established Jan. 1, 1965, quantity not recorded.

Table 4.—U.S. imports for consumption of abrasive materials (natural and artificial), by kinds

Kind	1964 Quantity	1964 Value	1965 Quantity	1965 Value
Corundum, crude or crushed short tons	1,969	$53,130	1,900	$46,990
Emery, flint, rottenstone, and tripoli, crude or crushed short tons	18,519	517,632	17,702	504,664
Silicon carbide, crude do	79,557	9,659,262	89,604	11,078,129
Aluminum oxide, crude do	136,391	14,099,179	153,482	16,045,262
Other crude artificial abrasives do	2,764	270,402	3,839	396,673
Abrasives, ground, grains, pulverized or refined:				
Rottenstone and tripoli short tons	(1)	(1)	-----	-----
Silicon carbide do	603	205,636	1,083	346,998
Aluminum oxide do	r 3,338	772,450	5,971	1,157,787
Emery, corundum, flint, garnet, and other, including artificial abrasives short tons	99	26,341	247	51,355
Papers, cloths, and other materials wholly or partly coated with natural or artificial abrasives	(2)	1,788,809	(2)	2,655,637
Hones, whetstones, oilstones, and polishing stones number	234,526	52,322	177,304	46,098
Abrasive wheels:				
Solid natural stone wheels do	4,878	6,845	3,536	6,390
Diamond do	12,483	108,757	60,757	188,188
Other	(2)	553,261	(2)	493,059
Articles not specifically provided for:				
Emery or garnet	(2)	9,406	(2)	20,669
Natural corundum or of artificial abrasive materials	(2)	37,878	(2)	82,162
Other	(2)	66,053	(2)	40,169
Grit, shot, and sand of iron and steel short tons	r 2,825	r 864,643	2,214	314,362
Diamonds:				
Diamond dies number	8,022	163,711	8,522	179,707
Crushing bort carats	r 3,819,033	r 9,544,366	2,612,309	6,874,618
Other industrial diamonds do	r 6,944,599	r 39,583,201	5,412,395	34,548,945
Miners' diamonds do	782,391	4,074,312	705,615	3,700,044
Dust and powder do	r 2,731,888	r 6,840,920	4,108,995	10,194,041
Total	-----	r 89,298,516	-----	88,971,947

r Revised.
[1] Revised to none.
[2] Quantity not recorded.

TRIPOLI [2]

Output was by seven companies in six States. Since January 1, 1965, the Illinois Minerals Co. has produced (amorphous silica) from the property at Elco, Ill., formerly operated by Ozark Minerals Co. Other new producing companies in 1965 were Alasil Corporation, Waterloo, Ala., and Caddo Minerals Co., Inc., Glenwood, Ark. Companies that continued production were Tamms Industries Co., Tamms, Ill. (amorphous silica); American Tripoli Division, The Carborundum Co., Seneca, Mo.; and Ottawa County, Okla.; (Missouri-Oklahoma-tripoli); Penn Paint & Filler Co., Antes Fort, Pa. (rottenstone); and Keystone Filler & Manufacturing Co., Muncy, Pa. (rottenstone).

Material from Alabama was used for foundry facing and that from Arkansas, Missouri, and Oklahoma was used principally for buffing, polishing, and cleansing. The products from Illinois and Pennsylvania were used as abrasives and fillers.

Processed tripoli prices remained virtually unchanged from 1964 according to quotations in E&MJ Metal and Mineral Markets.

[2] Tripoli includes tripoli from the Missouri-Oklahoma, and Arkansas fields; amorphous or soft silica from Alabama and southern Illinois; and rottenstone from Pennsylvania. Although they differ in some respects, all are fine-grained, porous silica materials.

Table 5.—Processed tripoli [1] sold or used by producers in the United States, by uses [2]

Year	Abrasives		Filler		Other, including foundry facings		Total	
	Short tons	Value (thousands)	Short tons	Value (thousands)	Short tons	Value (thousands)	Short tons	Value (thousands)
1956–60 (average)	32,990	$1,400	7,975	$184	4,901	$161	45,866	$1,745
1961	34,581	1,472	9,409	231	4,605	149	48,595	1,852
1962	38,241	1,641	9,578	252	4,863	152	52,682	2,045
1963	38,979	1,645	10,145	276	5,619	197	54,743	2,118
1964	42,371	1,831	10,865	295	5,253	169	58,489	2,295
1965	48,935	2,025	11,011	296	4,830	142	64,776	2,463

[1] Includes amorphous silica and Pennsylvania rottenstone.
[2] Partly estimated.

SPECIAL SILICA-STONE PRODUCTS

Grindstone sales were reported from Ohio; abrasive material for oilstones from Arkansas; whetstones from Indiana; grinding pebbles from Minnesota and Wisconsin; and tube-mill liners from Minnesota. For the second successive year there was no reported production of millstones.

Table 6.—Special silica-stone products sold or used by producers in the United States [1]

Year	Short tons	Value (thousands)
1956–60 (average)	4,502	$342
1961	2,495	238
1962	2,653	260
1963	2,693	255
1964	3,186	292
1965	3,603	432

[1] Includes grinding pebbles, oilstones and other sharpening stones, tube-mill liners, grindstones, and value of millstones (1956–63).

NATURAL SILICATE ABRASIVES

Garnet.—Sales of domestic garnet, most of which has no sales value until crushed, concentrated, and ground to definite particle size specifications by the producer, increased substantially in both Idaho and New York. Increases were noted in garnet used for sandblasting and for skid-resistant paving. Little change was noted in the quantity of garnet produced for glass grinding, metal lapping, and wood, leather, and plastic sanding. Some losses of sales of abrasive-grade garnet were reported to be temporary and might be regained in 1966. Producers in 1965 were Idaho Garnet Abrasive Co., Division of Sunshine Mining Co., and Emerald Creek Garnet Milling Co., Fernwood, Idaho; Barton Mines Corp., North Creek, N.Y.; and Cabot Corp., Willsboro, N.Y. There was no reported production from Porter Brothers Corp., Valley County, Idaho.

Table 7.—Abrasive garnet sold or used by producers in the United States

Year	Short tons	Value (thousands)
1956–60 (average)	11,396	$1,044
1961	12,057	1,036
1962	14,166	1,172
1963	14,626	1,412
1964	16,123	1,622
1965	19,330	1,717

NATURAL ALUMINA ABRASIVES

Corundum.—Commercial production of corundum has not been reported in the United States or Canada since 1946 when production in Canada was last reported. The American Abrasive Co., Westfield, Mass., imported and processed corundum that was used principally as abrasive grains and powder for optical grinding and in lapping compounds.

Table 8.—World production of corundum, by countries [1]
(Short tons)

Country	1961	1962	1963	1964	1965 p [2]
India	363	332	725	r 595	e 600
Rhodesia, Southern	2,792	3,348	r 5,940	r 2,870	e 4,600
South Africa, Republic of	159	349	79	60	345
World total e	8,000	9,000	11,000	9,000	11,000

e Estimate. p Preliminary. r Revised.
[1] Corundum is produced in U.S.S.R., data on production are not available, but estimated output is included in the totals.
[2] Compiled from data available April 1966.

Emery.—De Luca No. 1 mine at Peekskill, N.Y., was closed throughout 1965, being nonproductive for the first time in several years. Producers were De Luca Emery mine from De Luca No. 2 at Peekskill, N.Y., Di Rubbo American Emery Ore from the Kinkston mine at Croton-on-Hudson, N.Y.; and Peekskill Emery Co. at Peekskill, N.Y. The consumption of emery, which increased 59 percent above that for 1964, was approximately equal for heavy-duty nonslip floors and pavements, and for abrasive purposes.

Table 9.—Emery sold or used by producers in the United States

Year	Short tons	Value (thousands)
1956–60 (average)	9,691	$155
1961	6,180	106
1962	4,316	71
1963	6,732	119
1964	9,214	172
1965	10,720	204

INDUSTRIAL DIAMOND

Foreign and Industry Review.—A decrease of 32 percent in imports of crushing bort in 1965 was counterbalanced by an increase of 50 percent in imports of dust and powder. Although most of the crushing bort originates in the Congo (Léopoldville) major imports were from the Republic of South Africa in 1964, and Ireland in 1965. Most of the imports from Ireland were in May, July, and October. Total imports of crushing bort and dust and powder that have similar end uses have been surprisingly regular for the past 3 years as 6.5 million carats were imported in both 1963 and 1964 and 6.7 million carats was imported in 1965. Most of the decrease of approximately 1.5 million carats of "Other industrial diamond" can be accounted for by a decrease of 1 million carats in imports from Republic of South Africa. Imports of miners' diamond have been constant since a separate class was established for this import for the full calendar years 1964 and 1965.

Production of manufactured diamond suitable for grinding wheels and saws, in the United States, was estimated at 5.5 million carats. This is the highest estimate since commercial production was first announced in 1957. Diamond was also manufactured in Ireland, Sweden, Japan, Republic of South Africa, and in the U.S.S.R.

Table 10.—U.S. imports for consumption of industrial diamond (excluding diamond dies)

(Thousand carats and thousand dollars)

Year	Quantity	Value
1956–60 (average)	13,064	$55,763
1961	14,210	68,545
1962	12,281	51,040
1963	11,846	49,884
1964	r 14,278	r 60,042
1965	12,839	55,318

r Revised.

WORLD REVIEW

AFRICA

Angola.—Angolan Exploration Co. (Pty.), Ltd., rights to explore for diamond over 64,000 square kilometers along the coast from Ambriz to Baia dos Tigres was being contested. The South African firm had been given a concession reportedly valid for 2 years and renewable for 1 to 3 years. The company expected to spend about $1 million to explore the area.[3]

[3] Bureau of Mines. Mineral Trade Notes. V. 60, No. 4, April 1965, p. 21.

Table 11.—U.S. imports for consumption of industrial diamond (including diamond dust), by countries

Year and country	Crushing bort (including all types of bort suitable for crushing)		Other industrial diamond (including glazers' and engravers' diamond, unset)		Miners' diamond		Dust and powder	
	Carat	Value	Carat	Value	Carat	Value	Carat	Value
1964:								
North America:								
Canada	19,672	$110,478	203,234	$1,151,217	15,622	$66,855	9,322	$15,162
Mexico	60,330	120,084	-----	-----	930	1,860	-----	-----
Total	80,002	230,562	203,234	1,151,217	16,552	68,715	9,322	15,162
South America:								
Brazil	-----	-----	13,943	169,699	400	3,382	-----	-----
British Guiana	-----	-----	1,630	32,429	-----	-----	-----	-----
Chile	-----	-----	372	108	-----	-----	-----	-----
Colombia	-----	-----	131	1,767	-----	-----	-----	-----
Venezuela	76	114	12,273	131,737	-----	-----	-----	-----
Total	76	114	28,349	335,830	400	3,382	-----	-----
Europe:								
Belgium-Luxembourg	415,161	985,707	606,433	3,281,663	4,557	44,899	140,402	340,215
France	34,850	54,958	6,431	62,589	1,362	6,958	-----	-----
Germany, West	6,000	9,300	33,315	375,245	-----	-----	3,809	9,136
Ireland	427,000	1,101,946	393,308	1,020,536	680,797	3,560,484	[r] 818,882	[r] 2,148,234
Italy	-----	-----	-----	-----	-----	-----	634	1,584
Malta, Gozo	-----	-----	422	3,150	-----	-----	-----	-----
Netherlands	350,876	836,655	128,651	929,467	5,905	47,497	52,460	130,945
Sweden	-----	-----	1,939	15,460	-----	-----	-----	-----
Switzerland	5,472	13,133	18,332	159,882	151	814	25,722	31,542
United Kingdom	[r] 516,045	[r] 1,339,904	[r] 898,681	[r] 7,608,101	34,256	171,332	[r] 996,040	[r] 2,383,069
Total	[r] 1,755,404	[r] 4,341,603	[r] 2,087,512	[r] 13,456,093	727,028	3,831,984	[r] 2,037,949	[r] 5,044,725

[r] Revised.

Table 11.—U.S. imports for consumption of industrial diamond (including diamond dust), by countries—Continued

Year and country	Crushing bort (including all types of bort suitable for crushing)		Other industrial diamond (including glazers' and engravers' diamond, unset)		Miners' diamond		Dust and powder	
	Carat	Value	Carat	Value	Carat	Value	Carat	Value
1964:								
Africa:								
British West Africa and Sierra Leone	4,748	$11,483	222,271	$4,723,771	-----	-----	6,818	$13,358
Central African Republic	8,362	21,396	61,960	895,680	25,617	$120,897	-----	-----
Congo (Léopoldville)	r 792,108	r 1,865,218	r 284,187	r 1,005,558	1,000	5,692	r 436,714	1,125,209
Ghana	2,500	9,625	r 1,205,831	r 5,850,050	-----	-----	2,176	6,528
Guinea	-----	-----	313	2,359	-----	-----	-----	-----
Ivory Coast	-----	-----	1,869	19,529	-----	-----	-----	-----
Liberia	7,260	17,884	3,227	31,554	200	1,115	-----	-----
Maderia Islands	-----	-----	1,514	7,870	-----	-----	-----	-----
Portuguese Western Africa, n.e.c	-----	-----	3,113	8,404	-----	-----	-----	-----
South Africa, Republic of	1,029,307	2,724,698	2,560,014	10,101,336	1,545	10,852	210,863	572,197
Western Africa, n.e.c	r 47,004	r 106,961	r 225,091	r 1,277,749	3,511	17,555	4,552	13,957
Total	r 1,891,289	r 4,757,265	r 4,569,390	r 23,923,860	31,873	156,111	r 661,123	1,731,249
Asia:								
Hong Kong	-----	-----	47	579	-----	-----	-----	-----
Israel	92,262	214,822	17,277	181,500	5,038	12,635	-----	-----
Japan	-----	-----	35,886	525,772	1,500	1,485	7,494	21,534
Korea, South	-----	-----	2,904	8,350	-----	-----	-----	-----
Total	92,262	214,822	56,114	716,201	6,538	14,120	7,494	21,534
Oceania: Australia	-----	-----	-----	-----	-----	-----	16,000	28,250
Grand total	r 3,819,033	r 9,544,366	r 6,944,599	r 39,583,201	782,391	4,074,312	r 2,731,888	r 6,840,920

1965:								
North America:								
Canada	1,072	3,651	167,250	980,657	1,034	4,675	20,411	39,945
Mexico	-----	-----	-----	-----	1,000	1,000	-----	-----
Total	1,072	3,651	167,250	980,657	2,034	5,675	20,411	39,945
South America:								
Argentina	-----	-----	101	1,071	-----	-----	-----	-----
Brazil	1,000	2,000	35,620	478,729	1,150	4,268	138	4,158
British Guiana	-----	-----	1,700	24,727	-----	-----	-----	-----
Venezuela	1,928	4,608	13,198	117,233	-----	-----	-----	-----
Total	2,928	6,608	50,619	621,760	1,150	4,268	138	4,158
Europe:								
Belgium-Luxembourg	160,067	383,892	602,083	3,086,157	82	1,568	285,539	631,548
France	152	441	1,439	21,371	-----	-----	350	630
Germany, West	-----	-----	11,906	204,856	205	2,380	3,108	7,769
Iceland	-----	-----	-----	-----	18,000	96,857	-----	-----
Ireland	1,321,000	3,507,656	430,006	1,018,615	606,593	3,169,119	2,611,844	6,716,123
Netherlands	105,123	269,898	239,137	1,448,075	9,620	66,574	199,156	497,909
Sweden	-----	-----	87,037	172,571	-----	-----	-----	-----
Switzerland	-----	-----	88,435	1,202,181	-----	-----	4,920	10,988
United Kingdom	622,812	1,629,975	1,024,807	10,074,357	11,543	59,347	545,544	1,278,923
Yugoslavia	-----	-----	609	7,563	-----	-----	-----	-----
Total	2,209,154	5,791,862	2,485,459	17,235,746	646,043	3,395,845	3,650,461	9,143,890
Africa:								
British West Africa and Sierra Leone	10,919	32,625	63,126	561,089	-----	-----	396	791
Central African Republic	13,581	38,864	98,031	1,336,711	32,439	144,359	-----	-----
Congo, (Léopoldville)	196,942	467,318	153,424	428,683	3,050	16,671	900	2,363
Ghana	-----	-----	510,005	2,683,152	-----	-----	879	2,330
Guinea	-----	-----	5,545	45,809	-----	-----	-----	-----
Ivory Coast	-----	-----	4,883	26,186	-----	-----	-----	-----
Liberia	-----	-----	462	2,351	-----	-----	-----	-----
Portuguese Western Africa, n.e.c.	-----	-----	5,582	25,025	-----	-----	-----	-----
South Africa, Republic of	104,088	279,872	1,571,967	8,347,673	20,849	132,526	365,903	859,167
Western Africa, n.e.c.	73,625	253,818	197,000	1,358,945	50	700	32,562	80,474
Total	399,155	1,072,497	2,610,025	14,815,624	56,388	294,256	400,640	945,125

Table 11.—U.S. imports for consumption of industrial diamond (including diamond dust), by countries—Continued

Year and country	Crushing bort (including all types of bort suitable for crushing)		Other industrial diamond (including glazers' and engravers' diamond, unset)		Miners' diamond		Dust and powder	
	Carat	Value	Carat	Value	Carat	Value	Carat	Value
1965:								
Asia:								
Israel	-----	-----	13,630	$172,227	-----	-----	-----	-----
Japan	-----	-----	36,237	445,524	-----	-----	11,780	$35,358
Korea, South	-----	-----	400	5,577	-----	-----	-----	-----
Thailand	-----	-----	47,775	265,684	-----	-----	-----	-----
Total	-----	-----	98,042	889,012	-----	-----	11,780	35,358
Oceania: Australia	-----	-----	1,000	6,146	-----	-----	25,565	25,565
Grand total	2,612,309	$6,874,618	5,412,395	34,548,945	705,615	$3,700,044	4,108,995	10,194,041

Table 12.—World production of natural industrial diamond, by countries

(Thousand carats)

Country	1964	1965
Africa:		
Angola	345	277
Central African Republic	221	268
Congo (Brazzaville) [1] [2] [e]	4,949	4,982
Congo (Léopoldville)	14,457	12,490
Ghana	2,402	2,023
Guinea [1]	[r] 51	[e] 51
Ivory Coast	80	77
Liberia [1]	272	263
Sierra Leone	[r] 878	804
South Africa, Republic of:		
"Pipe" mines:		
Premier	1,668	[e] 1,963
De Beers Group [3]	759	[e] 916
Other Pipe Mines	41	[e] 42
Alluvial	192	[e] 126
South-West Africa	154	158
Tanzania	326	[e] 414
Total Africa	[r] 26,795	24,854
Other areas:		
Brazil [e]	175	175
British Guiana	49	68
India	1	1
U.S.S.R.	2,760	3,200
Venezuela	58	45
World total [4]	[r] 29,838	28,343

[e] Estimated. [r] Revised.
[1] Exports.
[2] Probable Origin, Republic of the Congo.
[3] Includes some alluvial from DeBeers Properties.
[4] Does not include minor world production.

Ghana.—A new plant capable of treating 80,000 tons of diamond-bearing gravel per month was completed at Akwatia for Consolidated African Selection Trust Ltd. (CAST). The plant is complete with sections for feeding, washing and screening, gravel storage, concentrating, and waste disposal. A 600-ton storage bin assures a steady rate of feed to the concentrator.[4]

In late 1964 the Ghanaian Government announced plans to establish a government organization to control the production and marketing of diamond. Plans were to withdraw existing licenses of diggers and centralize mining other than that done by CAST, Akim Concessions Ltd., and Cayco Ltd. under the Government organization. Strict control would be maintained to prevent smuggling.[5]

Guinea.—Soviet geologists have been prospecting in Guinea for the past few years during which several important mineral finds have been claimed. The most recent was a diamond find in the Forecariah area southeast of Conakry. It was not stated whether the find was an alluvial or kimberlite occurrence.[6]

Mozambique.—Two local residents were granted a concession to explore for diamond in the Chicualacuala, Pafurs, and Malvernia regions of Mozambique. Available capital for exploration was reported to be approximately $420,000.[7]

Sierra Leone.—The licensed diamond mining in Sierra Leone including licensing, location of deposits, geology, mining methods, and marketing were discussed.[8]

South Africa, Republic of.—Diamond-bearing yellow ground removed as overburden at the Finsch mine was being treated in a pilot plant. The Finsch mine was scheduled to start producing early in 1966 and be worked by open pit method until a depth of 500 to 600 feet had been reached after which mining would be underground. One million loads of ground had been stockpiled for treatment in the main plant and over half of the overburden had been removed from the top of the pipe that is 40 acres in area.[9]

Rand Mines Ltd. and De Beers Consolidated Mines Ltd. planned to prospect 8,970 acres adjacent to the De Beers Finsch mine in Cape Province on land owned and controlled by Northern Lime Co. If exploration was successful Rand Mines and De Beers would each be entitled to subscribe at par for 30 percent of stock in any mining company that might be formed. Northern Lime would be refunded costs incurred in acquiring prospecting rights and could purchase 40 percent of any stock at par value.[10] A diamond-bearing pipe 340 feet deep was discovered and reported to be producing exceptionally well between Dealesville and Boshof in the Orange Free State.[11]

A 1,000-ton-per-day plant, in which 500 tons per day of kimberlite ore were being treated, was put on stream in Orange Free

[4] Mining Journal (London). V. 265, No. 6786, Sept. 3, 1965, p. 167.
[5] Bureau of Mines. Mineral Trade Notes. V. 61, No. 5, November 1965, p. 12.
[6] Bureau of Mines. Mineral Trade Notes. V. 61, No. 1, July 1965, p. 13.
[7] Mining Journal (London). Diamond Prospecting in Mozambique. V. 265, No. 6789, Oct. 1, 1965, p. 237.
[8] Fairbairn, W. C. Licensed Diamond Mining in Sierra Leone. Min. Mag. (London), v. 112, No. 3, March 1965, pp. 166–167, 169, 171, 173, 175, 177.
[9] Mining Magazine (London). Plant for Diamond Recovery. V. 113, No. 4, October 1965, p. 313.
[10] South African Digest (Pretoria). Diamond Prospecting. V. 12, No. 32, Aug. 13, 1965, p. 15.
[11] Engineering and Mining Journal. V. 166, No. 9, September 1965, p. 226.

State. The extra capacity was to be used in treating dump material until a dump washing plant could be constructed. It was planned to increase the feed to the main plant to reach capacity rates. Additional exploration was planned.[12]

The Helam mine in the western Transvaal was started 8 years ago. It has 5 years of proven reserves and a probable life of more than 30 years, if mining is continued at the rate of 12,000 tons per month. Percent rate of recovery from newly mined kimberlite ranges from 225 carats per 100 tons to 290 carats per 100 tons. The average is 260 carats per 100 loads, the highest in the world. Combined production from kimberlite and tailings average 13,600 carats per month of which 65 percent are industrial stones.[13]

South-West Africa.—A new heavy-medium plant to increase the recovery of diamond to 10,000 carats per month at Consolidated Diamond mines was brought into production in September. The addition was completed in less than 1 year at a cost of $980,000 and should make possible a total production of 125,000 carats per month.[14]

Tanzania.—Diamond deposits were discovered near Kahama. Williamson Diamonds owned equally by the Tanzania Government and the De Beers Organization was planning to work the new discovery that contains both gems and industrial diamond.[15]

EUROPE

Greece.—Greek emery sales have declined owing to the competition from natural abrasives. Early in 1965 the Greek Ministry of Industry commissioned Fried. Krupp Industriebau of West Germany to investigate the economic feasibility of producing electrocorundum and a study of chemically producing corundum from emery was underway by an emery processing firm in Greece in cooperation with the Hellenic Industrial Development Bank.[16]

TECHNOLOGY

A method for manufacturing diamond developed at the University of Bonn was claimed to have absolute certainty and reproducibility. A cylinder of pure graphite mixed with nickel powder was in a chamber and the pressure raised to 59 to 70 kilobars. When the charge was raised to 1,200° C by an electric current the transformation began and resistance of the graphite sample increased. Cubes were produced at 1,240° C, cube-octahedrons between 1,300° C and 1,400° C, and octahedrons between 1,450° C and 1,500° C. The diamonds had a maximum diameter of 0.5 millimeter, but it was stated that larger diamonds could have been made in a larger pressure chamber. They were clear, transparent, and colorless to light green.[17] Another method of synthesizing diamond was developed by Japan, Inc., located just outside Tokyo. Graphite electrodes were inserted in a closed vessel filled with a dielectric fluid. Impulse heat and pressure were used and the electrodes were quenched in the fluid. The product was termed "instant diamonds."[18]

Clues needed to appraise the potential of any diamond occurrence and the economics of exploitation were discussed. The necessity for thorough sampling including milling large quantities of ore in a pilot mill. Costs and controlling returns for various deposits of different sizes were emphasized. Offshore and beach deposits had high exploratory and operating costs.[19]

An X-ray luminescent apparatus coupled with a microscope was used to study the distribution of small diamonds in kimberlite and the interrelationship with rock-forming minerals. The method was used to study diamond not visible to the naked eye—less than 0.1 micron. Both small and large diamond crystals are encrusted in a carbonate-serpentine mass. Additional work

[12] World Mining. V. 18, No. 12, November 1965, p. 77.

[13] South African Mining and Engineering Journal. V. 76, pt. 2, No. 3778, July 2, 1965, pp. 1538–1540, 1542–1544, 1546, 1548.

[14] Bloecher, F. William. Fine Grind. Min. Eng., v. 17, No. 12, December 1965, pp. 60–61.

[15] Mining Journal (London). Diamond Find in Tanzania. V. 265, No. 6777, July 9, 1965, p. 31.

[16] Bureau of Mines. Mineral Trade Notes. V. 60, No. 5, May 1965, pp.3–4.

[17] New Scientist. Simpler Route to Synthetic Diamond? V. 28, No. 464, October 1965, p. 27.

[18] Chemical Week. V. 97, No. 5, July 31, 1965, p. 52.

[19] South African Mining and Engineering Journal (Johannesburg). The Evaluation of South African Diamond Occurrences. V. 76, No. 3799, Nov. 26, 1965, pp. 2793–2794.

may help to explain the genesis of diamond.[20]

The residual energy of X-rays after passing through solids was used as the basis of a process for separating diamond from concentrate. Hand sorting from concentrate involved visual appraisal with accompanying possible errors in not detecting all diamond. Residual energies of X-rays after passing through diamond are at least 10 times as great as that remaining after passing through other materials. Residual energies were transformed into light to influence the cathode of a photoelectric cell. Amplified signals were used in separating the stones into diamond and nondiamond. Presized material was fed onto a drum whose surface was covered with cup-shaped recesses. Feed was held in the cups by suction. After identification diamond was blown off in a chute and other material was delivered to a second container. A diagrammatic layout of the separator and capacities and efficiencies were given.[21]

When nitrogen atoms with five electrons are attached to carbon stones with four electrons as in the diamond, the surplus electrons from the nitrogen can absorb low energy light. Investigations disclosed that the yellow color of both natural and manufactured diamond and the greenish color in some manufactured stones and in some Congo diamond was due to surplus electrons.[22]

Bulldozers were being used to push overburden into the sea to form breakwaters on the northwestern cape coastline. After removing up to 20 feet of overburden the same bulldozers were used to push diamondiferous gravel into stockpiles above high water. The gravel ranged from 6 inches to 2 feet in thickness.[23]

Results at a pilot plant at the Finsch mine indicated that the diamond was more difficult to recover on a grease table than diamonds from the Kimberly mine. The diamonds are better recovered on specially designed grease belts and a heavy-medium separator gives a better concentrate for further treatment. About 95 percent of the ore can be removed readily as a light fraction. The medium was a mixture of ferrosilicon and water with a specific gravity of 2.75. In plant operation gem diamond would be recovered in primary and secondary pans and fine-sized diamonds for industrial use would be recovered in additional pans. Pan concentrate would be treated by heavy-medium separation followed by grease belts and hand sorting.[24]

Dry grinding with resin-bonded diamond wheels at wheel surface speeds ranging from 2,500 to 3,000 standard cubic feet per minute, resulted in greater grinding efficiency than when excessive wheel speeds were used. Speeds of greater than 5,000 standard cubic feet per minute were only half as effective as the optimum speed.[25]

Surface irregularities of metals were ironed out and a satisfactory smoothness was obtained when a spherical-shaped diamond point was moved over the metal surface in an overlapping path of a series of such paths. Compression of the surface layer improved the fatigue strength. The greatest initial surface roughness could be tolerated with very ductile metals. With harder less-ductile metals the permissible degree of surface roughness was less. The smoothing tool had a radius of 1.3 millimeters.[26]

Cost-performance evaluation and test procedures for grinding carbides wet with resinoid diamond wheels were described in a series of articles. Total costs included cost of wheel plus labor cost and overhead. A method for determining the volumetric efficiency (cubic inches carbide ground per cubic inches wheel loss) was developed.[27]

Diamond saws were used for the first time to cut 3/16-inch-wide channels 1½ inches deep prior to laying cable for a road heating system at Shell Centre on the

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[20] Rozhkov, I. S., and K. K. Abrashev. Research on Diamond-Bearing Kimberlite Ores. Ind. Diamond Rev., v. 25, No. 296, July 1965, pp. 297–301.

[21] Industrial Diamond Review. Automatic Separation of Diamonds From Concentrate. V. 25, No. 290, January 1965, pp. 6–7.

[22] South African Mining and Engineering Journal (Johannesburg). Nitrogen in Diamonds Governs Their Shape and Colour. V. 76, pt. 2, No. 3802, Dec. 17, 1965, pp. 2973–2974.

[23] South African Mining and Engineering Journal (Johannesburg). Beachcombing by Bulldozer. V. 76, pt. 1, No. 3757, Feb. 5, 1965, p. 303.

[24] Mining Magazine (London). Plant for Diamond Recovery. V. 113, No. 4, October 1965, p. 313.

[25] Iron Age. Excessive Speed Reduces Dry Grinding Performance! V. 196, No. 4, July 22, 1965, pp. 48–49.

[26] Light Metals and Metal Industry (London). Diamond Ironing for Smoothing Metal Surfaces. V. 28, No. 328, September 1965, p. 69.

[27] Thompson, John R. Cost-Performance Evaluation of Diamond Wheels. Grinding and Finishing, v. 11, No. 8, August 1965, pp. 34–36.
———Test Procedures for Grinding Carbides Wet. Grinding and Finishing, v. 11, No. 10. October 1965, pp. 35–37.

South Bank of the Thames, London.[28]

Diamond was being used to groove master gratings from which other diffraction gratings were made for use in metrology, spectroscopy, and astronomy. Gratings with as many as 250,000 grooves to the inch were being made for use in space technology. The grooves were all parallel and equidistant to within 1 millionth of an inch.[29]

A diamond blade in a power hacksaw was used to fit precut marble slabs used in a hotel lobby. When a slab had to be cut a pattern was made on the floor and the slab was marked following the pattern. Cutting was so easy that no fixing was necessary during cutting that was done at speeds up to 24 inches per minute. It was estimated that the blade could have cut more than 1,000 linear feet of ⅞-inch marble before it had to be replaced.[30]

A rough-riding 8,000 square-foot deck section of the Golden Gate Bridge was restored to original smoothness with a desirable corduroy skid-resistant surface without rerouting traffic. A newly ground surface could be immediately opened to traffic. Bumps ranging from 1/6 to 3/8 inch were removed by 120 diamond-impregnated saw blades mounted on a single arbor. Only 42½ hours were required to restore the road surface.[31]

Diamond saws were used instead of silicon carbide saws in sawing a broad array of fused quartz carriers to hold thin silicon wafers for heat treating. Both ¼-inch plates and 3/16-inch plates were cut from a wheel-shaped fused quartz ingot 18 inches in diameter and 7 inches thick.[32]

Diamond was used in both grinding and polishing thin sections for electron microprobe analysis,[33] and a new holder for grinding thin sections using diamonds for wear points was highly satisfactory.[34]

Outstanding time savings in piercing and polishing small diamond dies were claimed for an ultrasonic drilling machine devised at the Moscow Cable Research Institute. First holes were irregular in shape and badly finished. Improvements were reported as testing proceeded. The advantages claimed were a reduction from 120 hours to 2 hours in drilling a diamond die 0.5 millimeter in diameter and a reduction from 3 hours to 30 minutes in polishing time. Dies were reported to be more durable.[35]

ARTIFICIAL ABRASIVES

Legislation and Government Programs.—As part of the program to reduce stockpiles of material not needed and to dispose of stockpiled materials not meeting specifications, the General Services Administration sold 56 short tons of impure silicon carbide. Sealed bids were opened on December 17, 1965. The successful bidder was American Metallurgical Products Co., Inc., Pittsburgh, Pa., who paid $4,032 for the lot.

Industry Review.—A 3-year trend for increased production of abrasive-grade aluminum oxide and silicon carbide in the United States and Canada has been established. Production of silicon carbide was 5,000 tons greater than in 1960, the previous record year. Most nonmetallic artificial abrasives are manufactured in Canada and processed in the United States. Some abrasive grain is returned to Canada for use in grinding wheels and other abrasive products. Silicon carbide production was at 89 percent of capacity; aluminum oxide at 64 percent; and metallic abrasives at 50 percent. Nonabrasive uses consumed 5 percent of the aluminum oxide and 41 percent of the silicon carbide.

Metallic abrasives continued to assume an increasingly more important role among the artificial abrasives. In 1965 metallic abrasives sold or used accounted for more

[28] Industrial Diamond Review. Diamonds Saw Asphalt at Shell Centre. V. 25, No. 292, March 1965, p. 117.

[29] Industrial Diamond Review. As A Rule It's Diamond. V. 25, No. 298, September 1965, pp. 394–395.

[30] Industrial Diamond Review. On-Site Trimming of a Marble Floor. V. 25, No. 300, November 1965, p. 491.

[31] Roads and Streets. Massed Diamond Blades Un-Roughen Famed Bridge Deck. V. 108, No. 10, October 1965, pp. 70–71.

[32] South African Mining and Engineering Journal (Johannesburg). Diamonds Tame Fused Quartz. V. 76, No. 3804, Dec. 31, 1965, p. 3076–3077.

[33] Cadwell, Donald E., and Paul W. Weiblen. Diamond Disc Preparation of Polished Thin Sections for Electron Microprobe Analysis. Econ. Geol., v. 60, No. 6, September–October 1965, pp. 1320–1325.

[34] Cochran, M. C., and J. R. Jensen. An Improved Holder for Grinding Thin Sections. Am. Minerologist, v. 50, Nos. 11, 12, November–December 1965, pp. 2092–2094.

[35] Tverskoy, Igor. Diamond Dies Drilled by Ultrasonics. Ind. Diamond Rev., v. 25, No. 301, December 1965, pp. 599–601.

Table 13.—Crude artificial abrasives produced in the United States and Canada

Year	Silicon carbide [1]		Aluminum oxide [1] (abrasive grade)		Metallic abrasives [2]		Total	
	Short tons	Value (thousands)	Short tons	Value (thousands)	Short tons	Value (thousands)	Short tons	Value (thousands)
1956–60 (average)	119,320	$18,862	180,181	$23,362	122,444	$17,307	421,945	$59,531
1961	125,726	20,078	136,951	18,735	109,515	16,124	372,192	54,937
1962	115,716	17,728	181,924	23,458	125,772	18,668	423,412	59,854
1963	109,351	15,530	160,064	20,936	133,408	20,057	402,823	56,523
1964	131,905	18,432	171,462	21,493	155,802	23,445	459,169	63,370
1965	138,282	19,963	195,476	24,909	190,547	28,230	524,305	73,102

[1] Figures include material used for refractories and other nonabrasive purposes.
[2] Shipments for U.S. plants only.

than 36 percent of the total quantity of artificial abrasives and nearly 39 percent of the total value. Production of metallic abrasives was a record high. An increase of 19 percent was registered for both quantity and value over the previous year's production. Four States supplied over 88 percent of the metallic abrasives production. These States, in descending order of production, were Ohio, Michigan, Pennsylvania, and Indiana. Ohio alone produced 37 percent of the total metallic abrasives.

Table 14.—Production, shipments, and stocks of metallic abrasives in the United States, by products

Year and product	Manufactured		Sold or used		Stocks Dec. 31 (short tons)	Annual capacity (short tons)
	Short tons	Value (thousands)	Short tons	Value (thousands)		
1964:						
Chilled iron shot and grit	40,823	$4,407	40,470	$4,618	13,805	253,438
Annealed iron shot and grit	35,710	4,028	35,541	4,199	1,813	[1] 101,894
Steel shot and grit	76,921	12,727	77,866	14,037	6,963	122,850
Other [2]	2,177	638	1,925	592	517	9,700
Total	155,631	21,800	155,802	23,446	[3] 23,098	385,988
1965:						
Chilled iron shot and grit	42,804	4,502	48,181	5,257	8,428	238,838
Annealed iron shot and grit	43,032	5,290	43,474	5,410	1,371	[1] 101,894
Steel shot and grit	96,436	15,360	95,857	16,764	7,542	128,530
Other [2]	3,303	759	3,035	799	785	9,450
Total	185,575	25,911	190,547	28,230	18,126	376,818

[1] Included in capacity of chilled iron shot and grit.
[2] Includes cut wire shot.
[3] Includes revisions in product detail.

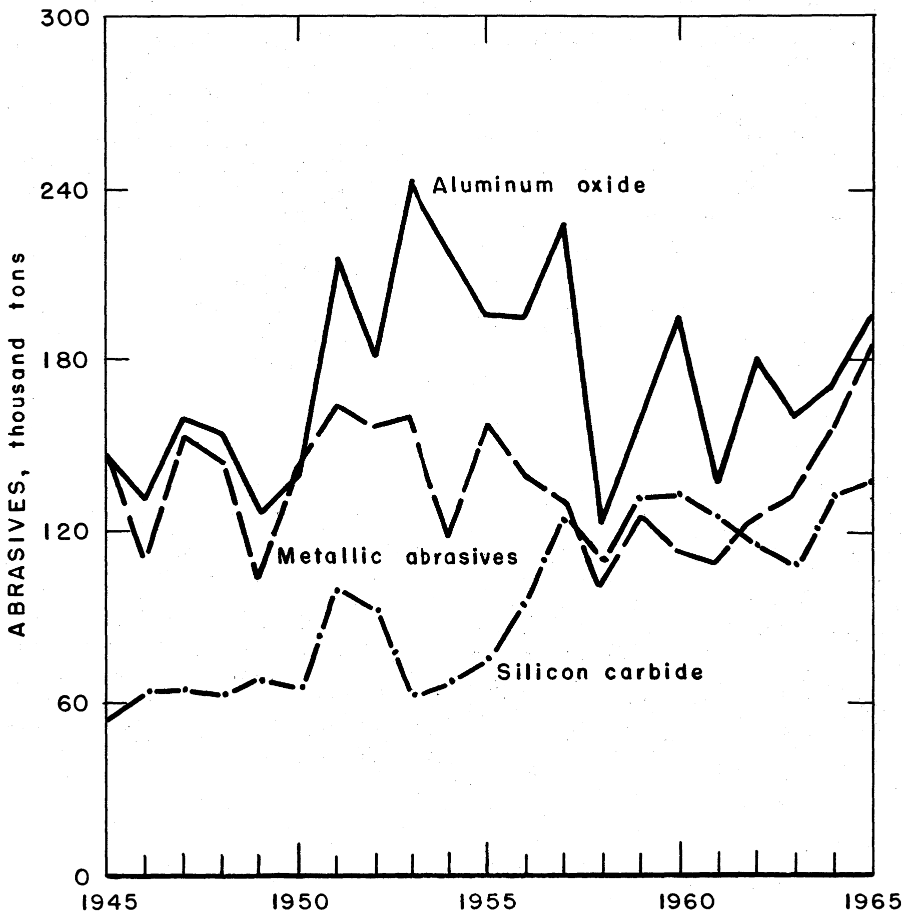

Figure 1.—Artificial abrasives production.

Table 15.—Stocks of crude artificial abrasives and capacity of manufacturing plants, as reported by producers in the United States and Canada

(Thousand short tons)

Year	Silicon carbide		Aluminum oxide		Metallic abrasives [1]	
	Stocks Dec. 31	Annual capacity	Stocks Dec. 31	Annual capacity	Stocks Dec. 31	Annual capacity
1956-60 (average)	12.3	136.1	33.2	296.1	16.5	262.2
1961	14.7	145.7	23.2	299.5	18.6	265.4
1962	19.2	144.9	33.8	299.5	21.2	363.9
1963	11.2	146.5	20.6	303.4	19.2	380.5
1964	15.0	152.5	14.5	298.8	r 23.1	386.0
1965	9.1	155.9	10.9	304.8	18.1	376.8

r Revised.
[1] United States only.

TECHNOLOGY

A new method was developed for producing high-purity silicon carbide by reacting graphite and a silicon tetrachloride-saturated hydrogen gas.[36]

An investigation of the cutting edges of abrasive wheels that although the cutting edges of the grit were affected by both the grinding action and the dressing action wear of the grain by sliding of the cutting edges did not result in a self-dressing action of grains in the usual grinding work.[37]

Electrolytically assisted honing showed promise of reducing honing time in finishing metal parts. In electrolytic honing the cathode is the honing tool and the anode is the work piece. Electrolyte was introduced through slots in the honing tool. Time savings of approximately 80 percent were realized in typical tests.[38]

Advantages of mechanical descaling over pickling of steel were discussed in considerable detail. This technique eliminated need for pickling in some instances. Among the claimed advantages for many operations were elimination of liquor-disposal problems, avoidance of hydrogen embrittlement, better control, speed up of operations, better surfaces for further treatment and, in some instances, lowering costs to about two-fifths of former pickling costs.[39]

MISCELLANEOUS MINERAL-ABRASIVE MATERIALS

In addition to the natural and artificial abrasive materials for which data are available, many other minerals were used for abrasive purposes. Oxides of tin, magnesium, iron, and cerium were used for polishing. Boron carbide and tungsten carbide were used as abrasives where extreme hardness was required. Finely ground and calcined clays, lime, talc, ground feldspar, river silt, slate flour, whiting, and other materials also were used as abrasives.

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[36] Wakelyn, N. T., and R. A. Jewell (assigned to U.S. Administrator of National Aeronautics and Space Administration). Production of High Purity Silicon Carbide. U.S. Pat. 3,174,827, Mar. 23, 1965.

[37] Tsuwa, Hideo. An Investigation of Wheel Cutting Edges. Grinding and Finishing, pt. 1, v. 10, No. 12, December 1964, pp. 22–27; pt. 2, v. 11, No. 1, January 1965, pp. 30–34.

[38] Iron Age. Honing Gets Electrolytic Help. V. 195, No. 15, Apr. 15, 1965, pp. 106–107.

Steel. Electrochemical Honing Nearing Production Stage. V. 157, No. 6, Aug. 9, 1965, p. 44.

[39] Toles, George E. Mechanical Descaling Over Pickling. Grinding and Finishing, v. 11, No. 6, June 1965, pp. 26–28.

Aluminum

By John W. Stamper [1]

Growth in demand for aluminum and international developments in the industry continued to be prominent. Apparent consumption in the United States increased 16 percent. In Europe joint ventures in the aluminum industry in France, Belgium, and West Germany were formed. New primary aluminum production plants were built or scheduled in Iceland, Brazil, Venezuela, Greece, the Netherlands, Japan, Australia, and the U.S.S.R.

A study of the two methods of replacing anode carbon in aluminum reduction cells (Soderberg and prebaked) indicated that the continuous Soderberg system is used by 63 percent of the aluminum plants in the free world, by about 46 percent of the facilities in the United States, and by about half of the entirely new plants built in the free world during recent years.

Table 1.—Salient aluminum statistics
(Thousand short tons and thousand dollars)

	1956–60 (average)	1961	1962	1963	1964	1965
United States:						
Primary production	1,772	1,904	2,118	2,313	2,553	2,754
Value	$880,307	$949,768	$998,559	$1,039,812	$1,196,013	$1,337,795
Price: Ingot, average cents per pound	26.7	25.5	23.9	22.6	23.7	24.5
Secondary recovery	336	340	462	506	552	641
Exports (crude and semicrude)	152	238	259	292	349	313
Imports for consumption (crude and semicrude)	263	255	377	466	453	621
Consumption, apparent	2,172	2,320	2,770	3,040	3,216	3,736
World: Production	4,145	5,185	5,580	6,075	6,720	7,415

Legislation and Government Programs.—Interested Government agencies and major aluminum producers held a number of group meetings and individual conferences to develop a long-range program to dispose of approximately 1.4 million short tons of primary aluminum, which was excess to the objective of 450,000 tons. A Memorandum of Understanding was signed on November 23 by the General Services Administration with the Aluminum Company of America, Kaiser Aluminum & Chemical Corp., Reynolds Metals Co., and Olin Mathieson Chemical Corp., who agreed to participate in the purchase of the aluminum excess.

Subject to obtaining congressional approval, the Office of Emergency Planning authorized the disposal of the excess aluminum. The disposal plan provides that sales will be through long-term contracts with primary aluminum producers (with set-asides to small business) pursuant to contracts requirements (included in the Department of Defense contracts and in contracts of other agencies, if feasible). Defense contractors and subcontractors will be required to purchase or pass on to the participating producers the quantities of excess stockpile aluminum needed for the end-products acquired under the contracts. Participating producers agreed to guarantee the sale of 150,000 tons from November 1, 1965, to December 31, 1966, and

[1] Commodity specialist, Division of Minerals.

their respective shares of 100,000 tons per year thereafter; or if the Government requirements involved in this disposal program in any such period are greater, a quantity not in excess of 200,000 tons in any such period. After December 31, 1966, certain deferrals of obligations to purchase will be permitted, but all obligations to purchase during each successive 4-year period (the first such period extending from November 1, 1965, through December 31, 1969) must be fulfilled by December 31, 1969, and during each successive 4-year period not later than the end of such period.

During the 2-month period ending December 31, 1965, GSA sales of aluminum from Defense Production Act (DPA) inventories were 49,455 short tons with a sales value of $24.5 million.

In March, GSA made a final offering of the 34,800 tons (of 135,000 tons), which remained to be sold under a 2-year program which started on May 1, 1963, and sold 5,800 tons valued at $2.8 million. The 29,000 tons which remained unsold was to be included as a part of the long-range aluminum disposal program.

The Business and Defense Services Administration announced that the aluminum set aside for defense and related orders for the first quarter of 1966 would be raised to 107,500 tons, compared with the 64,000 tons set aside in each quarter of 1965. The increase reflected the demand created by military action in South Viet-Nam.

The quantity of aluminum metal in the national (Strategic) stockpile at yearend was 1,129,000 tons. An additional 768,000 tons was in the DPA inventory.

DOMESTIC PRODUCTION

PRIMARY

Primary aluminum output reached a new record for the fourth successive year, 8 percent higher than in 1964 and virtually 100 percent of the yearend capacity.

Aluminum Company of America (Alcoa) activated the second and third potline at its Warrick, Ind., reduction plant, increasing annual capacity to 75,000 tons. The company reported production capacities at its primary aluminum reduction plants in 25,000 ton increments, resulting in slight changes from previous ratings at some of the plants as shown in table 3. Alcoa also planned to build, by 1966, a multimillion-dollar rolling mill at Lebanon, Pa., to produce aluminum foil.

Intalco Aluminum Corp. continued construction of a 76,000-ton-per-year aluminum reduction plant at Bellingham, Wash., and was expected to start operations at the plant by the second quarter of 1966. The company started construction of a second unit to bring total capacity of the plant to 152,000 tons by 1967.

Anaconda Aluminum Co. began production from a third potline at its Columbia Falls, Mont., aluminum reduction plant, bringing annual primary aluminum capacity of the facility to about 100,000 tons. A fourth line was scheduled to be built by 1968, raising capacity to 135,000 tons.

Through a continuing program of modernization and technologic improvements in operating practices, Kaiser Aluminum & Chemical Corp. raised capacity of its aluminum reduction plants at Chalmette, La.; Mead, Wash.; and Ravenswood, W. Va. bringing total capacity of the company's reduction plants, including its Tacoma, Wash., facility, to 650,000 tons per year. The company began truck deliveries of molten aluminum metal to the Chrysler Corp. foundry at Kokomo, Ind., from its

Table 2.—Production and shipments of primary aluminum in the United States

(Short tons)

Quarter	1964		1965	
	Production	Shipments	Production	Shipments
First	626,418	619,465	655,934	671,752
Second	626,680	645,665	691,235	692,866
Third	644,612	621,675	688,599	697,039
Fourth	655,037	668,093	718,710	724,927
Total	2,552,747	2,554,898	2,754,478	2,786,584

Table 3.—Aluminum production capacity in the United States, by companies
(Short tons per year)

Company and plant	Capacity: Actual, end of 1965: Prebaked	Capacity: Actual, end of 1965: Soderberg	Being built in 1965	Total, actual and under construction
Aluminum Company of America:				
Alcoa, Tenn	50,000	75,000		125,000
Badin, N.C	50,000			50,000
Evansville, Ind	75,000		100,000	175,000
Massena, N.Y	125,000		25,000	150,000
Point Comfort, Tex		175,000		175,000
Rockdale, Tex	175,000			175,000
Vancouver, Wash	100,000			100,000
Wenatchee, Wash	125,000			125,000
Total	700,000	250,000	125,000	1,075,000
Reynolds Metals Co.:				
Arkadelphia, Ark		55,000		55,000
Jones Mills, Ark	109,000			109,000
Listerhill, Ala		194,500		194,500
Longview, Wash		65,000		65,000
Massena, N.Y		115,000		115,000
San Patricio, Tex		95,000	9,500	104,500
Troutdale, Oreg	91,500			91,500
Total	200,500	524,500	9,500	734,500
Kaiser Aluminum & Chemical Corp.:				
Chalmette, La		257,000		257,000
Mead, Wash	193,000			193,000
Ravenswood, W. Va	159,000			159,000
Tacoma, Wash		41,000		41,000
Total	352,000	298,000		650,000
Anaconda Aluminum Co.: Columbia Falls, Mont		100,000	35,000	135,000
Consolidated Aluminum Corp.: New Johnsonville, Tenn	62,000		44,000	106,000
Harvey Aluminum, Inc.: The Dalles, Oreg		87,000		87,000
Ormet Corp.: Hannibal, Ohio	185,000		40,000	225,000
Intalco Aluminum Corp.: Bellingham, Wash			[1] 152,000	152,000
Grand total	1,499,500	1,259,500	405,500	3,164,500

[1] Prebaked anodes will be used.

Ravenswood, W. Va., reduction plant. Under a contract arrangement delivery of about 30,000 tons per year over the 300-mile distance is scheduled through 1970.

Early in the year Consolidated Aluminum Corp. (Conalco) completed expansion of its primary aluminum production facilities at New Johnsonville, Tenn., bringing total capacity to about 62,000 tons per year. Later in the year, Conalco announced that it would build another potline at New Johnsonville and expand the two existing ones to bring total primary aluminum capacity to 106,000 tons per year by the end of 1966.

Reynolds Metals Co. announced that capacity of its reduction plant at San Patricio, Tex., would be increased 10 percent to 104,500 tons of primary aluminum per year by late 1966. The expansion of the San Patricio plant was expected to be the first increase resulting from the $140 million expansion program Reynolds announced in 1964, which will raise the company's capacity to 815,000 tons per year by 1967, if needed. Reynolds also was planning an additional outlay of over $300 million to be spent by 1970 for increasing plant capacities for producing and fabricating primary aluminum.

Ormet Corp. planned to add 40,000-ton-per-year capacity to its aluminum reduction plant at Hannibal, Ohio, raising its capacity to about 225,000 tons per year by 1967. Revere Copper & Brass Corp., Inc., part owner of Ormet with Olin Mathieson Chemical Corp., started construction on a $55 million aluminum rolling mill near Scottsboro, Ala. By 1968 capacity of the new plant was scheduled to be 90,000 tons per year.

Ethyl Corp., a major manufacturer of petroleum and industrial chemicals, plastics, and paper products acquired a controlling interest in the William L. Bonnell Co., a major producer of aluminum extrusions at Newman, Ga. Vereinigte Aluminium Werke A.G., the largest producer of primary aluminum in West Germany, acquired the aluminum operations of Channel Master Corp., another important producer of aluminum extruded products.

The Tars & Chemical Division of the Koppers Co. Inc. announced that by 1966 a $1 million plant to produce carbon pitch, for use in making electrodes used in producing primary aluminum, would be built at Portland, Oreg. Reportedly the hot liquid pitch will be delivered by tank car to Northwest aluminum plants.

American Metal Climax Inc. announced the formation of Amax Aluminum Co. to consolidate its aluminum operations. The new company will operate as a division of the parent company and will include Kawneer Co., Inc., fabricators of architectural and industrial aluminum products; Hunter Engineering Co., fabricators of aluminum sheet, mill products, and special machinery and equipment; and Apex Smelting Co., the largest secondary aluminum smelter in the United States. The parent company's 50-percent interest in the Intalco Aluminum Corp. aluminum smelter, under construction at Bellingham, Wash., also will be consolidated under Amax Aluminum Co.

SECONDARY

The secondary aluminum industry had its best year on record, recovering 641,000 tons or about 89,000 tons more aluminum metal than in 1964. According to reports received by the Bureau of Mines, domestic recovery of aluminum alloys (including all constituents) from aluminum-base scrap totaled 691,000 tons. Metallic recovery from new scrap was 509,428 tons, an increase of 12 percent. Recovery from old scrap and sweated pig increased to 181,112 tons. An additional 1,262 tons of aluminum was recovered from copper-, zinc-, and magnesium-base scrap. The value of 639,456 million tons of aluminum recovered from processed aluminum scrap was $313 million computed from the average price of primary aluminum ingot of 24.5 cents per pound.

The calculated consumption of purchased aluminum-base scrap and sweated pig based on reports from consumers totaled 817,000 tons. Independent secondary smelters used 580,000 tons, or 71 percent. Primary producers used 95,000 tons, or 12 percent; fabricators used 92,000 tons, or 11 percent; and foundries and other consumers used 50,000 tons, or 6 percent.

The Bureau of Mines estimated that complete coverage of the industry would show a total scrap consumption of 970,000 tons and a secondary ingot production of 585,000 tons. Calculated aluminum recovery based on full coverage would total

Table 4.—Aluminum recovered from scrap processed in the United States, by kind of scrap and form of recovery

(Short tons)

Kind of scrap	1964	1965	Form of recovery	1964	1965
New scrap:					
Aluminum-base	[1] 427,518	[2] 480,444	As metal	24,130	26,199
Copper-base	67	99	Aluminum alloys	513,328	597,464
Zinc-base	150	80	In brass and bronze	1,945	671
Magnesium-base	279	391	In zinc-base alloys	6,292	9,350
			In magnesium alloys	1,522	1,718
Total	428,014	481,014	In chemical compounds	4,474	5,316
Old scrap:			Total	551,691	640,718
Aluminum-base	[1] 122,943	[2] 159,012			
Copper-base	98	84			
Zinc-base	450	470			
Magnesium-base	186	138			
Total	123,677	159,704			
Grand total	551,691	640,718			

[1] Aluminum alloys recovered from aluminum-base scrap in 1964, including all constituents, were 454,985 tons from new scrap and 140,150 tons from old scrap and sweated pig, a total of 595,135 tons.

[2] Aluminum alloys recovered from aluminum-base scrap in 1965, including all constituents, were 509,428 tons from new scrap and 181,112 tons from old scrap and sweated pig, a total of 690,540 tons.

Table 5.—Stocks and consumption of new and old aluminum scrap and sweated pig in the United States in 1965 [1]

(Short tons)

Class of consumer and type of scrap	Stocks, Jan. 1 [r]	Receipts	Consumption: New scrap	Consumption: Old scrap	Consumption: Total	Stocks, Dec. 31
Secondary smelters: [2]						
New scrap:						
Segregated 2S sheet and clips	457	12,897	12,586		12,586	768
Segregated 3S sheet and clips	625	9,319	9,266		9,266	678
Segregated 51S, 52S, 61S, etc., sheet and clips, less than 0.6 percent Cu	1,618	37,982	37,601		37,601	1,999
Segregated 14S, 17S, 24S, 25S, etc., sheet and clips, more than 0.6 percent Cu	394	10,118	10,121		10,121	391
Segregated 75S, 76S, 77S, 78S, 80S type sheet and clips, more than 0.6 percent Cu	504	6,751	6,860		6,860	395
Mixed low Cu clips, 0.6 percent maximum Cu	1,931	42,911	43,014		43,014	1,828
Mixed clips, more than 0.6 percent Cu	1,211	41,056	40,830		40,830	1,437
Cast scrap	172	8,158	8,026		8,026	304
Borings and turnings:						
Segregated 14S, 17S, 24S, 25S	325	7,113	7,091		7,091	347
Segregated 75S, 76S, 77S, 78S, 80S type	168	13,303	13,065		13,065	406
Segregated other	669	20,374	20,457		20,457	586
Mixed, Zn 1.0 percent maximum	1,436	37,765	36,949		36,949	2,252
Mixed, Zn over 1.0 percent	1,420	54,806	54,797		54,797	1,429
Dross and skimmings	6,544	82,934	80,955		80,955	8,523
Foil (includes both new and old)	314	2,898	2,981		2,981	231
Miscellaneous	883	17,430	17,343		17,343	970
Old scrap:						
Wire and cable	426	2,533		2,550	2,550	409
Pots and pans	1,282	34,701		34,500	34,500	1,483
Mixed alloy sheet	561	9,208		9,253	9,253	516
Aircraft	156	3,573		3,364	3,364	365
Castings and forgings	1,200	33,720		33,070	33,070	1,850
Pistons	149	4,745		4,807	4,807	87
Irony aluminum	1,414	19,975		20,355	20,355	1,034
Miscellaneous	1,717	16,069		15,476	15,476	2,310
Purchased pig	4,690	57,517		54,527	54,527	7,680
Total	30,266	587,856	401,942	177,902	579,844	38,278
Foundries, fabricators, and chemical plants:						
New scrap:						
Segregated 2S sheet and clips	133	8,960	8,607		8,607	486
Segregated 3S sheet and clips	320	34,937	34,882		34,882	375
Segregated 51S, 52S, 61S, etc., sheet and clips, less than 0.6 percent Cu	531	21,871	21,922		21,922	480
Segregated 14S, 17S, 24S, 25S, etc., sheet and clips, more than 0.6 percent Cu		76	76		76	
Segregated 75S, 76S, 77S, 78S, 80S type sheet and clips, more than 0.6 percent Cu	564	1,767	1,831		1,831	500
Mixed low Cu clips, 0.6 percent maximum Cu	172	10,036	9,620		9,620	588
Mixed clips, more than 0.6 percent Cu	49	3,600	3,551		3,551	98
Cast scrap	5	3,452	3,214		3,214	243
Borings and turnings:						
Segregated 14S, 17S, 24S, 25S						
Segregated 75S, 76S, 77S, 80S type		33	33		33	
Segregated other	2	162	162		162	2
Mixed, Zn 1.0 percent maximum						
Dross and skimmings	15	94	88		88	21
Foil (includes both new and old)	572	2,863	2,851		2,851	584
Miscellaneous	528	19,462	19,597		19,597	393
Old scrap:						
Wire and cable	162	5,212		5,087	5,087	287
Pots and pans		54		49	49	5
Mixed alloy sheet	2	94		73	73	23
Aircraft		1		1	1	
Castings and forgings	49	442		469	469	22
Pistons	2	15		17	17	
Irony aluminum	26	696		713	713	9
Miscellaneous	8	231		230	230	9
Purchased pig	3,013	28,069		28,718	28,718	2,364
Total	6,153	142,127	106,434	35,357	141,791	6,489

See footnotes at end of table.

Table 5.—Stocks and consumption of new and old aluminum scrap and sweated pig in the United States in 1965 [1]—Continued

(Short tons)

Class of consumer and type of scrap	Stocks, Jan. 1 [r]	Receipts	Consumption: New scrap	Consumption: Old scrap	Consumption: Total	Stocks, Dec. 31
Primary producers:						
New scrap:						
Segregated 2S sheet and clips	84	2,124	2,168	-----	2,168	40
Segregated 3S sheet and clips	190	5,931	6,031	-----	6,031	90
Segregated 51S, 52S, 61S, etc., sheet and clips, less than 0.6 percent Cu	3,990	30,650	28,598	-----	28,598	6,042
Segregated 14S, 17S, 24S, 25S, etc., sheet and clips, more than 0.6 percent Cu	77	14,163	14,175	-----	14,175	65
Segregated 75S, 76S, 77S, 78S, 80S type sheet and clips, more than 0.6 percent Cu	56	911	926	-----	926	41
Mixed low Cu clips, 0.6 percent maximum Cu	461	2,996	3,077	-----	3,077	380
Mixed clips, more than 0.6 percent Cu	-----	-----	-----	-----	-----	-----
Cast scrap	243	10,251	10,448	-----	10,448	46
Borings and turnings:						
Segregated 14S, 17S, 24S, 25S	1	10	5	-----	5	6
Segregated 75S, 76S, 77S, 78S, 80S, type	-----	1	1	-----	1	-----
Segregated other	41	229	227	-----	227	43
Mixed, Zn 1.0 percent maximum	-----	24	24	-----	24	-----
Mixed, Zn over 1.0 percent	-----	3	3	-----	3	-----
Dross and skimmings	-----	-----	-----	-----	-----	-----
Foil (includes both new and old)	110	5,231	5,293	-----	5,293	48
Miscellaneous	781	23,207	23,495	-----	23,495	493
Old scrap:						
Wire and cable	88	273	-----	361	361	-----
Castings and forgings	-----	4	-----	4	4	-----
Miscellaneous	-----	149	-----	149	149	-----
Total	6,122	96,157	94,471	514	94,985	7,294
Total of all scrap consumed:						
New scrap:						
Segregated 2S sheet and clips	674	23,981	23,361	-----	23,361	1,294
Segregated 3S sheet and clips	1,135	50,187	50,179	-----	50,179	1,143
Segregated 51S, 52S, 61S, etc., sheet and clips, less than 0.6 percent Cu	6,139	90,503	88,121	-----	88,121	8,521
Segregated 14S, 17S, 24S, 25S, etc., sheet and clips, more than 0.6 percent Cu	471	24,357	24,372	-----	24,372	456
Segregated 75S, 76S, 77S, 78S, 80S type sheet and clips, more than 0.6 percent Cu	1,124	9,429	9,617	-----	9,617	936
Mixed low Cu clips, 0.6 percent maximum Cu	2,564	55,943	55,711	-----	55,711	2,796
Mixed clips, more than 0.6 percent Cu	1,260	44,656	44,381	-----	44,381	1,535
Cast scrap	420	21,861	21,688	-----	21,688	593
Borings and turnings:						
Segregated 14S, 17S, 24S, 25S	326	7,123	7,096	-----	7,096	353
Segregated 75S, 76S, 77S, 80S type	168	13,337	13,099	-----	13,099	406
Segregated other	712	20,765	20,846	-----	20,846	631
Mixed, Zn 1.0 percent maximum	1,436	37,789	36,973	-----	36,973	2,252
Mixed, Zn over 1.0 percent	1,420	54,809	54,800	-----	54,800	1,429
Dross and skimmings	6,559	83,028	81,043	-----	81,043	8,544
Foil (includes both new and old)	996	10,992	11,125	-----	11,125	863
Miscellaneous	2,192	60,099	60,435	-----	60,435	1,856
Old scrap:						
Wire and cable	676	8,018	-----	7,998	7,998	696
Pots and pans	1,282	34,755	-----	34,549	34,549	1,488
Mixed alloy sheet	563	9,302	-----	9,326	9,326	539
Aircraft	156	3,574	-----	3,365	3,365	365
Castings and forgings	1,249	34,166	-----	33,543	33,543	1,872
Pistons	151	4,760	-----	4,824	4,824	87
Irony aluminum	1,440	20,671	-----	21,068	21,068	1,043
Miscellaneous	1,725	16,449	-----	15,855	15,855	2,319
Purchased pig	7,703	85,586	-----	83,245	83,245	10,044
Total	42,541	826,140	602,847	213,773	816,620	52,061

[r] Revised.
[1] Includes imported scrap.
[2] Excludes secondary smelters owned by primary aluminum companies.

Table 6.—Production and shipments of secondary aluminum alloys, by independent smelters

(Short tons) [1]

Product	1964 Production [2]	1964 Shipments [3]	1965 Production [2]	1965 Shipments [3]
Pure aluminum (Al minimum, 97.0 percent)	24,130	23,382	26,199	26,548
Aluminum-silicon (maximum Cu, 0.6 percent)				
95/5 Al-Si, 356, etc. (0.6 percent Cu maximum)	20,036	20,735	19,550	19,480
13 percent Si, 360, etc. (0.6 percent Cu maximum)	34,786	35,074	33,675	33,805
Aluminum-silicon (Cu, 0.6 to 2 percent)	8,561	8,337	9,263	9,448
No. 12 and variations	6,550	6,677	6,368	6,413
Aluminum-copper (maximum Si, 1.5 percent)	1,945	2,022	671	708
No. 319 and variations	52,358	53,352	50,199	49,157
Nos. 122, 138	1,757	1,744	910	750
AXS–679 and variations	219,569	220,116	248,767	240,806
Aluminum-silicon-copper-nickel	24,862	25,307	26,307	26,469
Deoxidizing and other destructive uses				
Grades 1 and 2	10,626	10,932	12,091	11,529
Grades 3 and 4	13,023	13,261	17,715	17,670
Aluminum-base hardeners	15,864	16,480	10,024	10,373
Aluminum-magnesium	1,522	1,564	1,718	1,693
Aluminum-zinc	6,292	6,219	9,350	9,293
Miscellaneous	30,410	30,717	27,457	26,794
Total	472,291	475,919	500,264	490,936

[1] Gross weight, including copper, silicon, and other alloying elements. Secondary smelters used 11,498 and 13,260 tons of primary aluminum in 1964 and 1965, respectively, in producing pure aluminum and secondary alloys.
[2] No allowance was made for consumption by producing plants.
[3] No allowance was made for receipts by producing plants.

769,000 tons and the metallic aluminum-alloy recovery would total 829,000 tons.

Secondary aluminum-alloy ingot production, as reported to the Bureau of Mines, totaled 500,000 tons, 6 percent more than in 1964. Data on remelt ingots excluded alloys produced from purchased scrap by the primary producers. The increase in shipments of AXS–679 and variations accounted for most of the increase in shipments of secondary aluminum.

Data obtained through a Bureau canvass were combined with data made available to the Bureau by the Aluminum Smelters Research Institute, which covered operations of its members. The combined coverage was estimated to represent about 85 percent of the secondary aluminum smelter industry.

U.S. Reduction Company started making delivery of molten secondary aluminum ingot to Chrysler Corp.'s foundry at Kokomo, Ind. Chrysler, which uses more aluminum per car than any other automobile maker, has molten metal contracts with Wabash Smelting Co. (another secondary alloy producer) and Kaiser Aluminum & Chemical Corp., a primary aluminum producer. U.S. Reduction also acquired a controlling interest in William F. Jobbins Co., another secondary aluminum smelter located at Aurora, Ill.

Rio Tinto-Zinc Corp. Ltd. (R.T.Z.) reported that Alloys & Chemicals Corp. of Cleveland, Ohio, a major producer of secondary aluminum alloys, used some primary aluminum from the Comalco Aluminium (Bell Bay) Ltd. reduction plant in Australia. R.T.Z. owns 50 percent of Comalco's Australian primary aluminum facility and a controlling interest in Alloys & Chemicals Corp.

Republic Foil Inc. reportedly will install an induction melting system to recover aluminum from aluminum foil scrap at its Salisbury, N.C., foil mill. The plant was expected to recover more than 2,500 tons of aluminum per year.

CONSUMPTION

Primary aluminum producers sold or used 9 percent more primary aluminum in 1965 than in 1964. However, the total apparent consumption of aluminum increased 16 percent. The difference was accounted for by a sharp increase in net trade and greater recovery of aluminum from scrap.

According to figures compiled by the Aluminum Association from industry estimates, the distribution of shipments of aluminum metal to various industries was as follows: Building and construction, 23 percent; transportation, 23 percent; consumer durables, 10 percent; electrical equipment, 13 percent; machinery and equipment, 7 percent; containers and packaging, 9 percent; and other industries, 9 percent. The remainder was exported. Per capita consumption increased from 34 pounds in 1964 to 38 pounds in 1965. As in 1964 the use of aluminum in electrical equipment and for containers was the fastest growing, increasing about 20 percent over 1964 consumption.

Net shipments of aluminum wrought and cast products by producers were 17 percent higher than in 1964. Shipments of rolled and continuous cast rod, bar, and wire jumped 28 percent, reflecting increased use of aluminum in electrical applications. Shipments of aluminum powder, flake, and paste increased 27 percent. The increase in this category was accounted for by a marked increase in atomized aluminum powder shipments.

The expanding market for aluminum in the building and construction industry, which along with the transportation industry uses more aluminum than any other industry was highlighted by an unusual roof, constructed of 574 cast aluminum panels, 4 feed wide, 5 feet long, and weighing 53 pounds each.[2] A report showed that the number of aluminum windows produced each year has increased from 13 percent of the total in 1953, when the number of wood and steel windows produced each surpassed that of aluminum, to over half of the total in 1964.[3]

The transportation industry, where aluminum's strength and lightweight are used to greatest advantage, continued as a significant market for aluminum products.

Passenger automobile makers used about 70 pounds of aluminum per car in the 1966 models compared with about 69 pounds per car in 1965 models. New model usage of aluminum per car ranged from 51 pounds in the Rambler to 128 pounds in the Corvair, which used an aluminum engine. Engines, transmissions, and electrical systems were the three main users of aluminum; however, significant uses of aluminum in radiators, brakes, air conditioners, trim, and wheels foreshadowed continued growth in this sector.

The largest Navy vessel ever built entirely of aluminum was launched. The vessel, which was a new type gunboat, is the first of seven of the PGM-84 class to be built. It is 165 feet long and required almost 80 tons of aluminum for its construction.

The United Tanker Corp. and Reynolds Metals Co. announced plans for a 226-foot aluminum-hulled vessel for service between Florida and Puerto Rico. About 300 tons of aluminum will be required for this vessel.

The Aluminaut, the all aluminum research submarine, built in 1964 for Reynolds Metals Co., set a depth record during the year of 6,250 feet.

A new Coast Guard Cutter which utilized about 260 tons of aluminum in the superstructure reportedly was launched. Aluminum was scheduled to be used for

[2] Engineering News Record. Aluminum Castings Shingle a Steep Roof. V. 175, No. 20, Nov. 11, 1965, p. 43.

[3] Light Metal Age. Aluminum Windows Now Have 53% of the Total Market. V. 23. No. 11 and No. 12, December 1965, pp. 23–24.

Table 7.—Apparent consumption of aluminum in the United States

(Short tons)

Year	Primary sold or used by producers [1]	Imports (net) [2]	Recovery from old scrap [3]	Recovery from new scrap [3]	Total apparent consumption
1956–60 (average)	1,723,266	112,662	69,794	266,310	2,172,032
1961	1,956,167	24,004	102,137	238,109	2,320,417
1962	2,184,876	123,839	128,520	333,236	2,770,471
1963	2,353,624	180,878	115,921	389,670	3,040,093
1964	2,554,898	109,901	123,677	428,014	3,216,490
1965	2,786,584	308,939	159,704	481,014	3,736,241

[1] Includes shipments to the Government: 1957, 324,311 tons; 1958, 323,128 tons; 1959, 73,235 tons; 1960, 37,002 tons; 1961, 52,138 tons; 1962, 41,544 tons; 1963, 24,293 tons; 1964 and 1965, none.

[2] Crude and semicrude. Includes ingot equivalent of scrap imports and exports (weight multiplied by 0.9). Includes some shipments to Government stockpiles. Figures not available.

[3] Aluminum content.

38 such vessels planned for the next decade. An estimated 52 percent of the approximately 328,000 pleasure boats made during 1965 had aluminum hulls.

The Titan II, which launched the manned Gemini spacecraft early in the year, was essentially an all-aluminum launch vehicle. The two-stage Titan II, built of aluminum, is 90 feet high and 10 feet in diameter. When it is fully fueled and topped by the 19-foot-high Germini spacecraft, the Titan II weighs 165 tons.

Because of the military action in South Viet-Nam, the use of aluminum in helicopters and other aircraft, landing mats, and expendable items such as ammunition and wing tanks increased significantly during the year.

According to a review of aluminum markets in 1965 [4] almost all of the overhead electric transmission and distribution installations use aluminum; growth in this application of aluminum reflects the rapid expansion of America's power grid. Aluminum Cable Steel Reinforced (ACSR) held about 90 percent of this market, but the use of Aluminum Conductor-Alloy Reinforced (ACAR) was expanding. Aluminum conductors were used in about 20 percent of underground residential distribution lines. Underground high-voltage (115,000 volts) tranmission using aluminum conductors was being tested by Virginia Electric & Power Co. Kaiser planned to market a sheathed aluminum cable for home wiring.

Aluminum continued to replace other materials in many container and packaging applications, especially in lids and cans for packaging beer and other beverages.[5] It was estimated by an industry source that in 1965 91 percent of the frozen-juice concentrates containers produced and 80 percent of the motor oil containers produced utilized aluminum-fiber composites. In addition, 4 percent of the beverage containers, 75 percent of the beer lids, 3 percent of the aerosol containers, and 30 percent of drawn cans for meat and fish produced in 1965 were made of aluminum.

The Bureau of Mines estimated consumption of aluminum mill products in the Western States in 1961 at 250,000 tons.[6] Projected consumption in 1985 was 1.1 million tons. The following distribution for wrought products was obtained from figures published by the Bureau of the Census:

[4] Light Metal Age. Onward Aluminum. V. 23, Nos. 11–12, December 1965, pp. 5–6, 24.

[5] Chemical & Engineering News. Steel Continues Grip on Can Material Market. V. 43, No. 37, Sept. 13, 1965, pp. 40–41.

[6] Fulkerson, Frank B., and Jerry J. Gray. Economic Trends in the Pacific Northwest Aluminum Mill Products Industry. BuMines Inf. Circ. 8267, 1965, 36 pp.

	Percent	
	1964	1965
Sheet, plate, and foil:		
Non-heat-treatable	41.1	40.8
Heat-treatable	5.9	5.8
Foil	7.4	6.9
Rolled and continuous cast rod and bar; wire:		
Rod, bar, etc.	3.0	2.7
Bare wire, conductor and nonconductor	1.3	1.4
Bare cable (including steel-reinforced)	6.4	7.5
Wire and cable, insulated or covered	2.1	2.3
Extruded rod, bar, pipe, tube, and shapes:		
Alloys other than 2,000 and 7,000 series [1]	25.8	25.5
Alloys in 2,000 and 7,000 series	1.2	1.4
Tubing:		
Drawn	1.4	1.4
Welded, nonheat-treatable [2]	1.6	1.6
Powder, flake, and paste:		
Atomized	.5	.6
Flaked	.1	.1
Paste	.4	.3
Forgings (including impact extrusions)	1.8	1.7
Total	100.0	100.0

[1] Includes a small amount of rolled structural shapes.
[2] Includes a small amount of heat-treatable welded tube.

Table 8.—Net shipments [1] of aluminum wrought and cast products by producers

(Short tons)

	1964	1965 p
Wrought products:		
Sheet, plate, and foil	1,315,320	1,524,582
Rolled and continuous cast rod and bar; wire	311,138	397,094
Extruded rod, bar, pipe, shapes, drawn and welded tubing and rolled structural shapes	723,690	855,084
Powder, flake, paste	23,138	29,424
Forgings	44,199	47,550
Total	2,417,485	2,853,734
Castings:		
Sand	115,412	134,326
Permanent mold	162,150	165,414
Die	343,640	401,758
Others	5,630	2,982
Total	626,832	704,480
Grand total	3,044,317	3,558,214

p Preliminary.

[1] Derived by subtracting the sum of producer's domestic receipts of each mill shape from the domestic industries' gross shipments of that shape.

STOCKS

Reflecting the increased demand, aluminum ingot stocks at primary reduction plants declined from 96,900 tons on January 1 to 64,800 tons on December 31, 1965, equivalent to just over a week's output. Reduction plants also had inventories of ingot and aluminum in process.

Independent secondary aluminum smelters produced more alloy ingot than was shipped and yearend stocks of secondary alloy ingots were 38,000 tons compared with 29,000 tons at the beginning of the year. Consumers yearend inventories of all types of aluminum scrap were about 10,000 tons higher than at the beginning of the year.

PRICES

The published domestic price for unalloyed primary aluminum was unchanged through October. Early in November one producer followed by others announced an increase of 0.5 cent per pound to 25 cents per pound. The increase was rescinded after the Government proposed to sell 300,000 tons of surplus aluminum. As described under Legislation and Government Programs, Government and industry later reached agreement on the orderly disposal of the Government's surplus aluminum. The price quoted for superpure aluminum (99.99 percent aluminum) at the beginning of the year was 44.5 cents per pound. The price was decreased to 44 cents per pound in March and effective May 12 through May 28 the quoted price was 45.3 cents per pound. For the remainder of the year the quoted price was 40 cents per pound.

The average of prices quoted by the American Metal Market for clippings, old sheet, castings, and borings and turnings of scrap aluminum increased about 1 cent per pound during the year. Most grades of smelters' alloys increased 2 cents per pound, and others increased by about 1 cent per pound. Steel deoxidizing grades increased 1.5 percent to 2.0 cents per pound.

Prices quoted at the end of 1965 for various grades of aluminum scrap clippings ranged from 12 to 14 cents per pound for 2075 (75S) to 16 to 17 cents per pound for 1100 (2S). Mixed aluminum clippings were quoted at 15 to 16 cents per pound. Old aluminum sheets and castings were quoted at 12 to 14 cents per pound, and aluminum borings and turnings were quoted at 13.5 to 14.5 cents per pound.

Effective at the and of the year quoted delivery prices for 10-ton lots of various grades of smelters' alloy delivered to the buyers plant ranged from 24 to 24.5 cents per pound for 380 (AXS–679) alloy, containing 3 percent zinc to 31.25 to 31.75 cents per pound for 218 alloy grades. Steel-deoxidizing grades ranged from 22 cents per pound for 85 percent aluminum (No. 4 grade) to 25.75 cents per pound for 95 percent aluminum (No. 1 grade).

FOREIGN TRADE

The quantity of crude and semicrude aluminum exported was 10 percent less than in 1964, but increased exports of high-valued products resulted in a decline in total value of only 2 percent.

As in past years the United Kingdom was the destination of most of the aluminum ingots, slabs and crude accounting for 22 percent of the total. West Germany, France, Brazil, and Argentina received most of the remainder.

Exports of aluminum scrap also declined markedly. West Germany received almost half of the total. The Netherlands, United Kingdom, and Japan received most of the remainder.

The total quantity of crude and semicrude aluminum imported was 37 percent higher than in 1964. This was due chiefly to sharply increasing imports of crude aluminum and alloys from Canada, which shipped 85,000 tons more than in 1964. Imports of crude aluminum metal and alloys from Norway declined slightly, but imports from France more than doubled.

Table 9.—U.S. exports of aluminum, by classes

Class	1964 Short tons	1964 Value (thousands)	1965 Short tons	1965 Value (thousands)
Crude and semicrude:				
Ingots, slabs, and crude	208,622	$92,227	203,642	$92,533
Scrap	68,615	21,476	38,547	12,452
Plates, sheets, bars, etc	69,761	50,982	65,172	51,323
Casting and forgings	1,832	4,671	2,256	6,669
Semifabricated forms, n.e.c	572	619	3,361	3,817
Total	349,402	169,975	312,978	166,794
Manufactures:				
Foil and leaf	1,666	2,671	3,093	5,199
Powders and pastes (aluminum and aluminum bronze, aluminum content)	554	708	629	887
Cooking, kitchen, and hospital utensils	1,179	3,095	1,130	2,932
Sash sections, frames (door and window)	1,775	2,917	3,579	6,546
Venetian blinds and parts	729	886	652	771
Wire and cable	8,632	5,282	7,928	5,506
Total	14,535	15,559	17,011	21,841
Grand total	363,937	185,534	329,989	188,635

Table 10.—U.S. exports of aluminum, by classes and countries

(Short tons)

Destination	1964 Ingots, slabs, and crude	1964 Plates, sheets, bars, etc. [1]	1964 Scrap	1965 Ingots, slabs, and crude	1965 Plates, sheets, bars, etc. [1]	1965 Scrap
North America:						
Canada	2,183	37,122	1,849	6,583	40,944	2,779
Mexico	289	3,110	35	370	3,031	21
Other	867	2,123	84	1,637	1,872	38
Total	3,339	42,355	1,968	8,590	45,847	2,838
South America:						
Argentina	13,976	81	----------	14,655	13	----------
Brazil	2,387	69	4	15,228	117	----------
Colombia	3,733	175	5	4,169	122	6
Venezuela	2,028	849	16	2,347	568	15
Other	2,362	1,490	22	3,614	1,734	19
Total	24,486	2,664	47	40,013	2,554	40
Europe:						
Belgium-Luxembourg	10,895	319	75	5,042	283	35
France	22,209	376	80	25,060	255	22
Germany, West	40,827	1,263	31,937	28,029	1,366	14,334
Greece	3,431	11	----------	1,257	47	11
Italy	8,399	2,927	9,326	6,062	3,051	3,327
Netherlands	12,047	3,003	960	9,286	1,150	5,884
Sweden	1,373	726	4	2,049	345	----------
Switzerland	1,255	11	242	731	179	420
United Kingdom	41,307	2,311	7,548	44,454	1,421	5,767
Other	14,801	1,050	359	8,083	987	120
Total	156,544	11,997	50,531	130,053	9,084	29,920
Africa	925	3,219	11	2,948	2,707	----------
Asia:						
India	1,888	6,671	----------	2,549	5,711	----------
Israel	2,265	496	3	1,321	407	----------
Japan	4,100	884	15,333	4,561	994	5,325
Korea, South	160	11	----------	3,448	10	----------
Philippines	4,112	56	----------	2,363	147	1
Other	8,183	3,113	352	5,716	2,504	357
Total	20,708	11,231	15,688	19,958	9,773	5,683
Oceania	2,620	699	370	2,080	824	66
Grand total	208,622	72,165	68,615	203,642	70,789	38,547
Value, thousands	$92,227	$56,272	$21,476	$92,533	$61,809	$12,452

[1] Includes plates, sheets, bars, extrusions, castings, forgings, and unclassified semifabricated forms.

Table 11.—U.S. imports for consumption of aluminum, by classes

Class	1964 Short tons	1964 Value (thousands)	1965 Short tons	1965 Value (thousands)
Crude and semicrude:				
Metals and alloys, crude	394,563	$163,419	527,252	$218,217
Circles and disks	7,049	4,423	7,238	4,515
Plates, sheets, etc., n.e.c	r 39,000	r 22,896	52,491	29,960
Rods and bars	r 4,493	r 3,057	6,755	4,518
Scrap	8,152	2,038	27,029	8,482
Total	453,257	r 195,833	620,765	265,692
Manufactures:				
Foil	5,292	5,893	4,090	5,223
Folding rules	(1)	1	(1)	6
Leaf (5.5 by 5.5 inches)	(2)	18	(2)	31
Flakes and powders	206	206	355	300
Tables, kitchen, hospital utensils, etc	2,323	3,757	7,500	5,031
Other manufactures	(1)	3,679	(1)	2,485
Total	(1)	13,554	(1)	13,076
Grand total	(1)	r 209,387	(1)	278,768

r Revised.
1 Quantity not recorded.
2 1964, 1,578,300 leaves, and 56,882,353 square inches of leaf; 1965, 3,390,000 leaves, and 55,315,007 square inches of leaf.

Table 12.—U.S. imports for consumption of aluminum, by classes and countries

(Short tons)

Country	1964 Metal, and alloys, crude	1964 Plates, sheets, bars, etc. [1]	1964 Scrap	1965 Metal, and alloys, crude	1965 Plates, sheets, bars, etc. [1]	1965 Scrap
North America:						
Canada	259,656	3,347	7,849	344,464	4,053	11,744
Other	390	(2)	93	10	11	57
Total	260,046	3,347	7,942	344,474	4,064	11,801
South America		16			5	2
Europe:						
Austria	331	1,260			1,365	
Belgium-Luxembourg	5	19,371			30,257	304
Denmark			16	200	24	1,058
France	14,884	5,269		33,724	6,675	
Germany, West	189	3,023		102	1,596	316
Italy	11	7,150		37	8,128	94
Norway	93,906			90,978	262	
Spain		1,567		385	1,250	
Sweden	460	458	169		347	268
Switzerland	2,007	296		6	150	
United Kingdom	24	521	8	5,998	969	2,036
Yugoslavia	110	2,353			2,809	
Other	3	117	17		180	3,988
Total	111,930	41,385	210	131,430	54,012	8,064
Africa	3,994			14,071	1	19
Asia:						
Japan	15,038	5,544		24,267	8,250	6,867
Taiwan	385	227		661	130	
Other	169	22			22	
Total	15,592	5,793		24,928	8,402	6,867
Oceania	3,001	1		12,349		276
Grand total	394,563	50,542	8,152	527,252	66,484	27,029
Value, thousands	$163,419	r $30,376	$2,038	$218,217	$38,993	$8,482

r Revised.
1 Includes circles and disks, bars and rods, and plates, sheets, etc.
2 Less than ½ unit.

WORLD REVIEW

Production of primary aluminum was 10 percent higher than in 1964. However, most of the increase was due to a marked increase in the estimated output in the U.S.S.R.

Canadian output declined, and the largest producer continued acquiring semifabricating facilities abroad and in Canada. Consumption of primary aluminum in Europe increased only slightly and joint ventures in aluminum semifabricating facilities in West Germany, Belgium, and France were formed. New primary aluminum reduction plants were scheduled in Iceland, Brazil, Venezuela, Greece, the Netherlands, Japan, Australia, and the U.S.S.R.

NORTH AMERICA

Canada.—Aluminum Company of Canada, Ltd. (Alcan), continued its policy of acquiring aluminum semifabricating and fabricating plants and obtained control of Polyfoil Papers Ltd., the leading supplier of household aluminum foil in the U.K., and Alcan Ltd., an aluminum extruder and finisher at Aurora, Ontario. The company brought in new aluminum reduction facilities at Kitimat, British Columbia, raising annual capacity there to 212,000 tons. However, certain older reduction facilities in Quebec were shut down for modernization during the year and total output by the company decreased about 2 percent to 728,000 tons. A new 24,000-ton-per-year addition to the Kitimat smelter was scheduled for completion during the first half of 1966. The modernization program at the Arvida reduction plant in Quebec was expected to continue through 1966.

Canadian British Aluminium Company

Table 13.—World production of aluminum, by countries

(Short tons)

Country	1961	1962	1963	1964	1965 p 1
North America:					
Canada	663,173	690,297	719,390	r 843,002	840,348
Mexico			6,100	r 19,487	21,041
United States	1,903,711	2,117,929	2,312,528	2,552,747	2,754,478
Total	2,566,884	2,808,226	3,038,018	r 3,415,236	3,615,867
South America: Brazil	22,078	22,202	19,412	r 29,366	32,617
Europe:					
Austria	74,578	81,668	84,287	85,646	86,790
Czechoslovakia	55,100	e 65,000	e 65,000	e 65,000	e 68,000
France	308,047	325,288	328,891	r 348,319	375,445
Germany:					
East e	50,000	50,000	50,000	50,000	55,000
West	190,212	196,017	230,142	242,418	258,407
Hungary	56,286	58,127	61,176	62,693	64,043
Italy	91,881	r 91,390	r 100,782	127,337	136,659
Norway	189,109	r 226,941	r 238,209	278,444	304,557
Poland (includes secondary)	52,488	53,007	51,365	52,639	52,117
Rumania					25,127
Spain	41,500	45,953	50,142	r 54,723	56,660
Sweden (includes alloys)	17,463	17,580	r 18,878	r 35,164	33,731
Switzerland	46,530	54,640	r 66,260	70,805	74,010
U.S.S.R. e	980,000	990,000	1,060,000	1,100,000	1,410,000
United Kingdom	36,169	38,113	34,243	35,516	39,911
Yugoslavia	30,211	30,843	39,567	38,320	44,443
Total e	2,200,000	2,325,000	r 2,480,000	r 2,645,000	3,085,000
Africa: Cameroon, Republic of	52,446	57,596	58,327	r 56,777	56,027
Asia:					
China e	110,000	110,000	110,000	110,000	110,000
India	20,263	39,025	r 60,881	60,830	74,041
Japan 2	169,424	r 188,991	246,854	292,950	322,756
Taiwan	9,938	12,135	13,148	r 21,354	20,847
Total e	309,600	r 350,200	430,900	r 485,100	527,600
Oceania: Australia	14,789	18,090	46,214	r 88,194	96,743
World total e	5,185,000	5,580,000	r 6,075,000	r 6,720,000	7,415,000

e Estimate. p Preliminary. r Revised.
1 Compiled mostly from data available June 1966.
2 Includes superpurity: 1961, 1,307; 1962, 1,969; 1963, 2,060; 1964, 2,092; and 1965 not available.

Table 14.—World producers of aluminum

(Thousand short tons)

Country, company, and plant location	Annual capacity, end 1965: Pre-baked	Annual capacity, end 1965: Soderberg	Participants
FREE WORLD			
North America:			
Canda:			
Aluminum Company of Canada, Ltd. (Alcan)			Aluminium, Ltd.
Arvida, Quebec	173	200	
Shawinigan, Quebec		70	
Isle Maligne, Quebec		115	
Kitimat, British Colombia		212	
Beauharnois, Quebec		38	
Canadian British Aluminium Co. Ltd			British Aluminium Co. Ltd., 54 percent; Quebec North Shore Paper Co. and private interests (Canadian), 46 percent.
Baie Comeau, Quebec		108	
Total	173	743	
Mexico:			
Aluminio Mexicano S.A. de C.V			Alcoa 35 percent; American and Foreign Power Co., 14 percent; and Mexican interests, 51 percent.
Veracruz		22	
United States [1]	1,500	1,259	
Total North America	1,673	2,024	
South America:			
Brazil:			
Alumino Minas Gerais, S.A			Aluminium, Ltd.
Ouro Preto, Minas Gerais		17	
Cia. Brasileira de Aluminio			Industria Votorantim, Ltd., 80 percent, and other Brazilian interests, 20 percent.
Sorocaba, Sao Paula		22	
Total		39	
Surinam:			
Surinam Aluminum Co			Alcoa.
Paranam		58	
Total South America		97	
Europe:			
Austria:			
Salzburger Aluminium G.m.b.H			Swiss Aluminium Ltd.
Lend		12	
Vereinigte Metallwerke Ranshofen-Berndorf, A.G.			Government owned.
Ranshofen		75	
Total		87	
France:			
Pechiney, Compagnie de Produits Chimiques et Electrometallurgiques			Privately owned (French).
Chedde (Haute-Savoie)	10		
La Praz (Savoie)	4		
La Saussaz (Savoie)	13		
St. Jean de Maurienne (Savoie)	39	43	
l' Argentiere (Hautes-Alpes)	22		
Rioupéroux (Isére)	25		
Auzat (Ariége)		23	
Sabart (Ariége)	24		
Noguéres (Basses-Pyrénées)		122	
Soc. d'Electro-chimie, d'Electro-Metallurgie et des Acieries Electriques d'Ugine			Do.
Venthon (Savoie)	10	18	
Lannemezan (Hautes-Pyrénées)		57	
Total	147	263	

See footnotes at end of table.

Table 14.—World producers of aluminum—Continued

(Thousand short tons)

Country, company, and plant location	Annual capacity, end 1965: Pre-baked	Annual capacity, end 1965: Soderberg	Participants
FREE WORLD—Continued			
Europe—Continued			
Germany West:			
Aluminium-Hütte G.m.b.H			Swiss Aluminium, Ltd.
Rheinfelden, Baden [2]		55	
Vereinigte Aluminium Werke A.G. (VAW)			Government owned.
Erftwerk, Grevenbroich [2]		38	
Innwerke, Töging	26	36	
Lippewerke, Lünen [2]		43	
Norf [2]		60	
Total	26	232	
Italy:			
Montecatini, Soc. Generale per l'Industria Mineraria e Chimica			Privately owned (Italian).
Mori		26	
Bolzano [3]		63	
Soc. Alluminio Veneto per Azioni (SAVA)			Swiss Aluminium, Ltd.
Portó Marghera		30	
Fusina	22		
Soc. Alluminio Italiano			Aluminium, Ltd.
Borgofranco, d'Ivrea	6		
Total	28	119	
Norway:			
A/S Aardal og Sunndal Verk			Government owned.
Aardal	22	99	
Sundalsöra		66	
Det Norske Nitride A/S			Aluminium, Ltd., 50 percent, and British Aluminium Ltd., 50 percent.
Eydehavn	11		
Tyssedal		22	
Norsk Aluminium A/S			Aluminium, Ltd., 50 percent and private (Norwegian) interests, 50 percent.
Höyanger		30	
Mosjoen Aluminium A/S			Alcoa, 50 percent and Electro-Chemisk A/S (Norwegian), 50 percent.
Mosjoen		63	
Sør-Norge Aluminium A/S			Swiss Aluminium Ltd., 80 percent; Compadec (French), 15 percent; Norwegian interests, 5 percent.
Husnes	33		
Total	66	280	
Spain:			
Empresa Nacional del Aluminio, S.A			Government and minority commercial interests (Spanish).
Valladolid		14	
Aviles		20	
Aluminio Espanol S.A			Pechiney.
Sabinanigo, Huesca		10	
Aluminio de Galicia			Pechiney and Kaiser, 36 percent and Spanish interests, 64 percent.
La Coruna		18	
Total		62	
Sweden:			
A/B Svenska Aluminiumkompaniet			Private (Swedish), 78 percent, and Aluminium, Ltd., 22 percent.
Kubikenborg		33	
Total		33	
Switzerland:			
Swiss Aluminium Ltd.			
Chippis	23	10	Privately owned (Swiss).
Steg	27		
Usine d'Aluminium de Martigny, S.A			Do.
Martigny		6	
Total	50	16	

See footnotes at end of table.

Table 14.—World producers of aluminum—Continued

(Thousand short tons)

Country, company, and plant location	Annual capacity, end 1965: Pre-baked	Annual capacity, end 1965: Soderberg	Participants
	FREE WORLD—Continued		
Europe—Continued			
United Kingdom:			
British Aluminium Co. Ltd			Tube Investments Ltd. (British), 47percent; Reynolds Metals Co., 45 percent; Reynolds Tube Investments Ltd., 4 percent; and miscellaneous shareholders, 4 percent.
Kinlochleven		11	
Fort William, Inverness-Shire		28	
Total		39	
Yugoslavia:			
State-owned works			Government owned.
Razine		4	
Lozovac		6	
Kidričevo		44	
Total		54	
Total Europe	317	1,185	
Africa: Cameroon, Republic of: Cie. Camerounaise de l'Aluminium Pechiney-Ugine (Alucam).			
Edea		58	Pechiney-Ugine (French). Caisse Centrale de la France d'Outremen (French) and the Cameroon Government.
Total		58	
Asia:			
India:			
Aluminium Corp. of India Ltd			Private (Indian).
Asansol, West Bengal		9	
Indian Aluminium Co. Ltd			Aluminium Ltd., 65 percent and Indian interests, 35 percent.
Alupuram, Kerala		13	
Hirakud, Orissa		23	
Hindustan Aluminium Corp. Ltd			Birla and private interests (Indian), 73 percent and Kaiser, 27 percent.
Renukoot, Uttar Pradesh	53		
Madras Aluminium Co. Ltd			Government owned (Madras State), 73 percent and Montecatini, 27 percent.
Mettur, Madras		11	
Total	53	56	
Japan:			
Showa Denko K.K. (Showa Electro-Chemical Industry Co. Ltd.).			Privately owned (Japanese).
Kitakata		39	
Omachi	13		
Chiba		38	
Nippon Keikinzoku K.K. (Japan Light Metals Co., Ltd.).			Aluminium Ltd., 50 percent and private (Japanese), 50 percent.
Kambara		100	
Niigata		35	
Sumitomo Kagaku K.K. (Sumitomo Chemical Co. Ltd.).			Private (Japanese).
Kikumoto		34	
Nagoya		52	
Mitsubishi Chemical Co			Do.
Naoetsu		50	
Total	13	348	
Taiwan:			
Taiwan Aluminium Corp			Government owned.
Takao		22	
Total Taiwan		22	
Total Asia	66	426	

See footnotes at end of table.

Table 14.—World producers of aluminum—Continued

(Thousand short tons)

Country, company, and plant location	Annual capacity, end 1965 Pre-baked	Soderberg	Participants
FREE WORLD—Continued			
Oceania: Australia:			
Comalco Aluminium (Bell Bay) Ltd			Kaiser Aluminium & Chemical Corp. (U.S.), 50 percent; Consolidated Zinc of Australia Pty. 50 percent; Alcoa (U.S.), 51 percent; Western Mining Corp. and other Australian interests, 49 percent.
Bell Bay, Tasmania	61		
Aloca of Australia, Pty. Ltd			
Geelong	45		
Total	106		
Total free world	2,162	3,790	
COMMUNIST COUNTRIES[4]			
Europe:			Government owned.
Czechoslovakia: Ziar Aluminium Works			
Svaty Kriz:		60	
Germany, East: Electrochemisches Kombinat			
Bitterfeld		39	
Lauta		35	
Total		74	
Hungary: Magyarsoviet Bauxit Ipar			
Felsogalla-Totis		17	
Ajka		22	
Inota		33	
Total		72	
Poland: Skawina Aluminium Works: Skawina		67	
Rumania: Slatina		25	
U.S.S.R.:			
Volkhov (Zvanka), Leningrad Oblast		50	
Zaporozhye (Dneprovskiy), Zaporozhskaya Oblast, Ukraine.		110	
Kamensk-Ural'skiy, Sverdlovskaya Oblast, Ural.		132	
Kandalaksha, Murmanskaya Oblast		28	
Novokuznetsk (Stalinsk), Kemerovskaya Oblast, Siberia.		132	
Bogoslovsk (Krasnoturinsk), Sverdlovskaya Oblast, Ural.		138	
Chirchik, Near Tashkent, Uzbekistan		33	
Sumgait (Kirovabad), Azerbaijan		110	
Nadvoitsy, Karelskaya, A.S.S.R		22	
Kanaker (Yerevan), A.S.S.R		50	
Volgograd (Stalingrad), Volgogradskaya Oblast.		220	
Irkutsk (Shelekhovo), Irkutskaya Oblast, Siberia.		250	
Krasnoyarsk, Krasnoyarskiy Kray, Siberia		165	
Total		1,440	
Asia:			
China: Nationalized plants		165	
Korea, North		39	
Total Communist countries		1,942	
Total world		7,894	

[1] See table 3 for breakdown of plants.
[2] Replaces anode carbon continuously but uses prebaked slabs instead of Soderberg paste.
[3] A few (number unknown) of the Soderberg cells reportedly were converted to prebaked cells in 1965.
[4] In a number of instances it was impossible to confirm the data on plants in Communist countries.

Ltd. (C.B.A.), produced 112,000 tons of primary aluminum at Baie Comeau, Quebec, bringing the total output to 840,000 tons, slightly below that of 1964.

Iceland.—Negotiations between the Government and Swiss Aluminium Ltd., to construct an aluminum reduction plant at Straumsvik, near Reykjavik, reportedly reached an advanced stage. The plant was expected to be built before 1970 and eventually would have a 60,000-ton-per-year capacity.

Mexico.—The estimated 1965 consumption of about 20,000 tons of primary aluminum was expected to be more than double by 1970, and expansion of all segments of the industry was planned or under study.

Reynolds Aluminio S.A. (RASA), an affiliate of Reynolds Metals Co. of the United States, reportedly planned a $5.3 million expansion of its rolling mill near Mexico City. RASA currently produces about 3,000 tons of sheet products and 1,700 tons of foil per year in addition to other products. Reynolds, through its subsidiary Reynolds International, Inc. applied for a license for the construction of an aluminum reduction plant in the State of Tabasco with an estimated capacity of 25,000 tons per year.

A 2-year plan of Aluminio S.A. de C. V. would reportedly raise its primary aluminum capacity at Vera Cruz to 44,000 tons per year.

Aluminio Industrial Mexicano S.A., an affiliate of Alcan and a producer of aluminum sheet and foil, planned a $2 million expenditure as part of a $10 million expansion program.

A $3.5 million aluminum continuous casting and rolling mill was scheduled to be built by 1966 at Puebla by Alumex S/A, which is owned 40 percent by American Metal Climax and 60 percent by American & Foreign Power Co. The Export-Import Bank of Washington approved a $1.8 million loan for the project.

SOUTH AMERICA

Brazil.—Cia. Brasileira de Aluminio in the State of Saõ Paulo planned to increase its annual production of aluminum mill products from about 21,000 to 50,000 tons by 1969. Capacity was about 8,000 tons of aluminum sheet, 2,000 tons of aluminum extrusions, and 10,000 tons of aluminum wire and cable. By 1969 the company planned to produce 22,000 tons of sheet, 25,000 tons of wire and cable, and 3,000 tons of tubing. The company reportedly was doubling capacity of its aluminum reduction plant.

The National Economic Council approved the plans of Aluminio Minas Gerais S.A. (ALUMINAS) for expanding its productive capacity to 23,000 tons per year. The company expected to increase capacity from about 17,000 tons per year in 1966 to 19,500 tons per year by mid–1966.

Aluminum Company of America (Alcoa) established a pilot company to carry out preliminary plans for an industrial complex for the production of alumina and aluminum at Pocos de Caldas, Minas Gerais. The company, to be known as Cia. Minera de Aluminio (ALCOMINAS), was expected eventually to use local bauxite to produce 50,000 tons per year of alumina and 25,000 tons per year of primary aluminum as well as rolled and extruded aluminum products.

Chile.—Cia. Manufacturas de Cobre S.A. (MADECO) was producing more than 900 tons of ACSR (Aluminum Cable Steel Reinforced) with technical assistance from Kaiser. The cable was scheduled for use in the Rapel electrification program and marked the first time aluminum has been used in preference to copper.

Surinam.—Production of primary aluminum was started by Surinam Aluminum Co. (Suralco) at its new 58,000-ton-per-year reduction plant at Paranam. Power for the plant is obtained from a 180,000-kilowatt hydroelectric facility built by Suralco on the Suriname River at Afobaka, 45 miles south of Paranam.

Venezuela.—Construction of an 11,000-ton-per-year primary aluminum plant and associated semi-fabricating facilities at Santo Tome de Guayana was expected to start late in the year by Aluminio del Caroni, S.A. (Alcasa). A $12.5 million loan to help finance the $22.5 million project was authorized by the Export-Import Bank of Washington. Alcasa is jointly owned by Reynolds International Inc. (a subsidiary of Reynolds Metals Co.) and Corporacion Venezolana de Guayana (CVG), a Government agency.

The reduction plant will be of conventional design. Power will be supplied by a wholly owned subsidiary of CVG.—Electrification del Caroni, C.A. (EDELCA) from the Caroni River hydroelectric system. Completion of the plant was expected in 1967 or 1968.

EUROPE

Consumption of primary aluminum leveled off at about the same rate as in 1964. Only the United Kingdom, West Germany, Switzerland, Austria, and Spain showed improvement compared with the previous year.

Belgium.—Kaiser Aluminum & Chemical Corp. of Oakland, Calif., entered into an equal partnership agreement with Phenix Aluminium S.A. at Ivoz-Ramet near Liège, Belgium. The new venture, capitalized at $6 million, will increase the output of aluminum foil at the Phenix plant. Present plant capacity is 5,000 tons per annum.

This is the second American-Belgian joint venture for the manufacture of aluminum foil. Reynolds Metals Co., in partnership with Société Générale de Belgique, produces aluminum foil at a plant near Mons.

France.—Production of primary aluminum was 8 percent higher than in 1964, but consumption, which historically has been less than output, declined slightly.

The two producers of primary aluminum and an independent mill product producer took steps intended to strengthen their competitive positions in the domestic and international aluminum industry. Péchiney, Compagnie de Produits Chimiques et Electrométallurgiques (Péchiney) and Société d'Electro-Chimie, d'Electro-Métallurgie et des Aciéries Electriques d'Ugine (Ugine), through their subsidiary, l'Aluminium Français, agreed to enter into a long-range arrangement with Reunion des Tréfileries et Laminoirs du Havre et de la Compagnie Française des Métaux (Trefimétaux), an independent producer of aluminum mill products. The two primary producers will supply Trefimétaux with primary metal if its needs cannot be satisfied through an arrangement with a proposed aluminum reduction plant in Curacao, Netherlands Antilles, which is planned by Kaiser. Trefimétaux reportedly is to receive one-fourth or about 15,000 tons annually from the Curacao facility.

In addition, Péchiney and Ugine will increase their existing participation in Compagnie Générale du Duralumin et du Cuiure (Cégédur) and Coquillard Froges, leading producers of aluminum mill products. Trefimétaux, which is among the 25 largest domestic firms, is to cooperate with Cégédur in the production and development of mill products of aluminum and aluminum alloy and with Coquillard in the production and development of aluminum foil.

Germany, West.—Aluminium Ltd. and Vereinigte Aluminium Werke, A.G. (VAW), (the largest producer of primary aluminum), planned to construct jointly a 200,000-ton-per-year aluminum rolling mill near Cologne by 1967. The state-owned VAW also acquired the Aluminum Division of Channel Master Corp., a producer of aluminum pipe, tubing, and extrusion billets in Ellenville, N.Y. Reported capacity of the facility was 15,000 tons of pipe and tubing and 30,000 tons of billet.

Table 15.—Non-Communist Europe: Consumption of primary aluminum
(Thousand short tons)

Country	1961	1962	1963	1964	1965 p
United Kingdom	313.2	315.8	351.1	401.4	402.9
Germany, West	320.2	323.3	334.4	390.2	400.4
France	227.2	259.7	267.3	274.8	274.0
Italy	115.7	126.8	141.1	132.3	124.6
Belgium and Luxembourg	73.7	74.4	98.0	124.1	122.4
Switzerland	51.4	57.4	(1)	56.2	68.3
Sweden	37.4	43.8	55.9	56.4	48.7
Austria	41.4	37.6	46.0	50.7	53.1
Spain	22.0	24.3	24.3	50.7	70.5
Norway	25.5	25.9	23.7	40.8	33.6
Other countries [2]	38.6	43.8	46.8	50.9	61.0
Total	1,266.3	1,332.8	1,440.0	1,628.5	1,659.5

p Preliminary.
[1] Data not available. Estimate included in total.
[2] The Netherlands, Greece, Denmark, Portugal, Ireland, and Turkey. Includes Bureau of Mines estimates.

Source: Organization for Economic Cooperation and Development (OECD).

Greece.—Aluminium de Grèce, S.A., completed the 62,500-ton-per-year aluminum reduction plant near Distomon. However, production was not expected until early 1966 when electricity from the Kremasta power plant would be available. The plant will use prebaked electrodes and operate at 70,000 amperes.

Hungary.—Installation of a modern silicon diode rectifier system and other improvements in cell efficiency increased primary aluminum reduction capacity at Ajka to 22,000 tons per year.

The Netherlands.—The 33,000-tons-per-year aluminum reduction plant under construction at Delfzijl, Groningen, by Aluminium Delfzijl was expected to begin production early in 1966. A second reduction plant reportedly was being planned in the province of Limburg.

A 130,000-ton-per-year plant near Rotterdam for producing carbon anodes used in aluminum production was near completion by Aluminium en Chemie Rotterdam N/V a wholly owned subsidiary of Swiss Aluminium Ltd. About half of the output was scheduled to be exported to the United States and the remainder was to be shipped to Norway and Iceland.

Norway.—Late in the year production of primary aluminum was started by Sør-Norge Aluminium A/S at its new reduction plant at Husnes. The plant is scheduled to be operating at full capacity of about 50,000 tons per year by the end of 1966. Expansion to about 110,000 tons per year by 1967 and to 190,000 tons per year after 1970 also was planned.

Work was started on a 25,000-ton-per-year expansion of the aluminum reduction plant at Mosjøen by Mosjøen Aluminium A/S (MOSAL). The expansion would bring total capacity to 88,000 tons per year by 1968.

Rumania.—The aluminum reduction plant at Slatina, which was built with assistance of Péchiney, began partial operations in the middle of the year. When completed, the plant reportedly will have 328 prebaked anode cells operating at 63,000 amperes, and an annual capacity of about 55,000 tons of primary aluminum. Lignite reportedly is the source of electric power. Alumina will be furnished by a new plant supplied from the Oreada refinery and pitch from Henedoara.

Sweden.—A/B Svenska Aluminiumkompaniet planned to increase primary aluminum productive capacity at Kubikenborg from 33,000 tons per year to 53,000 tons per year by the end of 1967.

U.S.S.R.—Production of primary aluminum reportedly was started from a second potline at Krasnoyarsk, bringing annual capacity to about 165,000 tons. It was indicated that large aluminum reduction plants were under construction at Bratsk, Irkutskaya Oblast, in Siberia and at Gissar in Tadzhikistan.

AFRICA

Ghana.—Overall construction of the 100,000-ton-per-year aluminum reduction plant being built at Tema was about one-third complete.

South Africa, Republic of.—The Government-owned Industrial Development Corp. announced that it would underwrite the construction of a $49 million, 45,000-ton-per-year primary aluminum plant. Local and foreign firms will be invited to participate. The new smelter was expected to be located at Phalaborwa or near Pietermaritzburg. Consumption of primary aluminum reportedly has been increasing at 12 to 14 percent per year during the past decade and reached 30,000 tons in 1964.

ASIA

India.—Production of primary aluminum was begun at the new 11,000-ton-per-year reduction plant of Madras Aluminium Co., Ltd.

The Indian Aluminium Co. completed the first half of an 11,000-ton expansion to the Alupuram smelter in mid-year, but a power shortage reduced production below capacity. The second half of the expansion was scheduled for completion in the second half of 1966, bringing total capacity of the company's reduction plants in Alupuram and Hirkud to 42,000 tons per year. The company continued engineering studies for the new bauxite, alumina, and aluminum facilities on the West Coast of India, which are expected to add 33,000 tons per year to primary aluminum capacity.

Hindustan Aluminium Corp. Ltd., raised annual capacity at its aluminum reduction plant at Renukoot to 53,000 tons per year. An additional potline was under construction to raise capacity by 20,000 tons.

Japan.—Japan Light Metals Co. Ltd., continued a flexible program to increase primary aluminum capacity at Kambara

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and Niigata which could result in a total capacity of 160,000 tons per year by 1967. The company also planned to construct a new plant with a primary aluminum capacity of 25,000 tons per year at Shimizu.

Sumitomo Chemical Co. Ltd., was expected to start construction of a new primary aluminum plant at Niihama in 1966. The plant was scheduled to be operating late in 1967 at a rate of 31,000 tons per year. Cost of the initial stage was expected to be about $22.4 million. It was planned to add an additional 30,000 tons capacity each year to attain an eventual capacity of 113,000 tons per year.

Production of superpurity aluminum (99.99 percent aluminum) by Sumitomo Chemical Co. Ltd., and Japan Light Metals Co. Ltd., reportedly was 1,230 tons and 824 tons, respectively.

Korea, South.—Toyo Menka and Showa Denko K.K. of Japan reportedly have made a provisional contract to supply a complete alumina and primary aluminum reduction plant to the Korean Aluminum Industrial Co. The 15,000-ton-per-year smelter was expected to cost $16 million.

OCEANIA

Australia.—Comalco Aluminium (Bell Bay) Ltd. announced plans to raise capacity of its primary aluminum smelter at Bell Bay, Tasmania, by almost 20,000 tons per year, bringing total capacity to 80,000 tons per year by late 1967.

The Australian Aluminium Co. Ltd. (Australuco), a wholly owned subsidiary of the Aluminum Company of Canada, announced plans to build a 30,000- to 40,000-ton primary aluminum plant near New Castle, New South Wales. Construction of the $23 million facility was scheduled to begin in 1967 and to be completed by 1969 or 1970.

TECHNOLOGY

Two methods of replacing anode carbon in aluminum reduction plants were in use. Both have advantages and disadvantages depending to a large extent on local conditions but also on other factors. For example, the prebaked system generally consumes less electrical power, is easier to operate, and is somewhat cleaner insofar as air pollution is concerned. The Soderberg system involves a lower initial cost and in the older plants, lower operating labor cost. Plants using the prebaked system have considerably more flexibility in controlling total plant production than have plants using the Soderberg electrodes. The two systems apparently are closely competitive with respect to metal quality and consumption of carbon.

Data in table 14 show that in 1965 64 percent of the reduction plants in the free world used the Soderberg method for replacing anode carbon. However, only 46 percent of the plants in the United States used Soderberg anodes, and of the remaining free world plants about 79 percent used Soderberg electrodes. Three of the plants in West Germany used a Soderberg-type cell which utilizes prebaked slabs of carbon for the anode. Of the totally new reduction plants built in the free world between 1960 and 1965 about one-half used the Soderberg system.

In a study of the petroleum coke industry of the United States, the Bureau of Mines discussed the sources, specifications, and utilization of petroleum coke in electrodes for domestic aluminum reduction plants.[7]

Discussion of the oxidation of aluminum by carbon dioxide in a cryolitic electrolyte indicated that the reactions of carbon dioxide with dissolved sodium probably are more important in reducing the current efficiency in aluminum reduction cells than the reaction with aluminum.[8]

A photograph and a brief description of a 2,750-ton hydraulic press for making carbon block anodes for aluminum reduction was published.[9] The press, which weighs 600,000 pounds, forms 450-pound carbon blocks, 31.5 inches long, 21 inches wide, and 24 inches high, under 8,300 pounds per square inch.

The current and energy efficiencies of aluminum reduction cells of high amperage (80,000 amperes and higher), which have

[7] Kemnitzer, William J., and Curt D. Edgerton, Jr. Petroleum Coke on the West Coast of the United States. Its Production, Utilization, and Role in the Conservation of Petroleum. BuMines Inf. Circ. 8259, 1965, 80 pp.

[8] Frank, W. B. Oxidation of Aluminum by Carbon Dioxide in the Presence of Cryolitic Electrolyte. J. Electrochem. Soc., v. 112, No. 6, June 1965, pp. 649–650.

[9] Light Metal Age. Carbon Block Press. V. 23, Nos. 11–12, December 1965, p. 32.

been developed commercially, initially were not as high as expected. Circulation and convexity of the molten aluminum in the cell associated with the distribution of electromagnetic forces in the cell were believed to have been among the factors preventing attainment of expected efficiencies. An electromagnetic cell model which permitted simple and rapid variation of some of the parameters was described.[10] The model reportedly reproduced the electro-magnetic field components as functions of location for all possible bus bar and input arrangements of an 80,000-ampere cell.

A thermodynamic analysis of the carbothermic reduction of alumina was published.[11] Using recent thermodynamic data on aluminum carbide, the author suggested that liquid aluminum is not present in the aluminum - carbon - oxygen system under equilibrium conditions below 1,800° C and that appreciable quantities of an aluminum oxide exists in the gaseous state.

At the annual meeting of the American Institute of Mining, Metallurgical and Petroleum Engineers at Chicago in February, A. Daurat of Péchiney discussed the production of superpurity aluminum at Mercus, France. Seventy-four 18,000-ampere pots are in the plant, corresponding to an annual capacity of 4,200 tons of superpure aluminum per year. The superpurity aluminum, containing 99.99 (or better) percent aluminum, is refined from commercial electrolytic or cell-grade aluminum by electrolysis in a molten bath consisting of a mixture of fluorides and chlorides of barium, sodium, and aluminum.

The cell consists of three molten layers. The bottom layer is the anode. It consists of the cell-grade aluminum alloyed with about 30 percent copper which is heavier than the bath and the pure aluminum product. The molten salt makes up the middle layer and the superpure aluminum floats on the top of the bath. Graphite electrodes are used.

The main drawback to the process, which is the principal method used for producing superpure aluminum, is its high costs. However, electric energy consumption per pound at Mercus had declined from about 9 kilowatt-hours to about 6.25 kilowatt-hours in recent years.

Alternative methods for producing superpure aluminum were under development. In one process, being developed by Reynolds Metals Co., 8- and 20-inch-diameter ingots of specified purity reportedly were produced at a fraction of the cost necessary to operate 3-layer electrolytic refining cells.[12] The process comprises continuous fractional crystallization of a portion of a liquid aluminum feed stream under conditions of strong agitation at the surface of the growing crystal. The remaining and slightly less pure portion of the feed stream is returned to normal plant usage. Elements which tended to concentrate in the less pure portion included iron, silicon, copper, manganese, zinc, and gallium. Titanium apparently solidified with the purified product. Iron was the easiest of the elements to remove.

The practice of delivering aluminum metal in the molten state directly from the reduction plant or secondary smelter was used increasingly. Molten primary aluminum was transported by truck as far as 300 miles in insulated crucibles.[13] Secondary aluminum alloys were transported molten for distances up to 130 miles. The loss in temperature of the metal during transit reportedly is negligible.

The use of aluminum in deoxidizing steels was the subject of several reports. In one experimental study it was indicated that the oxygen concentration in a melt in equilibrium with alumina and hercynite ($FeO \cdot Al_2O_3$) was 0.058 percent. At higher oxygen concentrations, the deoxidation product was hercynite while at lower concentrations alumina was formed.[14] Another report indicated that rimming steels capped by the addition of about 1 pound of aluminum per ton of steel had a better surface than those that were mechanically capped.[15]

Commercially pure aluminum, designated as the 1000 series, is noted primarily for its high electrical and thermal conduc-

[10] Capitaine, W. E., and W. H. Schmidt-Hatting. Magnetic Fields in High-Amperage Aluminum Reduction Cells. J. Metals, v. 17, No. 3, March 1965, pp. 271–275.

[11] Worrell, Wayne L. Carbothermic Reduction of Alumina. A Thermodynamic Analysis. Canadian Metallurgical Quarterly, v. 4, No. 1, January–March 1965, pp. 87–95.

[12] Dewey, John L. Freeze-Purification Process Upgrades Aluminum Purity. J. Metals, v. 17, No. 9, September 1965, pp. 940–943.

[13] Chemical & Engineering News. Kaiser Aluminum & Chemical Will Ship up to 60 Million Pounds of Molten Aluminum. V. 43, No. 27, July 5, 1965, p. 9.

[14] McLean, A., and R. G. Ward. Aluminum Deoxidation Products in Rimmed Steel. J. Metals, v. 17, No. 5, May 1965, pp. 526–528.

[15] Steel Times (London). Capping Ingots of Rimming Steel. V. 191, No. 5067, Aug. 27, 1965, p. 269.

tivity, corrosion resistance, and high reflectivity. In the annealed condition it has low strength and is relatively soft. However, it is available in strain-hardened conditions of higher strength and reduced ductility. Wrought alloys in the 2000 series, which contain 1.9 to 6.8 percent copper, are heat-treatable to strength levels exceeding those of mild steel. Manganese is the principal alloying element in the nonheat treatable 3000 series of aluminum alloys, The 4000 series, which contain about 4.5 to 13.5 percent silicon as the main alloying ingredient, includes alloys used for forged pistons. The aluminum-magnesium alloys in the 5000 series have moderate strength and generally high corrosion resistance and weldability which make them suitable for welded structures in marine and cryogenic applications. Alloys in the 6000 series contain both magnesium and silicon as the principal alloying constituents and are heat-treatable and have good ductility, weldability, and corrosion resistance. Alloys in the 7000 series which contain zinc and some magnesium include the strongest aluminum alloys commercially available. Alclad alloys include those which are clad on one or both sides with high-purity aluminum or another alloy to improve surface properties.[16]

Melting procedures for aluminum and its alloys were described.[17] Removal of oxides, degassing, grain refinement and control of trace elements is the objective of good melting practices for producing aircraft quality aluminum castings. Gaseous or liquid fluxing methods are used to remove oxides. Chlorine, or a mixture of sodium and potassium chloride and cryolite, or volatile chlorides, such as zinc chloride, are preferred fluxing agents, although many fluxing materials for specialized use also contain other materials.

Hydrogen is the gas most likely to cause trouble in aluminum alloys and it is best removed by bubbling gaseous chlorine, or nitrogen, or a mixture of the two through the melt. Titanium and boron are used for grain refining. Recent tests indicated that a master alloy, containing about 5.5 percent titanium, 1.1 percent boron, and the balance in aluminum was superior to and more economical than titanium alone in refining several aluminum alloys.[18] Control of trace elements is accomplished by utilization of high-purity aluminum alloys and careful attention to prevent contamination.

Basic data on wrought, cast, and powdered aluminum products were given in a report.[19] Some aluminum alloys retain their strength at 500° F and higher. Alloys used for wrought products normally are unsatisfactory for casting because good casting characteristics require higher percentages of alloying elements.

A new die-casting alloy was being developed for automotive engine blocks. The new alloy, which contains 16 to 18 percent silicon, was abrasion resistant after special finishing, thus, eliminating the need for steel inserts for cylinder walls.[20]

Some predictions indicate that by the late 1970's, 90 percent of nonferrous metal production will be cast by continuous processes. Machines developed for continuously casting aluminum and other nonferrous metals into a variety of shapes were described in detail.[21]

A report indicated that the cost of metal losses, depreciation, maintenance, crucibles, fluxes, and fuels in melting aluminum metal in oil-fired crucible furnaces was less than half of the melting costs of using an open-flame furnace and only about two-thirds of the cost of using electric induction furnaces.[22]

A series of papers on the preparation and chemical and electrochemical brightening and anodizing of aluminum were published.[23]

Installation of commercial facilities for continuously annealing aluminum strip suspended by an airstream was planned. This method reportedly overcomes basic obstacles toward obtaining uniform metallurgy

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[16] Materials in Design Engineering. Wrought Aluminum and Its Alloys. V. 61, No. 6, June 1965, pp. 117–132.

[17] Kirk, W. A. Melting Procedures for Aluminum and Magnesium Alloys. Foundry, v. 93, No. 12, December 1965, pp. 62–65.

[18] Crouch, G. H., J. G. Monck, and J. C. Hoff. Aluminum Alloys. Modern Metals, v. 21, No. 2, March 1965, pp. 56–59.

[19] Holt, Marshall, and Kenneth O. Bogardus. The 'Hot' Aluminum Alloys. Product Eng., v. 36, No. 17, Aug. 16, 1965, pp. 88–96.

[20] Modern Metals. New Casting Alloy Boosts Prospects of All-Aluminum Engine. V. 21, No. 7, August 1965, pp. 62, 64.

[21] Light Metals and Metal Industry (London). Continuous Casting of Non-Ferrous Metals. V. 28, No. 322, March 1965, pp. 38–50.

[22] Light Metals and Metal Industry (London). Economic Aspects of Metal Melting In Non-Ferrous Foundries. V. 28, No. 325, June 1965, pp. 47–51.

[23] American Society for Testing and Materials. Anodized Aluminum. ASTM Special Tech. Pub. No. 388, Feb. 9, 1965, 144 pp.

and flawless annealing in all gages up to one-eighth inch in thickness and prevents staining and gouging of the heated metal. Because of its speed as well as labor and space-saving features, the method was expected to supplant the batch-annealing system in current use.[24]

A producer of electrolytic, galvanized steel sheet found that a thin galvanized coating (which is applied much faster than thicker coatings) overlaid with vapor-deposited aluminum formed as easily as hot-dip galvanized sheet, cost less than ordinary electrolytic galvanized sheet, and met coating standards for automotive markets.[25] A new process for preparing aluminum for plating by other metals was described. First aluminum is treated to obtain a uniform surface and then it is immersed in a tin solution. This is followed immediately by a brief electrolytic strike in a special bronze plating bath.[26]

A report indicated that it may be feasible to produce parabaloid mirrors, 30 inches in diameter, by electroforming aluminum in a molten bath of a metallic salt such as aluminum chloride with lithium hydride.[27] Although the electrolyte is flammable and explosive, it was believed that electroforming could be conducted safely. Aluminum foil spoons, made by an air-forming technique opened up a new packaging use for aluminum.[28] A large can manufacturer introduced a new squeeze-tube container which utilized layers of plastic and foil. The report indicated that 75 percent of the tubes currently produced are of pure aluminum.[29]

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[24] Iron and Steel Engineer. Air Flotation of Aluminum Strip Used in Annealing. V. 42, No. 7, July 1965, p. 170.

[25] Bennett, K. W., Aluminum Joins Zinc for Best of Both. Iron Age, v. 196, No. 18, Oct. 28, 1965, p. 26.

[26] Merriam, J. C. Plating-On-Aluminum Process Passes Production Tests. Iron Age, v. 196, No. 21, Nov. 18, 1965, pp. 80–81.

[27] Materials in Design Engineering. Electroformed Aluminum Parts Feasible. V. 62, No. 4, October 1965, p. 6.

[28] American Metal Market. Air Forming Technique Is Seen Opening Up New Packaging Uses. V. 72, No. 148, Aug. 4, 1965, p. 13.

[29] Metal Bulletin (London). Treat to Aluminium Collapsible. No. 4991, Apr. 23, 1965, p.29.

Antimony

By Donald E. Moulds [1]

Consumption of primary antimony increased approximately 7 percent in 1965. This consumption rate was last exceeded during the Korean War in 1953. Despite the high requirements, supply of primary antimony from domestic and foreign sources plus deliveries of antimony from Government sales in October 1964 and January 1965 was ample. While domestic metal quotations remained unchanged throughout the year, the reported price of foreign metal declined steadily. Secondary output of antimony continued upward and reached a new high of 24,300 tons as secondary lead smelters processed a record tonnage of antimonial lead scrap. Imports of antimony declined 11 percent during the year with the decrease principally in the form of refined metal and oxide.

Legislation and Government Programs.—At yearend Government stocks of antimony totaled 49,491 tons of which 159 tons was nonstockpile grade. The reduction in Government stocks resulted from the delivery of 765.7 tons of antimony metal and 350 tons of antimony ore, sold by General Services Administration in January under authorization of Public Law 88–615 enacted in 1964. This authorization was for 5,000 tons, of which 2,750 tons remain unsold. In addition, 12,227 tons of antimonial lead was held in the national stockpile.

[1] Commodity specialist, Division of Minerals.

Table 1.—Salient antimony statistics

(Short tons)

	1956–60 (average)	1961	1962	1963	1964	1965
United States:						
Production:						
Primary:						
Mine	663	689	631	645	632	845
Smelter [1]	10,103	11,329	11,727	12,117	13,358	12,389
Secondary	21,267	19,466	19,362	20,803	22,339	24,321
Exports of ore, metal and alloys	260	44	45	143	807	14
Imports, general (antimony content)	13,302	13,942	16,833	17,781	r 16,718	14,879
Consumption [2]	13,372	12,697	15,452	16,532	15,839	16,919
Price: New York, average cents per pound	32.88	33.89	34.75	34.75	42.22	45.75
World: Production	56,700	57,200	59,100	61,300	68,100	69,100

r Revised.

[1] Includes primary content of antimonial lead produced at primary lead smelters.

[2] Includes primary content of antimonial lead produced at primary lead smelters and antimony content of alloys imported 1956 through 1963. Not available thereafter.

DOMESTIC PRODUCTION

MINE PRODUCTION

Domestic mine production increased 34 percent over that of 1964 and reached the highest level since closure of the Bradley Mining Co. antimony-tungsten mine at Stibnite, Idaho, in 1952. Antimony recovered as a byproduct of lead-silver ores, produced by the Sunshine Mining Co., Hecla Mining Co., and Silver Dollar Mining Co. in Idaho, was the predominant source of mine production. Seven antimony mines were reopened in northern Nevada, and small shipments of ore containing 35 to 50 percent antimony were reported. The Stampede mine in Alaska, operated by Earl R. Pilgrim & Co., produced small tonnage of antimony ore. Nevcal Minerals, Inc., was reported to be initiating operations at a property in San Bernardino County, Calif., and Silver Ridge Mining Co. Ltd., proceeded with development of its Eagle Creek property near Fairbanks, Alaska.

SMELTER PRODUCTION

Primary.—Production of 12,400 tons of antimony from primary materials at domestic smelters represented a 7-percent decrease below that of 1964. Output of all classes of refined materials decreased, although output of ground and processed sulfide material was about double the small production of the previous year. The source of feed material for the smelters was as follows: 17 percent from domestic ores and 83 percent from foreign ores. Approximately 19 percent of the antimony obtained was a byproduct in the refining of lead ores from domestic and foreign sources. Of this byproduct antimony, about 1,400 tons was recovered as antimonial lead and the remainder was recovered as oxide.

Materials produced by the smelters consisted of the following: Metal, 34 percent; oxide, 52 percent; antimonial lead, 11 percent; and the remaining 3 percent as ground sulfide and as residues for reprocessing. Antimony metal was produced by National Lead Co. and Sunshine Mining Co. Oxide was produced by American Smelting and Refining Company, Harshaw Chemical Co., McGean Chemical Co., M.&T. Chemicals, Inc., and National Lead Co. Antimony sulfide was produced by Foote Mineral Co., Hummel Chemical Co., and McGean Chemical Co.

Secondary.—The secondary lead smelting industry continued to expand consumption of scrap material, of which a major portion contains antimony, and achieved a new record output of lead and antimony. In 1965, the antimony recovered, increased 9 percent to 24,300 tons with a valuation of $22.3 million. This valuation reflected, in part, the increased average price of domestic antimony. Secondary smelters recovered 22,600 tons, primary smelters recovered 600 tons, and manufacturers and foundries recovered the remaining 1,100 tons. Sources of old scrap, which contributed 89 percent of the antimony, consisted of the following: Batteries, 66 percent; type metal, 24 percent; babbitt, 7 percent; and other end products, 3 percent. New scrap, consisting of refining and manufacturing residues and drosses, also increased over the tonnage reported for 1964. Antimony in scrap is usually recovered as antimonial lead, with additions or removal of antimony as necessary in the refining stage to meet specifications for the various antimonial lead alloys. Approximately 3,800 tons of primary antimony was used in 1965 to supplement the secondary antimony supply at secondary smelters and foundries.

Table 2.—Antimony mine production and shipments in the United States

(Short tons)

Year	Antimony concentrate		Antimony	
	Quantity	Antimony content, percent	Produced	Shipped
1956–60 (average)	3,994	17.2	663	720
1961	4,245	16.2	689	1,646
1962	3,941	16.0	631	732
1963	3,540	18.2	645	503
1964	3,296	19.2	632	789
1965	4,711	17.9	845	848

Table 3.—Primary antimony produced in the United States
(Short tons, antimony content)

Year	Class of material produced: Metal	Oxide	Sulfide	Residues	Byproduct antimonial lead	Total
1956–60 (average)	3,623	4,473	90	457	1,460	10,103
1961	4,558	4,609	84	355	1,723	11,329
1962	4,407	4,788	53	366	2,113	11,727
1963	4,160	5,983	76	392	1,506	12,117
1964	4,418	6,748	53	447	1,692	13,358
1965	4,216	6,485	94	205	1,389	12,389

Table 4.—Secondary antimony produced in the United States, by kind of scrap and form of recovery
(Short tons, antimony content)

	1964	1965		1964	1965
Kind of scrap:			Form of recovery:		
New scrap:			In antimonial lead [1]	16,199	16,574
Lead-base	2,272	2,529	In other lead alloys	6,110	7,726
Tin-base	87	82	In tin-base alloys	30	21
Total	2,359	2,611	Total	22,339	24,321
Old scrap:			Value (millions)	$18.9	$22.3
Lead-base	19,941	21,675			
Tin-base	39	35			
Total	19,980	21,710			
Grand total	22,339	24,321			

[1] Includes 303 tons of antimony recovered in antimonial lead from secondary sources at primary plants in 1964 and 595 tons in 1965.

Table 5.—Byproduct antimonial lead produced at primary lead refineries in the United States
(Short tons)

Year	Gross weight	Antimony content: From domestic ores [1]	From foreign ores [2]	From scrap	Total: Quantity	Total: Percent
1956–60 (average)	50,515	913	548	1,082	2,543	5.1
1961	35,080	1,010	713	171	1,894	5.4
1962	33,325	1,361	752	136	2,249	6.7
1963	18,818	836	670	384	1,890	10.0
1964	24,023	997	695	303	1,995	8.3
1965	27,895	998	391	595	1,984	7.1

[1] Includes primary residues and a small quantity of antimony ore.
[2] Includes foreign base bullion and small quantities of foreign antimony ore.

CONSUMPTION AND USES

Industrial requirements are supplied by antimony derived from primary and secondary materials. Consumption of secondary antimony occurs mostly in the production of antimonial lead. The total requirements in 1965 were 41,200 tons in comparison with a total requirement of 38,200 tons in 1964. The breakdown of the use of secondary antimonial lead in various products is not available, and only consumption of primary antimony is reported to the Bureau of Mines.

Consumption of primary antimony increased in 1965 and continued the upward trend in requirements since 1961. This upward trend was interrupted only by the curtailed consumptions in 1964, necessitated by a shortage in supply of oxide. Requirements for antimony were approximately equal for metal products using antimony metal predominantly as a lead alloying agent, and for nonmetal products requiring antimony essentially as a trioxide. Requirements for metal products have increased 33 percent since 1961 and, in comparison with those of 1964, an increase was registered for all classes except collapsible tubes and foil. Flameproofing compounds, ceramics and glass, and plastics increased significantly in antimony. This increase offset the decrease of antimony requirements in pigments and rubber products. Of the 1,853 tons of antimony consumed in the ceramics and glass category, 75 percent was consumed by the ceramics industry. Other unclassified nonmetal use of antimony, predominantly in industrial chemicals, adhesives, and paper, was 100 tons less than the 1964 amount. The use of antimony in flame-retardant compounds is continuing to provide new products for specialized use in plastics and wood-based materials that have improved commercial possibilities in the high-temperature field.

Table 6.—Industrial consumption of primary antimony in the United States [1]

(Short tons, antimony content)

Year	Class of material consumed						Total
	Ore and concentrate	Metal	Oxide	Sulfide	Residues	Byproduct antimonial lead	
1956–60 (average)	567	4,949	5,847	92	457	1,460	13,372
1961	106	4,994	5,450	69	355	1,723	12,697
1962	137	6,126	6,642	68	366	2,113	15,452
1963	266	7,124	7,173	71	392	1,506	16,532
1964	252	6,050	7,325	73	447	1,692	15,839
1965	404	6,992	7,847	81	206	1,389	16,919

[1] Includes antimony content of imported antimonial lead consumed 1956 through 1963. Not available thereafter.

Table 7.—Industrial consumption of primary antimony in the United States, by class of material produced

(Short tons, antimony content)

Product	1956–60 (average)	1961	1962	1963	1964	1965
Metal products:						
Ammunition	5	W	W	W	15	36
Antimonial lead [1]	4,393	4,708	6,090	6,462	5,952	6,382
Bearing metal and bearings	871	737	682	992	804	821
Cable covering	177	141	114	101	49	68
Castings	80	53	64	49	50	76
Collapsible tubes and foil	24	24	112	72	53	49
Sheet and pipe	247	147	127	81	99	104
Solder	115	97	172	188	149	244
Type metal [1]	799	448	429	652	513	642
Other	143	152	271	199	167	214
Total [1]	6,854	6,507	8,061	8,796	7,851	8,636
Nonmetal products:						
Ammunition primers	12	15	14	15	17	16
Fireworks	34	20	23	36	47	46
Flameproofing chemicals and compounds	962	1,138	1,215	1,601	1,626	1,971
Ceramics and glass	1,747	1,223	1,146	1,465	1,649	1,853
Matches	20	W	9	5	W	W
Pigments	1,210	845	1,161	1,009	1,173	855
Plastics	922	1,228	1,269	1,352	1,289	1,469
Rubber products	232	287	460	597	492	477
Other	1,379	1,434	2,094	1,656	1,695	1,596
Total	6,518	6,190	7,391	7,736	7,988	8,283
Grand total	13,372	12,697	15,452	16,532	15,839	16,919

W Withheld to avoid disclosing individual company confidential data; included with "Other."

[1] Includes antimony content of imported antimonial lead consumed 1956 through 1963. Not available thereafter.

STOCKS

Industrial stocks of primary antimony, as reported to the Bureau of Mines, steadily increased each quarter to a total of 8,600 tons at yearend, the largest reported since 1956. This increase represents a gain of 1,300 tons during the year. The only stock decline in comparison with 1964 was in the form of oxide.

Table 8.—Industry stocks of primary antimony in the United States, December 31

(Short tons, antimony content)

Stocks	1961	1962	1963	1964	1965
Ore and concentrate	850	1,450	1,970	1,647	2,735
Metal	1,680	1,599	1,420	1,433	1,585
Oxide	2,398	1,895	1,861	2,895	2,705
Sulfide	107	90	81	81	98
Residues and slags	873	999	1,081	935	1,088
Antimonial lead [1]	538	403	651	309	411
Total	6,446	6,436	7,064	7,300	8,622

[1] Inventories from primary sources at primary lead smelters only.

PRICES

The shortage in supply of antimony ore during 1963–64, caused by increased demand and readjustment in trade channels, which induced sharp increases in price of ore, metal, and oxide, was eased by sale of Government stocks in October 1964 and January 1965. Supply availability from expanded free world areas, as well as increased Chinese marketings in Europe, resulted in a weakening ore market in the second quarter of 1965. During the third and fourth quarters of the year, further deterioration in the import market occurred. This deterioration brought the quoted price for prime 65-percent antimony ore at New York down from $8.25 to $6.50 per short ton unit of contained antimony.

The domestic price of antimony oxide also declined from a high of 60 cents per pound to a yearend price of 47.5 cents per pound. While the quoted price of 99.5-percent domestic metal continued unchanged at 45.75 cents per pound in bulk at New York, the dealer price for imported metal declined from a range of 54 to 60 cents, dependent on quality, at the beginning of the year to a range of 43 to 47 cents per pound at yearend.

Table 9.—Antimony price ranges in 1965

Type of antimony:		*Price*
Domestic metal [1]	cents per pound	44.00
Foreign metal [2]	do	43.00 to 58.00
Antimony trioxide [3]	do	47.50 to 60.00
Antimony ore,[3] 50 to 55-percent	dollars per short-ton unit	5.50 to 8.25
Antimony ore, minimum 60-percent	do	6.00 to 8.50
Antimony ore, minimum 65-percent	do	6.25 to 8.75

[1] RMM brand, f.o.b., Laredo, Tex.
[2] Duty-paid delivery, New York.
[3] Quoted in E&MJ Metal and Mineral Markets.

FOREIGN TRADE

Exports.—During 1965 exports of antimony, including antimony as ore, refined, wrought and unwrought alloys, and scrap amounted to less than 14 tons gross weight. Of this, France received 5 tons and the remainder consisted of small shipments to 12 countries.

Imports.—General imports of antimony in various forms decreased 11 percent to 14,900 tons, of which about 5,300 tons was delivered in the fourth quarter. Ore imports, primarily from Mexico, Republic of South Africa, and Bolivia, were 300 tons less than the 1964 imports. Ecuador and Uruguay were new South American sources of antimony. Imports of metal, 53 percent from Yugoslavia, decreased 21 percent in comparison with the 1964 imports. Imports of oxide decreased 30 percent as shipments from all suppliers except France were substantially reduced. The United Kingdom, Belgium-Luxembourg, and France together supplied 92 percent of the total import of oxide.

Table 10.—U. S. imports[1] of antimony, by countries

Year and country	Antimony ore			Needle or liquated antimony		Antimony metal		Antimony oxide	
	Short tons (gross weight)	Antimony content: Short tons	Antimony content: Value (thousands)	Short tons (gross weight)	Value (thousands)	Short tons	Value (thousands)	Short tons (gross weight)	Value (thousands)
1956–60 (average)	15,743	6,224	$1,366	81	$37	4,786	$2,251	1,888	[2] $774
1961	16,204	6,713	1,389	13	6	4,912	2,347	1,980	935
1962	20,122	8,602	2,168	17	8	4,740	2,309	2,910	1,391
1963	22,807	9,784	2,675	22	11	5,696	2,958	2,089	1,038
1964:									
Austria				4	3				
Belgium-Luxembourg						302	278	1,168	1,362
Bolivia	3,240	2,128	919			43	7		
Canada						(3)	24	113	121
Chile	562	357	147						
France								248	237
Germany, West						(3)	1	310	324
Honduras	15	10	2						
Hungary								11	8
Japan								39	34
Korea, South	140	85	36						
Mexico	12,652	3,937	633			r 352	r 227		
Netherlands								9	10
Pakistan								83	30
Peru	288	180	86			425	217		
South Africa, Republic of	6,528	3,951	1,454					4	3
Switzerland								6	8
Thailand	55	28	17			118	73		
United Kingdom				27	18	470	381	1,140	885
Yugoslavia						1,712	1,384		
Total	23,480	10,676	3,294	31	21	r 3,422	r 2,592	3,131	3,022
1965:									
Belgium-Luxembourg				3	2	129	113	715	611
Bolivia	3,806	2,304	1,286			5	5		
Canada	58	15	2			(3)	19		
Chile	405	256	133						
Congo (Leopoldville)						3	8		
Ecuador	129	78	41						
France								298	274
Germany, West						(3)	5	113	96
Honduras	54	28	14						
Japan								18	17
Mexico	11,895	3,770	638			283	190		
Morocco	304	118	56						
Netherlands								32	29
Pakistan								11	10
Peru	218	153	69			240	193		
South Africa, Republic of	5,353	3,292	1,864			95	37		
Spain						16	13		
Thailand	529	259	168			7	6		
United Kingdom				20	16	476	393	991	765
Uruguay	135	87	39						
Yugoslavia						1,442	1,165		
Total	22,886	10,360	4,310	23	18	2,696	2,147	2,178	1,802

r Revised.
1 Data are general imports; that is, they include antimony imported for immediate consumption plus material entering the country under bond. Table does not include antimony contained in lead-silver ores.
2 1957 data known to be not comparable with other years.
3 Less than ½ unit.

Table 11.—U.S. imports for consumption of antimony [1]

Year	Antimony ore: Short tons (gross weight)	Antimony ore: Antimony content: Short tons	Antimony ore: Antimony content: Value (thousands)	Needle or liquated antimony: Short tons (gross weight)	Needle or liquated antimony: Value (thousands)	Antimony metal: Short tons	Antimony metal: Value (thousands)	Type metal and antimonial lead [2] (short tons)	Antimony oxide: Short tons (gross weight)	Antimony oxide: Value (thousands)
1956–60 (average)	15,743	6,224	$1,366	84	$38	4,775	$2,247	669	1,886	[3] $773
1961	16,204	6,713	1,389	13	6	4,912	2,347	665	1,980	935
1962	20,122	8,602	2,168	17	8	4,720	2,300	1,064	2,910	1,391
1963	22,807	9,784	2,675	22	11	5,717	2,968	[4] 552	2,089	1,038
1964	23,480	10,676	3,294	31	21	3,307	2,481	([5])	3,131	3,022
1965	22,886	10,360	4,310	23	18	2,650	2,112	([5])	2,173	1,798

[1] Does not include antimony contained in lead-silver ore.
[2] Estimated antimony content; for gross weight and value, see Lead chapter of 1965 Minerals Yearbook.
[3] 1957 data known to be not comparable with other years.
[4] Data not comparable with earlier years.
[5] No longer separately classified.

WORLD REVIEW

Algeria.—During the first half of 1965, the Société de la Vieille Montagne reopened its antimony mine located at Hamman N'Bails in eastern Algeria. Production in 1965 amounted to 220 short tons of ore containing 32.35 percent antimony. Production is expected to exceed 1,100 tons in 1966.

Australia.—Output of antimony is essentially a byproduct of the refining of lead-zinc ores from Broken Hill, New South Wales, and the Rosebery area mines in Tasmania. A new antimony discovery in 1965 near Dorrigo, New South Wales, by Dundee Mines Ltd., is reported to have 450,000 tons of ore containing 4.5 percent antimony. Development was in progress and ore was stockpiled.

Bolivia.—Production of antimony was approximately equal to the high level established in 1964. A short strike at the mines operated by Empresa Minera Unificada, S.A. (EMUSA) slightly curtailed output. Of antimony produced, the small privately owned mines, selling ore to the State-owned Banco Minero de Bolivia, represented 38 percent, and exports by EMUSA and the two mines owned by Metal Traders, Inc., New York, represented 61 percent. The remainder comes as a byproduct from the nationalized lead-zinc mines operated by Corporación Minera de Bolivia.

Table 12.—World production of antimony (content of ore except as indicated) by countries

(Short tons)

Country	1961	1962	1963	1964	1965 [p] [1]
North America:					
Canada [2]	666	966	801	[r] 796	616
Guatemala (U.S. imports)	71	32	31		
Mexico [3]	3,978	5,257	5,320	5,278	4,924
United States	689	631	645	632	845
South America:					
Bolivia (exports) [3]	7,430	7,331	8,337	10,626	10,606
Peru [3]	870	575	[r] 674	[r] 752	583
Europe:					
Austria	668	767	548	585	434
Czechoslovakia [e]	1,800	2,200	2,200	2,200	2,200
France			110	[r] 185	
Italy	276	369	266	376	293
Portugal			7	13	11
Spain	190	175	65	[r] 60	1,012
U.S.S.R. [e]	6,300	6,600	6,700	6,700	6,800
Yugoslavia (metal)	2,715	2,966	2,933	3,008	3,051
Africa:					
Algeria	720	149			71
Morocco	406	449	744	[r] 1,720	2,477
Rhodesia, Southern	68	61	66	49	[e] 200
South Africa, Republic of	11,804	11,697	12,410	14,200	13,901
Asia:					
Burma [3]	[r] 166	[r] 75	(4)	(4)	55
China [e]	16,500	16,500	16,500	16,500	16,500
Iran [5]				[6] 66	[e] [6] 80
Japan	215	190	212	554	[e] 600
Pakistan	15	75	9	90	67
Ryukyu Islands	112				
Sarawak				86	
Thailand	25	19	676	1,399	[e] 1,380
Turkey	1,502	1,962	1,981	1,915	[e] 2,340
Oceania: Australia	132	74	83	[r] 305	39
World total [1]	57,200	[r] 59,100	[r] 61,300	[r] 68,100	69,100

[e] Estimate. [p] Preliminary. [r] Revised.
[1] Compiled mostly from data available June 1966.
[2] Antimony content of smelter products exclusively from mixed ores.
[3] Includes antimony content of smelter products derived from mixed ores.
[4] Revised to none.
[5] Year ended March 20 of year following that stated.
[6] Exports.

Canada.—The Consolidated Mining & Smelting Co. of Canada Ltd. (COMINCO), produced all of the Canadian antimony at Trail, British Columbia, as a byproduct of refining lead-zinc concentrates. The antimony produced was consumed in output of antimonial lead at the refinery. Output in 1965 decreased approximately 23 percent below that of 1964. Extensive exploration and development was undertaken on an antimony deposit near Tulsequah, British Columbia, by New Taku Mines Ltd., in a joint venture with Mineral Development Co., a subsidiary of Homestake Mining Co. Yukon Antimony Corp. accomplished underground development and testing at an antimony-silver property 30 miles southwest of Robinson, Yukon Territory. Exploratory drilling was initiated at a new antimony discovery about 35 miles southwest of Golden, British Columbia, by Columbia River Mines Ltd.

China.—Information concerning Chinese output was not available. Heavy offerings of regulus reported at the Canton and other industrial fairs and the availability of imported regulus in the European area indicate an effort by the Chinese to again supply the Western market.

Japan.—Mine production of recoverable antimony in concentrates was approximately as high as the 1964 output of 550 tons. Nevertheless, the reduced demand for refined antimony resulted in a substantial cutback in production by the two major antimony smelters in Japan, which rely essentially on imported ores.

Mexico.—The production of antimony ores by the mines of National Lead Co. and other small individually operated mines, all of which was exported to the National Lead Co. smelter at Laredo, Tex., was well below the 1964 output. A small tonnage of antimony was also produced in various smelter byproducts for export and refining.

Morocco.—The reopening of several antimony mines in 1964–65, as well as the expanded output of the largest antimony producer, Omnium de Gérance Industrielle et Minière, resulted in a 44 percent increase in production over that of 1964.

Rhodesia, Southern.—Antimony was obtained as a byproduct of gold mining operations at the Sebakwe mine near Que Que and shipped as a concentrate to the United Kingdom. A new company, Rhodesian Antimony Ltd., was formed to investigate a new deposit in the Que Que area.

South Africa, Republic of.—The Consolidated Murchison (Transvaal) Goldfields & Development Co. Ltd., produced 22,700 short tons of cobbed ore and concentrates in 1965 in comparison with the 23,600 tons produced in 1964. The entire decrease was in cobbed ore. The mine was worked to capacity, and the stocks of ore and concentrate increased by almost 3,000 tons. The Alpha shaft was bottomed at 3,615 feet in January and the installation of permanent hoisting equipment completed. Development in the various sections of the mine was conducted, and reserves were increased to 480,000 tons by yearend. The expansion of the crushing and concentrating capacity was carried forward with completion expected in January 1966.[2]

Thailand.—Interest in antimony continued with a number of small mines coming into production at a rate of 5 to 10 tons of 55-percent antimony ore monthly. A new mining company, Minerals Development Co. Ltd., was reportedly formed by Thai citizens to engage in exploration and evaluation of tin and antimony properties.

Turkey.—Development of an antimony ore deposit near Nigde in the Zamanti mining district by Rasih ve Ihsan Madencilik Skiti was in progress. Handpicked ore, containing up to 60 percent antimony, was stocked and the Mineral Research and Exploration Institute of Turkey has estimated a reserve of 74,000 tons of ore averaging 12.5 percent antimony.

Yugoslavia.—The antimony mines produced about 140,000 tons of ore ranging from 1 to 4 percent antimony and production of regulus amounted to 3,050 tons averaging 99.5 percent antimony.

TECHNOLOGY

The semiconductor and thermoelectric properties of ultra-high-purity antimony metal, as an alloying element with bismuth, indium, and tellurium, have become a major research area. Development of new techniques and applications of antimony metal and oxide in commercial alloys and compounds continued especially in relation to alloys of lead and to flameproofing compounds.

The results of the investigations of the antimony-lead-tellurium system[3] and the arsenic-antimony system[4] were reported. A report on a technique for electrodeposition of gallium antimonide and indium antimonide was published,[5] and a rapid method of polarographic determination of antimony in antimonial lead was presented.[6] A battery using a potassium chloride-antimony chloride electrolyte was under study by a research team from colleges in Montana and Oregon, which offers an advantage in operation at subzero temperatures.[7]

The Geological Survey published a professional paper covering the ore deposits (including antimony) of Humboldt and Lander Counties, Nev.[8]

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[2] Consolidated Murchison (Transvaal) Goldfields & Development Co. Ltd., Annual Report, 1965, pp. 12–13.

[3] Henger, G. W., and E. A. Peretti. Constitution of the Lead– and Antimony–Rich Regions of the Antimony–Lead–Tellurium System. J. Less–Common Metals, v. 8, No. 2, February 1965, pp. 124–135.

[4] Skinner, Brian J. The System Arsenic–Antimony. Econ. Geol., v. 60, No. 2, March–April 1965, pp. 228–239.

[5] Hobson, Melvin C., Jr., and Henry Leidheiser, Jr. Increased Rate of Formation of InSb on an Antimony Surface During Electrolytic Treatment. Trans. AIME, v. 233 (Met. Soc.), No. 3, March 1965, pp. 482–484.

[6] Scholes, I. R., and K. H. Denmead. The Polarographic Determination of Alloying Amounts of Antimony in Antimonial Lead. Metallurgia (Manchester, England), v. 71, No. 428, June 1965, pp. 295–296.

[7] Product Engineering. V. 36, No. 23, Nov. 8, 1965, p. 65.

[8] Roberts, R. J., and D. C. Arnold. Ore Deposits of the Antler Peak Quadrangle, Humboldt and Lander Counties, Nevada. Geol. Survey Prof. Paper 459–B, 1965, 94 pp.

Asbestos

By Timothy C. May [1]

California maintained its position as the leading domestic producer of asbestos. Production of asbestos increased 17 percent in quantity and 25 percent in value over that of 1964. Most of the increase in production came from California. The nation ranked sixth among world producers. World production exceeded 3.5 million tons. Canada continued to be the leading free world producer, with an output close to 1.4 million tons in 1965. Imports of asbestos were 3 percent less than 1964. Exports of unmanufactured asbestos in 1965 increased 59 percent in volume over those of 1964.

Legislation and Government Programs.—As of December 31, 1965, the stockpile inventory of specification grade chrysotile was 33 percent below the stockpile objective and amosite was 43 percent in excess. Approximately 850 short tons of subspecification grade chrysotile was authorized as a short-term release from the Defense Production Act inventory. Sales offerings were made but only 6 tons were purchased with a value of $937.

Under the Agricultural Trade Development and Assistance Act of 1954 (Public Law 480, 83d Cong.), the Department of Agriculture, through the Commodity Credit Corporation (CCC), bartered agricultural commodities for 5,681 tons of amosite and 6,146 tons of crocidolite.

[1] Commodity specialist, Division of Minerals.

Table 1.—Salient asbestos statistics

	1956-60 (average)	1961	1962	1963	1964	1965
United States:						
Production (sales) short tons	43,925	52,814	53,190	66,396	101,092	118,275
Value thousands	$4,682	$4,347	$4,677	$5,108	$8,143	$10,162
Exports and reexports (unmanufactured) short tons	3,771	3,799	2,949	10,044	27,147	43,126
Value thousands	$560	$759	$598	$1,304	$3,199	$5,294
Exports and reexports of asbestos products (value) thousands	$13,852	$13,825	$14,274	$16,267	$16,288	$19,101
Imports for consumption (unmanufactured) short tons	679,903	616,529	675,953	667,860	739,361	719,559
Value thousands	$61,742	$58,942	$64,112	$61,739	$72,973	$70,457
Consumption, apparent [1] short tons	720,057	665,544	726,194	724,212	813,306	794,708
World: Production do	2,167,000	2,770,000	3,050,000	3,210,000	3,540,000	3,570,000

[1] Measured by quantity produced, plus imports, minus exports.

The stockpile position as of December 31, 1965, was as follows:

Table 2.—Stockpile objective and Government inventories as of December 31, 1965
(Short tons)

	Stockpile objective	National	Supplemental	Commodity Credit Corporation	Defense Production Act	Total
Amosite	40,000	11,705	43,465	2,134	--------	57,304
Chrysotile	13,700	6,072	2,864	199	--------	9,135
(Subspecification)	None	(152)	(3,193)	--------	(2,343)	(5,688)
Crocidolite	None	1,566	44,245	2,243	--------	48,054

DOMESTIC PRODUCTION

Production of asbestos in California was 36 percent higher than in 1964, accounting for the substantial increase in domestic output.

Vermont Asbestos Mines Division of Ruberoid Co., Lowell mine, near Hyde Park, Vt., continued as the major producer of chrysotile. Production was 7 percent below that of 1964.

Production in Arizona was approximately the same as in 1964. Three companies reported shipments of chrysotile from Gila County, Ariz.; Asbestos Manufacturing Co. from the Phillips mine; Jaquays Mining Corp. from the Regal and Chrysotile Mines; and Metate Asbestos Corp. from the Lucky Seven mine.

Production and shipments were made by the following California companies. Asbestos Bonding Co. from the Phoenix mine, Napa County; Atlas Mineral Corp. from the Rover Pit and Santa Cruz mines, Fresno County; Coalinga Asbestos Co., Inc., Fresno County; Pacific Asbestos Corp. from the Pacific Asbestos mine, Calaveras County; and Union Carbide Corp., Nuclear Division, from the Joe 5 mine, San Benito County.

Powhatan Mining Co., Baltimore, Md., produced anthophyllite asbestos at the Burnsville mine, Yancey County, N.C. Shipments were slightly below those of 1964.

CONSUMPTION AND USES

Total consumption of asbestos in 1965 dropped slightly from that of 1964. Approximately 95 percent of the chrysotile consumed was short fiber of less than spinning length and was used chiefly in the manufacture of building materials. The major uses of asbestos were the following: Asbestos cement products, floor tile, asbestos paper, friction materials and gaskets, textiles, plastics, paints, roof coatings, caulks, and many miscellaneous items.

Consumption of amosite and crocidolite in 1965, based on imports, was substantially less in 1964. See table 5.

PRICES [2]

Quotations for Arizona asbestos, f.o.b. Globe, were listed as follows:

Grade	*Per short ton*
Crude No. 1	$1,410 to $1,650
Crude No. 2	610 to 900
AAA	800
Group No. 3 (nonferrous filtering and spinning)	425 to 750
Group No. 4 (nonferrous plastic and filtering)	385 to 500
Group No. 5 (plastic and filtering)	$250 to $400
Group No. 7 (refuse and shorts)	58 to 90

Canadian (Quebec) chrysotile, f.o.b. mine, prices changed depending on grade of fiber, as of January 1, 1965.

[2] Asbestos. V. 47, No. 6, December 1965, p. 44.

Canadian (Quebec) chrysotile asbestos prices, f.o.b. mine, were as follows:

Grade	Per short ton	
	1964	Jan. 1, 1965
Crude No. 1	Can $1,410 to $1,475	Can $ ----- $1,410
Crude No. 2, crude run of mine and sundry	610 to 875	640 to 875
No. 3, spinning fiber	350 to 650	345 to 565
No. 4, shingle fiber	180 to 245	190 to 320
No. 5, paper fiber	120 to 150	115 to 156
No. 6, waste, stucco, or plaster	----- 86	----- 95
No. 7, refuse or shorts	40 to 80	40 to 80

Prices for British Columbia chrysotile asbestos, f.o.b. Vancouver, from Cassiar Asbestos Corp. Ltd., were as follows:

Grade	*Per short ton*
C–1	Can$1,522
AAA	787
AA	625
A	470
AC	325
AD	260
AK	220
AS	181
AX	160
AY	120

Vermont asbestos prices, f.o.b. Hyde Park or Morrisville, were as follows:

Grade	*Per short ton*
Group No. 3, spinning and filtering	$319 to $370
Group No. 4, shingle fiber	176 to 296
Group No. 5, paper fiber	$121 to $144
Group No. 6, waste, stucco, or plaster	--- 88
Group No. 7, shorts and floats	40.50 to 75

Market quotations were not available for African and Australian asbestos because sales were negotiated privately. The following average values were calculated from U.S. Department of Commerce import data:

	Per short ton	
Imports:	*1964*	*1965*
Amosite:		
South Africa, Republic of	$157	$156
Chrysotile:		
Rhodesia, Southern	226	186
South Africa, Republic of	173	177
Crocidolite:		
Australia	197	190
South Africa, Republic of	198	195

FOREIGN TRADE

Exports of manufactured products increased 17 percent over those of 1964. Canada accounted for 25 percent of the total value. The products consisted of asbestos gaskets and packings, asbestos textiles and yarns, clutch facings and linings, brake linings, and manufactures other than friction materials.

Imports of amosite and crocidolite in 1965 decreased 29 and 15 percent, respectively. Imports of low-iron spinning-length chrysotile from British Columbia increased to 6,038 tons from 4,948 tons and imports of all grades increased to 27,392 tons from 18,640 tons in 1964. Of all the chrysotile imported, fiber of less than spinning length amounted to 94 percent.

Table 3.—U.S. exports and reexports of asbestos and asbestos products

Product	1964 Quantity	1964 Value	1965 Quantity	1965 Value
Exports:				
Unmanufactured:				
Crude and spinning fibers----short tons----	620	$168,137	1,251	$326,095
Nonspinning fibers------do----	12,887	1,881,195	24,221	3,621,528
Waste and refuse------do----	13,312	1,112,664	17,523	1,322,501
Total unmanufactured------do----	26,819	3,161,996	42,995	5,270,124
Products:				
Brake lining and blocks-molded, semi-molded, and woven----	(1)	4,808,497	(1)	4,727,861
Clutch facing and lining------number----	2,046,247	1,840,560	2,020,864	1,690,590
Construction materials, n.e.c.--short tons----	12,988	3,204,223	11,566	2,684,776
Pipe covering and cement------do----	3,951	1,599,039	(2)	(2)
Textiles, yarn, and packing------do----	1,520	3,566,507	2,526	5,595,007
Manufactures, n.e.c.----	NA	1,235,055	NA	4,388,676
Total products----	----------	16,253,881	----------	19,086,910
Reexports:				
Unmanufactured:				
Crude and spinning fibers----short tons----	108	17,725	50	10,306
Nonspinning fibers------do----	2	660	81	13,075
Waste and refuse------do----	218	18,861	----------	----------
Total unmanufactured----	328	37,246	131	23,381
Products:				
Brake lining and blocks-molded, semi-molded, and woven----	----------	----------	(1)	1,712
Clutch facing and lining------number----	----------	----------	5,000	4,100
Construction materials, n.e.c--short tons----	114	22,496	----------	----------
Textiles, yarn, and packing------do----	(3)	122	(3)	900
Manufactures, n.e.c.----	NA	11,870	NA	7,542
Total products----	----------	34,488	----------	14,254

NA Not available.
[1] Values have been summarized: quantities not shown.
[2] Effective Jan. 1, 1965, no longer separately classified, included with manufactures, n.e.c.
[3] Less than ½ unit.

Table 4.—U.S. imports for consumption of asbestos (unmanufactured), by classes and countries

Year and country	Crude (including blue fiber) Short tons	Crude (including blue fiber) Value	Textile fiber Short tons	Textile fiber Value	All other Short tons	All other Value	Total Short tons	Total Value
1964:								
Australia	475	$94,022	---------	---------	---------	---------	475	$94,022
Bolivia	3	4,800	---------	---------	---------	---------	3	4,800
Canada	4,466	795,546	13,881	$5,380,633	648,626	$54,404,684	666,973	60,580,863
Finland	117	4,400	---------	---------	934	42,522	1,051	46,922
Italy	---------	---------	---------	---------	6	7,395	6	7,395
Mexico	---------	---------	---------	---------	304	32,995	304	32,995
Mozambique	---------	---------	90	37,273	239	41,921	329	79,194
Portugal	---------	---------	---------	---------	5	560	5	560
Portuguese Western Africa, n.e.c.	---------	---------	---------	---------	130	10,386	130	10,386
Rhodesia and Malawi [1]	7,633	1,518,126	90	35,719	6,271	1,330,350	13,994	2,884,195
South Africa, Republic of	49,607	8,843,905	---------	---------	924	169,208	50,531	9,013,113
Spain	---------	---------	---------	---------	50	8,374	50	8,374
U.S.S.R.	---------	---------	---------	---------	20	732	20	732
Venezuela	---------	---------	---------	---------	624	26,996	624	26,996
Yugoslavia	2,785	107,148	---------	---------	2,081	74,977	4,866	182,125
Total	65,086	11,367,947	14,061	5,453,625	660,214	56,151,100	739,361	72,972,672
1965:								
Australia	260	49,669	---------	---------	---------	---------	260	49,669
Bolivia	7	5,260	---------	---------	---------	---------	7	5,260
Canada	4,210	680,991	17,105	6,138,587	636,734	53,560,020	658,049	60,379,598
Chile	2	1,640	---------	---------	---------	---------	2	1,640
Finland	50	5,175	---------	---------	2,475	150,859	2,525	156,034
Italy	---------	---------	---------	---------	2	2,550	2	2,550
Mozambique	---------	---------	30	12,391	51	21,925	81	34,316
Portugal	959	33,289	---------	---------	45	4,213	1,004	37,502
Rhodesia and Malawi [1]	6,482	1,111,691	223	91,098	5,482	1,116,122	12,187	2,318,911
South Africa, Republic of	40,011	7,124,938	11	2,542	911	181,715	40,933	7,309,195
U.S.S.R.	---------	---------	---------	---------	33	3,637	33	3,637
Yugoslavia	3,461	122,762	---------	---------	1,015	36,156	4,476	158,918
Total	55,442	9,135,415	17,369	6,244,618	646,748	55,077,197	719,559	70,457,230

[1] All believed to be from Southern Rhodesia.

Table 5.—U.S. imports for consumption of asbestos, from specified countries, by grades
(Short tons)

Grade	1964 Canada	1964 Southern Rhodesia [1]	1964 Republic of South Africa	1965 Canada	1965 Southern Rhodesia [1]	1965 Republic of South Africa
Chrysotile:						
Crudes	4,466	7,633	817	4,210	6,482	1,804
Spinning and textile	13,881	90	--------	17,105	223	11
All other	648,626	6,271	924	636,734	5,482	911
Crocidolite (blue)	--------	--------	24,858	--------	--------	21,165
Amosite	--------	--------	23,932	--------	--------	17,042
Total	666,973	13,994	50,531	658,049	12,187	40,933

[1] Reported by the Bureau of the Census as Rhodesia and Malawi.

WORLD REVIEW

NORTH AMERICA

Canada.—For the first time since 1958 production (measured by sales) of asbestos decreased. The decline was due in part to large shipments late in 1964 to consumers who anticipated a price increase that became effective January 1, 1965. Production in 1965 was 3 percent less than in 1964 and value was 4 percent lower. Production in Newfoundland and British Columbia increased 10 and 27 percent, respectively, while production in Quebec, the largest producing Province, decreased 4 percent from that of 1964. During the first 9 months, the value of asbestos exports was Can$108.3 million, an increase of 1 percent over that of 1964; however, the quantity decreased to 918,257 tons from 926,740 tons in 1964.

In 1965 the market price for Canadian asbestos increased for the first time during the past 4 years.

Table 6.—World production of asbestos, by countries [1]
(Short tons)

Country [1]	1961	1962	1963	1964	1965 [p] [2]
North America:					
Canada (sales)	1,173,695	1,215,814	[r] 1,275,530	[r] 1,420,769	1,387,555
United States (sold or used by producers)	52,814	53,190	66,396	101,092	118,275
South America:					
Argentina	----------	[r] 203	[r] 365	[r] 542	[e] 550
Bolivia (exports)	57	56	10	[r] 7	3
Brazil	[e] [3] 3,400	[e] [3] 4,900	[4] 1,440	NA	[4] 1,204
Venezuela	650	----------	----------	----------	----------
Europe:					
Austria	564	503	638	----------	----------
Bulgaria	1,213	[e] 1,100	[e] 1,100	[e] 1,100	[e] 1,100
Finland [5]	10,340	10,869	10,108	11,611	[3] 13,307
France	30,746	28,364	26,645	24,250	7,716
Italy	62,804	[r] 60,860	[r] 63,016	75,573	79,214
Portugal	21	----------	29	----------	33
Spain	11	----------	----------	----------	----------
U.S.S.R. [e]	880,000	1,100,000	1,200,000	1,300,000	1,300,000
Yugoslavia	6,709	7,401	9,074	9,280	10,585
Africa:					
Bechuanaland	1,924	2,375	2,368	2,161	888
Kenya	151	212	78	204	136
Mozambique	162	370	----------	----------	----------
Rhodesia, Southern	161,610	142,196	142,255	153,450	[e] 172,400
South Africa, Republic of	194,834	221,302	205,744	215,592	240,752
Swaziland	30,792	32,830	33,350	39,862	40,884
United Arab Republic (Egypt)	254	606	192	[r] 1,739	3,225
Asia:					
China [e]	100,000	100,000	110,000	130,000	140,000
Cyprus	16,207	22,391	19,962	[r] 13,755	15,733
India	1,624	1,865	2,989	3,271	4,989
Japan	18,799	15,407	18,210	17,979	[e] 18,000
Korea, South	341	1,333	2,120	[r] 1,402	[e] 2,000
Philippines	83	1,037	421	586	[e] 600
Taiwan	44	525	604	526	883
Turkey	496	709	408	[r] 1,291	1,376
Oceania:					
Australia	16,746	18,416	13,374	[r] 13,545	11,647
New Zealand	373	457	439	(6)	----------
World total (estimate) [1]	2,770,000	3,050,000	3,210,000	3,540,000	3,570,000

[e] Estimate. [p] Preliminary. [r] Revised.
[1] Asbestos also is produced in Czechoslovakia, Eritrea, Greece, North Korea, and Rumania. No estimates for these countries are included in the total, as production is believed to be negligible.
[2] Compiled from data available June 1966.
[3] Data represents fiber.
[4] Bahia only.
[5] Includes asbestos flour.
[6] Revised to none.

It was reported that the Canadian Government would provide financial assistance towards the development of an asbestos mine at Clinton Creek, about 70 miles northwest of Dawson in the Yukon Territory, owned by Cassiar Asbestos Corp. With Government aid the initial 37 miles of the Dawson-Alaska boundary road will be reconstructed and a new road and river bridge from the boundary road to the mine will be constructed.[3]

The history of the development of Advocate Mines Ltd. Baie Verte mine was traced from discovery through initial exploration, financing, ore body delineation and evaluation, construction of the plant, construction of deep-sea shipping facilities, provision of a closed shipping season, through to realization of full production capacity. The mine began production in 1963. It is at the north end of the Burlington Peninsula, White Bay District, Newfoundland, 3.8 miles from the town of Baie Verte.[4]

As the result of the shutdown of the Johns-Manville Co. Ltd. plant at Matheson, Ontario, asbestos production decreased to less than $80,000 from $2.2 million in 1964.

It was announced that McAdam Mining Corp. expects to have its Chibougamau area asbestos property in production by 1967. Total cost of bringing the property to production was estimated to be Can-$17.5 million.[5]

The Quebec Asbestos Mining Association issued a "Handbook of Canadian Asbestos Products." The brochure was prepared to provide architects and engineers with general information about the Canadian asbestos industry. The handbook is published both in English and French.[6]

SOUTH AMERICA

Bolivia.—The crocidolite deposits of Bolivia were geologically mapped by the Bolivian National Department of Geology (Denageo). The main deposits, close to the Espiritu Santo River at an elevation of 500 meters, are in the Alto Chapare region on the eastern slopes of the Cordillera de Cochabamba. The largest mines operate sporadically.[7]

EUROPE

United Kingdom.—Turner & Newall Ltd., Manchester, issued a booklet on the history and activities of its organization. The companies of Turner & Newall Ltd., operate more than 20 factories and 40 sales offices and employ approximately 39,000 people. Interests of the group cover asbestos, chemicals, and plastic materials.

It was announced that Turner Asbestos Cement Co. Ltd., opened the first asbestos-cement factory in Northern Ireland and the eighth Turner asbestos-cement factory in the United Kingdom.[8]

Italy.—Production, imports, and exports of asbestos increased substantially in 1964. most of the imported product was high-grade long fiber. Imports of 48,380 tons was 13 percent higher than 1963, and exports of 9,939 tons was 41 percent more than in 1963.[9]

U.S.S.R.—U.S.S.R. exports of asbestos in 1964 were 233,908 tons compared with 198,524 tons in 1963. Asbestos was shipped to 25 countries with East Germany accounting for 12 percent; West Germany and France, 11 percent each; Poland, 9 percent; Czechoslovakia and Japan, 8 percent each; Hungary, 7 percent; India, 6 percent; and the remainder was distributed among 17 countries.[10]

AFRICA

South Africa, Republic of.—Production of asbestos in 1965 consisted of 80,735 tons of amosite, 121,122 tons of crocidolite, and 38,895 tons of chrysotile. Exports were as follows: Amosite, 75,981 tons; crocidolite, 108,279; and chrysotile, 25,299. The total volume of local sales of asbestos was 22,428 tons, almost twice that of 1964.[11]

It was reported that Griqualand Exploration & Finance Ltd., acquired the Hans Merensky Trust asbestos interests in the Kuruman area of Cape Province. Two producing mines at Eldorado and Coretse South were equipped with a modern mill, having a capacity of 7,000 tons of fiber.[12]

Rhodesia, Southern.—Following the Unilateral Declaration of Independence on November 11, 1965, the United Kingdom

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[3] Northern Miner (Toronto). Federal Program to Aid Cassiar. No. 22, Aug. 19, 1965, p. 32.

[4] Hutcheson, J. R. M. Canada's Newest Asbestos Producer—Advocate Mines Ltd. Canadian Min. and Met. Bull. (Montreal), v. 58, No. 642, October 1965, pp. 1070–1076.

[5] Northern Miner (Toronto). No. 51, Mar. 11, 1965, p. 4.

[6] Quebec Asbestos Mining Association (Quebec). Handbook of Canadian Asbestos Products. 1963, 44 pp.

[7] World Mining. Bolivia's Blue Asbestos Deposits. V. 18, No. 6, June 1965, pp. 33, 55.

[8] Steel Times (London). V. 191, No. 5063, July 30, 1965, p. 134.

[9] Bureau of Mines. Mineral Trade Notes. V. 61, No. 5, November 1965, p. 5.

[10] Metal Bulletin (London). No. 5051, Nov. 26, 1965, p. 28.

[11] Republic of South Africa (Pretoria). Minerals Dept. of Mines Quarterly Inf. Circ. October–December 1965, pp. 36, 38, 41.

[12] South Africa Mining and Engineering Journal (Johannesburg). V. 76, pt. 2, No. 3800, Dec. 3, 1965, p. 2843.

on December 1, issued stringent economic and financial measures against Rhodesia which included embargo on imports of chrysotile asbestos.

The rate of asbestos production in Southern Rhodesia is governed by the export demand. In 1964 output increased to 153,450 tons having a value 14 percent more than 1963 output. Exports went to 52 countries and included all grades of fiber. The largest market was the United Kingdom, which purchased 46,364 tons of asbestos from Rhodesia, out of total asbestos exports of 177,821 tons. Production of chrysotile was approximately 12 percent more than in 1964. Exports were at about the same level as in 1964.

Most of the Rhodesian material came from the substantial mining interests of Turner & Newall Ltd., which controls the largest Rhodesian producer, the Shabanie Mine. This mine employs 3,800 people.

One of Rhodesia's largest customers was the cement piping and sheeting industry of Western Europe. The Pangani mine near Filabusi is being reopened and equipped to produce a grade of fiber suitable for export to asbestos cement manufacturers.[13]

ASIA

Japan.—Asbestos was mined exclusively in Hokkaido, although it occurs in several other widely scattered areas in Japan. The Hokkaido deposits in the Yamabe District are chrysotile, but some amphibole has been produced in the past particularly in Kyushu. Mine production in 1964 was 17,979 tons, slightly lower than the record 18,210 short tons set in 1963. However, demand increased in all segments of industry and brought on a rise of 24.7 percent in imports over those of the previous year. Canada provided about 60 percent of the imports.[14]

OCEANIA

Australia.—Total exports of crocidolite in 1964 were 7,280 tons. Of this amount almost 50 percent was exported to Malaysia, 14 percent to Japan, 6 percent to Italy, 5 percent to the United States, and the remainder to other countries. There were no exports of chrysotile in 1964. Imports of chrysotile in 1964 was 32,075 tons. Canada supplied 96 percent of the total. Imports of amosite were 6,677 tons, and crocidolite 27 tons.

The principal use of asbestos fiber was in the manufacture of asbestos cement products. Other uses include manufacture of plastic floor and wall tiles, friction materials, insulating materials and mill board.[15]

TECHNOLOGY

Major advances in the design of asbestos mills were discussed. Particular reference was made to the new Advocate asbestos mill in Baie Verte, Newfoundland, and the Johns-Manville Jeffrey mill at Asbestos, Quebec. The mill buildings themselves and the air process systems which constitute the fiber aspirating and dust collection operations were discussed.[16]

A new system of asbestos fiber extraction was developed. A full-scale plant incorporating the latest principles was commissioned at the crocidolite property of Merencor Asbestos mines on the farm Eldoret in the Kuruman District, Northern Cape, Republic of South Africa. The general method of fiber separation used was discussed.[17]

A patent was issued covering a method for removing contaminants from milled chrysotile asbestos fiber, so as to produce a fiber product suitable for use as a filter material in the food preparation industry.[18]

A method for defiberizing asbestos fiber bundles was patented.[19]

The development and application of a computer program to an open pit mine design problem was described. An automatic mill control system including remotely operated feeders, automatic sam-

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13 Mining Journal (London). Embargoes on Rhodesian Minerals. V. 265, No. 6799, Dec. 10, 1965, pp. 421–422.

14 Bureau of Mines. Mineral Trade Notes. V. 60, No. 2, February 1965, p. 6.

15 Department of National Development, Bureau of Mineral Resources, Geology, and Geophysics. The Australian Mineral Industry, 1964 Review. Canberra City, A.C.T., Australia, 1965, 343 pp.

16 Hahn, J., J. Lemberg, and K. Deksnis. Designing an Asbestos Mill. Canadian Min. Jour. (Quebec), July 1965, pp. 37–42.

17 South African Mining and Engineering Journal (Johannesburg). V. 76, pt. 2, No. 3786, Oct. 22, 1965, pp. 2470–2474.

18 de Lisle, A. L. Production of Improved Asbestos Fiber. U.S. Pat. 3,184,288, May 18, 1965.

19 Oesterheld, K. A. A Method of Dressing Crude Asbestos. U.S. Pat. 3,170,834, Feb. 23, 1965.

pling of fiber being processed, and a closed-circuit television system went into operation in the mill of National Asbestos Mines Ltd.[20]

Drilling and blasting methods employed at the Cassiar mine in British Columbia near the Yukon border were discussed. Specific problems such as working in frozen ground were mentioned, and the breaking characteristics of the various rock formations were outlined.[21]

The different mining systems used in asbestos mining, including underground methods in massive deposits, shrinkage stoping, sublevel and panel stoping, caving systems, and underground methods in tabular deposits were mentioned.[22]

Patents were also issued for the following: Rodmill and milling method for defiberizing mine-run asbestos ore or asbestos fiber bundles;[23] a method for making an improved process and apparatus for the manufacture of articles from a water slurry of asbestos fiber and portland cement;[24] and improved apparatus for shaping and compressing roofing tiles or other sheets formed from an aqueous mixture of asbestos fiber and portland cement.[25]

The proceedings of the New York Academy of Sciences on the biological effects of asbestos were published. Papers included the following subjects: Asbestos materials in modern technology; lung tissue and mineral matter; human exposure to asbestos; clinical studies of pulmonary asbestosis; asbestos and neoplasia; and problems and perspectives.[26]

Investigations were undertaken to determine whether mesothelioma of the pleura and peritoneum had any important relation with asbestos exposure. Materials and methods used and the results obtained were described.[27]

The decomposition of amosite was discussed. When amosite is heated in argon or nitrogen physically combined water is lost up to 500° to 700° C. Above 500° C (static) of 700° C (dynamic) dehydroxylation occurs endothermically, giving a pyroxene as the main product.[28]

The use of crocidolite as a component of asbestos-reinforced plastic pipe was described. Crocidolite has excellent heat resistance, high modulus of elasticity, exceptional strength, and resists acids, alkalis, neutral salts, and organic solvents.[29]

Asphalt asbestos curbing is currently included in State specifications or alternates in five States: Massachusetts, New Hampshire, Maine, Delaware, and New York.[30]

Greater use of asbestos in asphalt hot mixes for paving was reported. The use of asbestos in asphalt mixes provides a tougher surface, increased resistance to indentation under heavy load and high temperatures, plus better flexibility and improved resistance to weather.[31]

The extension skirt for the second-stage engine of Gemini 4 space rocket was made of asbestos felt impregnated with a specially developed phenolic resin. The extension skirt weighing 650 pounds directs the flow of gases from the two second-stage exhaust nozzles.[32]

It was reported that asbestos phenolic materials are used in aerospace applications. These materials include tape-wrapped backup insulation, rocket motor liners, ablation-resistant structures, and insulator panels. They are resistant to flames, chemicals, and water. Also, they have a high modulus of elasticity and strength at all environmental temperatures.[33]

It was reported that the body of the Corvette automobile is made of panels of reinforced plastic attached to a steel "bird cage" frame. Powdered asbestos is used

[20] O'Brien, N., and F. J. Nowak. An Application of a Computer to Open-Pit Mine Design. Canadian Min. and Met. Bull. (Montreal), v. 58, No. 638, June 1965, pp. 649–654.

[21] Horsley, T. L. Drilling and Blasting at the Cassiar Mine. Canadian Min. and Met. Bull. (Montreal), v. 58, No. 638, June 1965, pp. 625–627.

[22] Sinclair, W. E. Asbestos Mining Systems. Asbestos, v. 47, No. 2, August 1965, pp. 2–8.

[23] Bacher, J. P. (assigned to F. L. Smidth & Co., New York). Method and Apparatus for Defibration of Fibrous Materials. U.S. Pat. 3,186,647, June 1, 1965.

[24] Sirera, S. B. British Pat. 979,447, Jan. 6, 1965.

[25] Marchioli, G., and G. Gremigni. British Pat. 985,563, Mar. 10, 1965.

[26] Annals of the New York Academy of Sciences. Biological Effects of Asbestos. V. 132, art. 1, December 1965, 766 pp.

[27] Selikoff, I. J., J. Churg, and E. C. Hammond. Relation Between Exposure to Asbestos and Mesothelioma. New England J. Medicine, v. 272, Mar. 18, 1965, pp. 560–565.

[28] Hodgson, A. A., A. G. Freeman, and H. F. W. Taylor. The Thermal Decomposition of Amosite. Mineralogical Magazine (London), v. 35, No. 271, September 1965, pp. 445–463.

[29] Cryor, R. E. Asbestos-Reinforced Plastic Pipe. Chem. Eng., v. 72, No. 16, Aug. 2, 1965, pp. 134–136.

[30] Roads and Streets. Asbestos-Asphalt Curbing. V. 108, No. 12, December 1965, pp. 75, 81.

[31] Chemical Week. Asbestos Bright Spot. V. 96, No. 7, Feb. 13, 1965, p. 82.

[32] Asbestos. V. 47, No. 2, August 1965, p. 16.

[33] Materials in Designing Engineering. Asbestos Phenolics. V. 61, No. 6, June 1965, p. 4.

as the reinforcing agent in the joining of the various reinforced plastic parts.[34]

A method was patented for preparing a homogeneous, well-dispersed mass of asbestos fiber and a molding solution by projecting a fluffy asbestos into mixing blades which are turning in the molding solution and continuing the mixing while adding more fibers.[35]

A method for the use of asbestos (amosite, chrysotile, or crocidolite) fiber as a base or matrix to be coated with a ceramic frit and then with a thermosetting resin on the other face was patented.[36]

A patent was granted on a method for upgrading the filtration rate of asbestos fiber to provide fast-filtering asbestos fiber product slurries or feed stocks for use in wet-process asbestos-cement or like manufacturing procedures.[37]

Patents were issued for the use of microdimensional chrysotile asbestos fiber as a cosuspending agent in a pesticidal composition;[38] for improved porous, flexible, high-bulk asbestos-glass fiber paper or felt for saturation with plastic molding compositions;[39] for use of asbestos in grease-resistant floor tiles;[40] for production of asbestos fiber-vinyl halide resin compositions that are resistant to the deteriorating effects of heat;[41] for use of asbestos fiber in latex-bonded sheet materials;[42] for a method for making aluminum phosphate-bonded laminated asbestos sheets of increased dielectric strength;[43] for a method to prevent discoloration in resin-base floor tiles caused by use of iron-containing asbestos therein;[44] and for a method to prevent iron-induced degradation of vinyl halide resin-base floor tile or like materials.[45]

The following patents were granted for asbestos-cement products: Method of making ceramic-glazed sheets from an aqueous mixture of asbestos fibers and portland cement;[46] method for forming sharp corners and irregular contours and cross-sectional shapes in products manufactured from an aqueous slurry of asbestos fibers and portland cement;[47] production of improved articles from an aqueous mixture of portland cement and a blend of amosite and chrysotile asbestos fibers;[48] method for inhibiting growth of fungus organisms in products manufactured from a slurry of asbestos fiber and portland cement;[49] a composition for use in forming good-quality, cured asbestos-cement products;[50] method for producing asbestos-cement articles, whereby dry asbestos fiber and dry particulate portland cement are tumbled together in a mixing zone while being sprayed with water;[51] an improved method for corrugating relatively thick sheets formed from an aqueous mixture of asbestos fiber and portland cement;[52] method

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[34] Siegrist, Fred L. Assembly of Reinforced Plastic Automobile Bodies. Metal Prog., v. 88, No. 4, October 1965, pp. 239, 241, 250, 252, 254.

[35] Gouveia, A. P. (assigned to Johns-Manville Corp., New York). Method and Apparatus for Preparing a Fiber-Reinforced Molding Composition. U.S. Pat. 3,175,807, Mar. 30, 1965.

[36] Shaines, A. (assigned to American Radiator & Standard Sanitary Corp., New York). Method of Coating Resin On Ceramic. U.S. Pat. 3,172,775, Mar. 9, 1965.

[37] Pundsack, F. L., and G. P. Reimschussel (assigned to Johns-Manville Corp., New York). Method of Improving the Filtration Characteristics of Asbestos. U.S. Pat. 3,173,831, Mar. 16, 1965.

[38] McCoy, F. C., and H. C. Knowles (assigned to Texaco Inc., New York). U.S. Pat. 3,171,779, Mar. 2, 1965.

[39] Quinn, R. G. (assigned to Johns-Manville Corp., New York). Asbestos-Glass Fiber Saturating Paper Containing Thermoplastic Resin and Aluminum Acid Phosphate. U.S. Pat. 3,212,960, Oct. 19, 1965.

[40] Bartlett, F. J. W. (assigned to the Ruberoid Co., New York). Flooring Materials. U.S. Pat. 3,194,775, July 13, 1965.

[41] Scullin, J. P. (assigned to Tenneco Chemicals, Inc., a corporation of Delaware). Stabilized Asbestos Containing Vinyl Halide Resin Compositions. U.S. Pat. 3,194,786, July 13, 1965.

[42] Eisenberg, B. J. (assigned to U.S. Rubber Co., New York). Latex Bonded Asbestos Fiber Sheet Material. U.S. Pat. 3,193,446, July 6, 1965.

[43] Bolton, M. J., G. A. Joyner, Jr., and R. H. Lux (assigned to General Electric Co., Schenectady, N.Y.). Method of Making Insulation, and Products Formed Thereby. U.S. Pat. 3,177,107, Apr. 6, 1965.

[44] Hecker, A. C., M. W. Pollock, and S. Cohen (assigned to Argus Chemical Corp., New York). Prevention of Colored Iron Compounds in Asbestos Containing Polyvinyl Chloride Resins. U.S. Pat. 3,184,428, May 18, 1965.

[45] Thompson, H. R. (assigned to Nopco Chem. Corp., Newark, N.J.). Stabilization of Vinyl Halide Resin Compositions Containing Iron-Bearing Asbestos. U.S. Pat. 3,180,848, Apr. 27, 1965.

[46] Greiner, N. S. (assigned to Johns-Manville Corp., New York). Asbestos-Cement Sheets. U.S. Pat. 3,197,529, July 27, 1965.

[47] French, C. V. (assigned to Johns-Manville Corp., New York). Method of Manufacturing Asbestos-Cement Articles. U.S. Pat. 3,197,536, July 27, 1965.

[48] Snyder, W. H. (assigned to Johns-Manville Corp., New York). Asbestos-Cement Products. U.S. Pat. 3,169,878, Feb. 16, 1965.

[49] Greiner, N. S. (assigned to Johns-Manville Corp., New York). Asbestos Cement Products. U.S. Pat. 3,197,313, July 27, 1965.

[50] Redican, F. W., L. R. Blair, J. C. Yang, and R. J. Gorman (assigned to Johns-Manville Corp., New York). Manufacture of Asbestos-Cement Products. U.S. Pat. 3,219,467, Nov. 23, 1965.

[51] Schulze, H. C. Process for Forming Cement and Asbestos Articles. U.S. Pat. 3,204,019, Aug. 31, 1965.

[52] Oesterheld, K. A. (assigned to Eurasbest, A. G., Besel, Switzerland). Method for Corrugating Sheets of Asbestos Cement. U.S. Pat. 3,173,828, Mar. 16, 1965.

for forming in situ on a sloping roof a series of cast Bermuda-type concrete roof tiles, using an aqueous mixture of chysotile asbestos floats, portland cement, and either a heavy sandstone aggregate or preferably a lightweight aggregate.[53]

The anthophyllite mineralization in the area is localized in the zones of enstatite-anthophyllite and talc-carbonate rocks. Rich asbestos mineralization is related to the enstatite-anthophyllite rocks having a coarse crystalline texture.[54]

Using molten salt bath and vapor deposition methods, whiskers exceeding 25 mm in length were grown; three different aluminum borate compositions were identified by X-ray and chemical analyses.[55]

Density measurements were made on 23 bulk specimens of chrysotile and 7 massive serpentine samples, both by using mercury and by coating and by coating the samples with paraffin and immersing them in water. Arizona chrysotile had a density lower than Canadian chrysotile. Arizona massive serpentine blocks had less porosity.[56]

A booklet entitled "Fire Protection of Sturctures" was issued by Turner Asbestos Cement Co. Ltd., Manchester, England. The publication includes an interpretation of the 1965 building regulations for England and Wales in relation to asbestos and asbestos-cement materials. The importance of asbestos and asbestos-cement products when constructing buildings that will minimize the risk of heavy losses by fire is described. Details and photographs are included.[57]

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[53] Woodworth, C. L. (assigned to Ari-Zonalite Co., Glendale, Ariz.). Method of Casting Cementitious Shingles on a Sloping Roof. U.S. Pat. 3,222,436, Dec. 7, 1965.

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Barite

By Donald E. Eilertsen [1]

The trends of barite output, imports, consumption, and world production continued upward.

Table 1.—Salient barite and barium-chemical statistics
(Thousand short tons and thousand dollars)

	1956–60 (average)	1961	1962	1963	1964	1965
United States:						
Primary:						
Mine or plant production	956	731	887	803	817	846
Sold or used by producers	933	797	860	824	830	852
Value	$10,555	$9,300	$9,820	$9,402	$9,796	$10,192
Imports for consumption	646	608	737	578	600	712
Value	$4,606	$5,185	$6,009	$4,637	$4,796	$5,553
Consumption [1]	1,498	1,391	1,211	1,230	1,277	1,388
Ground and crushed sold by producers	1,237	1,036	1,023	1,030	1,077	1,169
Value	$33,396	$25,182	$24,285	$25,517	$26,948	$29,444
Barium chemicals sold by producers	94	97	104	109	117	125
Value	$12,921	$13,770	$14,656	$15,837	$17,101	$17,935
World: Production	3,136	3,140	3,430	3,220	3,400	3,790

[1] Includes some witherite.

DOMESTIC PRODUCTION

Approximately 50 mining operations in 11 States produced barite. Yearend stocks of barite at mining operations totaled 105 million tons compared with 110 million tons in 1964.

Table 2.—Domestic barite sold or used by producers in the United States, by States
(Thousand short tons and thousand dollars)

State	1956–60 (average) Quantity	1956–60 (average) Value	1961 Quantity	1961 Value	1962 Quantity	1962 Value
Arkansas	352	$3,227	278	$2,630	259	$2,232
California	W	W	21	295	7	133
Georgia	(1)	(1)	107	2,046	109	1,987
Missouri	275	3,515	227	3,052	304	3,994
Nevada	105	681	130	863	138	954
South Carolina and Tennessee	[1] 133	[1] 2,474	13	253	16	327
Other States [2]	68	658	21	161	27	193
Total	933	10,555	797	9,300	860	9,820

State	1963 Quantity	1963 Value	1964 Quantity	1964 Value	1965 Quantity	1965 Value
Arkansas	236	2,161	233	2,202	249	2,379
California	5	31	6	45	4	21
Georgia	117	2,013	109	2,022	W	W
Kentucky	6	85	6	96	---	---
Missouri	287	3,680	267	3,451	329	4,219
Nevada	120	760	149	1,261	91	583
New Mexico	1	6	W	W	(3)	2
Tennessee	24	404	39	519	31	442
Washington	---	---	---	---	(3)	1
Other States [2]	28	262	21	200	148	2,545
Total	824	9,402	830	9,796	852	10,192

W Withheld to avoid disclosing individual company confidential data; included with "Other States."
[1] Georgia included with South Carolina and Tennessee.
[2] Idaho (1956–64), Kentucky (1959–62), Montana, North Carolina (1961 only), New Mexico (1956–62), South Carolina (1963–65), Texas (1961–65), Utah (1959–62), and Washington (1957–62).
[3] Less than ½ unit.

[1] Commodity specialist, Division of Minerals.

CONSUMPTION AND USES

Most of the barite consumption in the United States was used as a weighting material by the well-drilling industry, but an appreciable quantity was also consumed in the manufacture of a number of barium chemicals. The following firms produced barium chemicals from barite, except where indicated: Chemical Products Corp., Cartersville, Ga.; Chicago Copper & Chemical Co., Blue Island, Ill.; witherite—Ethyl Corporation, Baton Rouge, La.; Inorganic Chemicals Division, FMC Corp., Modesto, Calif.; witherite and barite—The Great Western Sugar Co., Denver, Colo.; Holland-Suco Color Co., Huntington, W. Va.; Mallinckrodt Chemical Works, St. Louis, Mo.; Ozark Smelting & Refining Co., Coffeyville, Kan.; and Pittsburgh Plate Glass Co., Chemical Division, Natrium, W. Va.

Three firms bought various barium chemicals for processing into other barium chemicals. These firms were J. T. Baker Chemical Co., Phillipsburg, N.J., Barium & Chemicals Inc., Steubenville, Ohio, and Inorganic Chemicals Division, FMC Corp., Carteret, N.J.

Table 3.—Ground and crushed barite produced and sold by producers in the United States

(Thousand short tons and thousand dollars)

Year	Plants	Production (quantity)	Sales: Quantity	Sales: Value
1956-60 (average)	33	1,258	1,237	$33,396
1961	35	1,101	1,036	25,182
1962	35	1,012	1,023	24,285
1963	34	1,027	1,030	25,517
1964	33	1,079	1,077	26,948
1965	31	1,169	1,169	29,444

Table 4.—Crude barite (domestic and imported) used in the manufacture of ground barite and barium chemicals in the United States[1]

(Thousand short tons)

Year	In manufacture of—: Ground barite [2]	In manufacture of—: Barium chemicals and lithopone	Total
1956-60 (average)	1,325	172	1,498
1961	1,224	167	1,391
1962	1,043	168	1,211
1963	1,048	182	1,230
1964	1,103	174	1,277
1965	1,199	189	1,388

[1] Includes some witherite in the manufacture of barium chemicals.
[2] Includes some crushed barite.

Table 5.—Ground and crushed barite sold by producers, by consuming industries

Industry	Short tons	Percent of total	Short tons	Percent of total	Short tons	Percent of total
	1956-60 (average)		1961		1962	
Well drilling	1,172,905	95	941,539	91	934,007	91
Glass	19,465	2	30,713	3	39,017	4
Paint	17,348	1	16,128	2	19,786	2
Rubber	19,832	2	24,007	2	26,235	3
Undistributed	7,196	--	23,395	2	4,045	--
Total	1,236,746	100	1,035,782	100	1,023,090	100
	1963		1964		1965	
Well drilling	907,134	89	930,965	87	986,889	84
Glass	56,362	5	56,866	5	70,158	6
Paint	34,611	3	58,396	6	68,827	6
Rubber	28,479	3	26,675	2	29,992	3
Undistributed	3,121	--	3,787	--	12,718	1
Total	1,029,707	100	1,076,689	100	1,168,584	100

Table 6.—Barium chemicals produced and used or sold by producers in the United States

(Short tons)

Chemical and year	Plants	Produced	Used [1] by producers [2] in other barium chemicals	Sold by producers [3] Short tons	Sold by producers [3] Value
Black ash: [4]					
1956–60 (average)	9	111,666	107,647	2,975	$263,641
1961	8	105,117	102,591	2,363	228,358
1962	10	107,418	105,114	3,393	365,904
1963	8	112,953	102,945	3,374	322,941
1964	9	114,421	110,676	3,605	344,295
1965	7	124,279	118,805	3,954	375,815
Carbonate (synthetic):					
1956–60 (average)	6	74,295	29,541	44,407	4,596,503
1961	7	78,665	28,599	47,401	5,119,826
1962	7	79,313	27,683	49,484	5,415,751
1963	7	78,411	25,688	52,026	5,685,281
1964	7	81,018	28,088	53,897	6,021,728
1965	6	85,609	28,734	57,264	6,206,303
Chloride (100 percent $BaCl_2$):					
1956–60 (average)	3	7,729	26	7,614	1,221,818
1961	3	10,891	------	10,290	1,697,606
1962	5	10,888	------	10,276	1,703,123
1963	4	11,100	------	11,299	1,842,105
1964	5	11,425	------	11,590	1,926,885
1965	3	11,214	------	10,975	1,892,909
Hydroxide:					
1956–60 (average)	5	14,284	70	13,658	2,295,578
1961	4	13,715	------	13,873	2,167,245
1962	4	16,328	------	16,925	2,745,135
1963	4	18,746	------	18,436	3,018,482
1964	5	23,384	W	23,313	3,688,060
1965	5	30,211	W	30,459	4,662,887
Other barium chemicals: [5]					
1956–60 (average)	--	32,423	5,936	25,274	4,543,116
1961	--	27,878	W	23,452	4,557,193
1962	--	27,850	W	23,864	4,425,798
1963	--	26,555	W	23,462	4,967,844
1964	--	28,365	W	24,598	5,120,053
1965	([6])	29,006	W	21,926	4,796,988
Total: [7]					
1956–60 (average)	--	------	------	93,928	12,920,656
1961	14	------	------	97,379	13,770,228
1962	15	------	------	103,942	14,655,711
1963	14	------	------	108,597	15,836,653
1964	14	------	------	117,003	17,101,021
1965	12	------	------	124,578	17,934,902

W Withheld to avoid disclosing individual company confidential data.
[1] Includes purchased material.
[2] Of any barium chemical.
[3] Exclusive of purchased material and exclusive of sales by one producer to another.
[4] Black-ash data include lithopone plants.
[5] Includes barium acetate, nitrate, oxide, peroxide, sulfate, and other compounds for which separate data may not be revealed.
[6] Barium acetate, 1 plant; nitrate, 3; oxide, 2; peroxide, 1; and sulfate (synthetic) 5.
[7] A plant producing more than 1 product is counted only once in arriving at total.

PRICES

The quoted prices of crude and ground chemical-grade and drilling-mud-grade barites and of most barium chemicals were unchanged during the year.

Table 7.—Price quotations for crude and ground barite in 1965

(Per short ton)

Item	1965
Chemical grade, f.o.b. shipping point, carlots:	
Hand picked, 95 percent $BaSO_4$, 1 percent Fe	$18.50
Flotation or magnetic separation; 96–97.5 percent $BaSO_4$, 0.3–0.7 percent Fe (add $3 for 100-pound bags)	19 to 23.50
Water ground; 99.5 percent $BaSO_4$, 325 mesh, 50-pound bags	45 to 49
Drilling-mud grade, f.o.b. shipping point, carlots:	
83–93 percent $BaSO_4$, 3–12 percent Fe specific gravity 4.20–4.30:	
Crude, bulk	12 to 16
Some restricted sales	11.50
Ground	26.75
Imported, 4.20–4.30 specific gravity, bulk, c.i.f. gulf ports	11 to 14

Source: E&MJ Metal and Mineral Markets.

Table 8.—Price quotations for barium chemicals in 1965

(Per short ton, except as noted)

Item		1965
Barium carbonate, precipitated, bags, carlots, works		$111.50
Barium chlorate, drums, works	per pound	.32 to .41
Barium chloride, anhydrous, bags, carlots, works		176.00
Barium dioxide (peroxide), drums, freight equalized	per pound	.30
Barium hydrate, crystalline, bags, carlots, truckloads, delivered		224.00
Barium monohydrate, 99 percent, bags, carlots, delivered	per 100 pounds	12.00
Barium nitrate, barrels, carlots, truckloads, delivered	per pound	.16
Less carlots, less truckloads, delivered	do	.17
Barium oxide, ground, drums, carlots, truckloads, freight, delivered		288.00
Blanc fixe, direct process, bags, carlots, works		[1] $156–$175

[1] $160 until March 8; then $156–$160 until April 26; then $156–$175 to year end.

Source: Oil, Paint and Drug Reporter.

FOREIGN TRADE

Lithopone exports decreased sharply in 1965 over those of 1964.

The average declared values per short ton of imported crude barite at foreign ports were as follows: Canada, $8.20; Mexico, $6.12; Brazil, $7.26; Peru, $10.25; Ireland, $7.56; Yugoslavia, $8.35; Greece, $9.52; Turkey, $8.23; and Morocco, $9.80.

The imported barite entered the United States through the following customs districts of entry, New Orleans, La., 32.12 percent; Laredo, Tex., 33.53 percent; Sabine, Tex., 18.32 percent; Galveston, Tex., 12.83 percent; El Paso, Tex., 3.07 percent; and San Diego and San Francisco, Calif., 0.13 percent.

Table 9.—U.S. exports of lithopone

Year	Short tons	Value
1963	839	$135,874
1964	1,184	191,774
1965	609	187,300

Table 10.—U.S. imports for consumption of barite, by countries

Type and source	1964 Short tons	1964 Value	1965 Short tons	1965 Value
Crude barite:				
North America:				
Canada	141,845	$1,204,669	155,736	$1,276,966
Mexico	188,635	1,219,540	243,195	1,488,106
South America:				
Brazil	-----	-----	11,128	80,766
Peru	117,937	1,137,265	104,012	1,066,598
Europe:				
Greece	24,512	186,031	11,769	112,014
Ireland	63,541	480,528	80,378	607,859
Italy	7,648	69,456	-----	-----
Spain	8,572	72,155	-----	-----
United Kingdom	-----	-----	43,479	328,805
Yugoslavia	14,080	110,117	8,727	72,852
Africa: Morocco	33,179	315,772	48,160	472,140
Asia: Turkey	-----	-----	5,659	46,572
Total	599,949	4,795,533	712,243	5,552,678
Ground barite:				
North America:				
Canada	997	37,967	-----	-----
Mexico	-----	-----	449	7,605
Europe: Germany, West	64	3,295	21	977
Total	1,061	41,262	470	8,582

Table 11.—U.S. imports for consumption of barium chemicals

Year	Lithopone Short tons	Lithopone Value	Blanc fixe (precipitated barium sulfate) Short tons	Blanc fixe (precipitated barium sulfate) Value	Barium chloride Short tons	Barium chloride Value	Barium hydroxide Short tons	Barium hydroxide Value
1956-60 (average)	81	$10,817	1,486	$114,063	1,335	$116,732	113	$19,829
1961	74	8,843	1,378	122,174	1,019	93,105	11	1,880
1962	98	12,538	1,724	152,267	1,150	107,214	11	1,680
1963	159	21,360	1,602	157,332	1,152	103,890	---	---
1964	r 172	r 21,387	2,314	217,595	1,133	101,018	6	945
1965	190	34,249	1,624	181,400	889	79,625	6	945

Year	Barium nitrate Short tons	Barium nitrate Value	Barium carbonate, precipitated Short tons	Barium carbonate, precipitated Value	Other barium compounds Short tons	Other barium compounds Value
1956-60 (average)	684	$103,123	1,393	$98,331	93	$50,495
1961	807	128,120	1,190	86,123	160	111,427
1962	807	125,253	1,501	112,406	126	95,931
1963	948	145,341	838	58,302	107	78,286
1964	601	90,176	1,040	71,367	96	47,733
1965	568	83,834	826	53,452	291	165,429

r Revised.

Table 12.—U.S. imports for consumption of crude, unground, and crushed or ground witherite

Year	Crude unground Short tons	Crude unground Value	Crushed or ground Short tons	Crushed or ground Value
1963	2,690	$113,813	90	$5,956
1964	2,407	97,546	25	1,708
1965	2,570	112,244	25	1,752

WORLD REVIEW

Ireland.—The demand for barite sharply increased because of the flurry of oil exploration in northern Europe and in the North Sea. Dresser Industries, Inc., of the United States, was reportedly expecting to produce about 100,000 tons of barite in 1965, at the property of Silvermines Lead and Zinc Co. Ltd. The 1965 target output of byproduct barite for Irish Base Metals Ltd. (a firm controlled by Northgate Ex-

Table 13.—World production of barite, by countries [1]
(Short tons)

Country	1961	1962	1963	1964	1965 p [2]
North America:					
Canada	191,404	226,600	173,503	r 169,149	201,357
Mexico	274,153	350,684	283,246	359,372	406,405
United States	731,381	886,964	803,106	816,706	845,656
Total	1,196,938	1,464,248	1,259,855	r 1,345,227	1,453,418
South America:					
Argentina	31,476	13,819	r 25,350	r 15,107	e 15,000
Brazil	68,834	60,241	37,601	r 36,968	70,601
Chile	1,551	1,156	1,123	r 1,203	3,143
Colombia	11,272	8,800	11,574	r 11,244	9,700
Peru	122,538	126,271	r 137,557	145,934	113,711
Total	235,671	210,287	r 213,205	210,456	212,155
Europe:					
Austria (marketable)	2,716	1,192	2,395	r 1,390	2,538
France	95,007	92,570	82,078	r 92,397	e 93,000
Germany, West (marketable)	518,951	512,231	466,419	487,884	e 490,000
Greece	82,673	78,712	93,696	74,957	e 132,000
Ireland	4,659	22	10,192	68,629	e 93,000
Italy	r 143,555	r 133,976	r 114,229	r 93,408	156,412
Poland	41,161	49,841	50,376	r 50,376	e 53,000
Portugal	2,285	1,489	1,828	r 384	1,199
Rumania	NA	NA	NA	NA	49,604
Spain	37,449	42,923	54,312	r 65,183	e 65,000
U.S.S.R. e	165,000	200,000	220,000	220,000	240,000
United Kingdom [3]	91,677	84,754	61,066	r 68,343	67,241
Yugoslavia	114,872	114,379	115,176	r 112,072	e 112,000
Total e [1]	r 1,330,000	1,350,000	1,310,000	r 1,370,000	1,590,000
Africa:					
Algeria	33,883	r 30,404	r 32,421	r 32,665	47,142
Morocco	90,591	98,980	104,228	99,036	114,508
Rhodesia, Southern	-----	-----	1,953	1,561	e 1,500
South Africa, Republic of	1,962	1,873	2,704	2,835	1,477
Swaziland	454	68	93	17	541
United Arab Republic (Egypt)	1,734	1,356	4,545	6,017	16,924
Total	128,624	r 132,681	r 145,944	r 142,131	182,092
Asia:					
Burma	2,248	4,462	-----	-----	e 2,200
China, mainland e	90,000	90,000	100,000	110,000	110,000
India	17,325	36,004	r 41,752	50,954	50,611
Iran [4]	20,944	16,535	e 16,500	e 16,500	e 16,500
Japan	32,243	42,016	41,360	r 43,810	e 44,000
Korea:					
North e	60,000	65,000	75,000	75,000	90,000
South	772	1,014	3,040	r 3,024	1,419
Pakistan	489	3,264	r 5,422	13,235	9,740
Philippines	2,109	459	1,008	1,627	e 1,700
Turkey	-----	2,094	1,081	6,669	13,206
Total e [1]	226,000	261,000	r 285,000	r 321,000	339,000
Oceania: Australia	21,523	14,038	9,206	r 13,778	11,591
World total e	r 3,140,000	r 3,430,000	r 3,220,000	r 3,400,000	3,790,000

e Estimate. p Preliminary. r Revised. NA Not Available.
[1] Barite is produced in Bulgaria, Czechoslovakia and East Germany, but data on production are not available. Estimates by author of chapter included in total, with the exception of Bulgaria.
[2] Compiled mostly from data available June 1966.
[3] Includes witherite.
[4] Year ended March 20 of year following that stated.

ploration, Ltd., Canada) was reported at 112,000 tons.[2]

Rhodesia, Southern.—The Dodge Mine at Shamva, the country's only producer of barite, exported all its 1964 barite output to the Republic of South Africa for use in the glass industry.[3]

Tunisia.—The Hamman Zriba fluorspar mine, closed for more than 10 years, was reopened. Annual production was expected to reach 35,000 tons of barite and 25,000 tons of fluorspar.[4]

Turkey.—Mineral Research and Exploration Institute (MTA) tentatively estimated Turkey's barite reserve at 3 million tons. Madeni ve Kimyevi Boyalari Fabrikasi Ltd. (Mineral & Chemical Paint Plant) of Istanbul was the country's only producer of barite in 1963. It produced about 1,000 tons of barite, near Alanya, for processing to lithopone. A private miner named Hamdi Bozbag reportedly exported about 5,400 tons of barite in 1964 to the United States for use in well drilling; thus Turkey was for the first time a barite exporter. The Bozbag properties, near Maras, and near a railroad and the port of Iskenderun, could probably yield annually more than 50,000 tons of barite.[5]

United Kingdom.—The new Cavendish mill at Eyam, Derbyshire, was reported to have a capacity of 100,000 tons of fluorspar, 18,000 tons of barite, and 3,850 tons of lead annually.[6]

TECHNOLOGY

A large map showing barite resources in residual, bedded, vein, and other types of deposits in conterminous United States together with references was published.[7]

The occurrence of pabstite, a new barium-tin-titanium silicate mineral, at Santa Cruz, Calif. was reported.[8]

The Bureau of Mines did some work on microgrinding barite. Petroleum researchers developed a rapid instrumental method for analyzing the composition of oil well scales containing principally barium sulfate.[9]

A new continuous rotary-drum method of producing coated steel strip from molten materials was described, the coating material possibly being barium chloride.[10]

The price list of a select bibliography of Government research reports on barium titanate was published.[11]

A comprehensive brief digest on barium and barium compounds was published.[12]

Patents were issued on numerous barium compositions.[13]

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Bauxite

By Lloyd R. Williams [1]

World production of bauxite reached a new high, 37 million tons, 10 percent or more than in 1964. About 51 percent of the world production was in the Western Hemisphere. Jamaica was the leading producer, followed by Surinam and British Guiana.

Production of bauxite in the United States increased 3 percent and was equivalent to 13 percent of the domestic supply of new bauxite. A record 5.9 million short tons of alumina and aluminum oxide products was produced from bauxite. Aluminum production accounted for 84 percent of the bauxite consumed. (Aluminum metal is discussed in the "Aluminum" chapter of this volume).

Legislation and Government Programs.—No withdrawals were made from the Government strategic or nonstrategic stockpiles. Jamaican, Surinam, and refractory types of bauxite remained on the group I list of strategic materials for the national stockpile.

During the year, 512,000 long dry tons of Jamaican-type ore was acquired by barter, bringing the total Government inventories to 8,859,000 tons of Jamaican-type ore.

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Table 1.—Salient bauxite statistics
(Thousand long tons and thousand dollars)

	1956–60 (average)	1961	1962	1963	1964	1965
United States:						
Production, crude ore (dry equivalent)	1,634	1,228	1,369	1,525	1,601	1,654
Value	$15,925	$13,937	$15,609	$17,234	$17,875	$18,632
Imports for consumption	7,514	9,206	10,575	9,212	10,180	11,400
Exports (as shipped)	27	151	259	203	r 279	147
Consumption (dry equivalent)	7,984	8,621	10,577	11,318	12,546	13,534
World: Production	21,932	28,945	30,835	30,260	33,230	36,530

r Revised.

Table 2.—U.S. defense materials inventories and objectives as of December 31, 1965

	Alumina (short dry tons)		Bauxite (long ton s)		
			Metal grade, dried		
	Crude fused	Abrasive grain	Jamaican type	Surinam type	Refractory grade, calcined
Objective	160,000		5,000,000	5,300,000	173,000
Government inventories:					
National (strategic) stockpile	200,000		880,000	4,963,000	299,000
DPA inventories			1,370,000		
CCC and supplemental stockpile	178,000	51,000	6,609,000	2,927,000	
Total	378,000	51,000	8,859,000	7,890,000	299,000

DOMESTIC PRODUCTION

Output of crude bauxite in the United States increased 3 percent, while shipments to consumers from mines and processing plants increased 12 percent.

Arkansas produced 96 percent of the total U.S. output. The two leading producers in Arkansas were Aluminum Company of America (Alcoa) and Reynolds Metals Co., and each shipped crude ore to its own alumina plant. Calcined bauxite was produced by American Cyanamid Co., Norton Co., and Stauffer Chemical Co. Activated bauxite was produced by Porocel Corp. and Stauffer Chemical Co.

Harbison-Walker Refractories Co., R. E. Wilson Mining Co., and Wilson-Snead Mining Co. operated bauxite mines in Barbour and Henry Counties, Ala., and American Cyanamid Co. mined in Bartow and Sumter Counties, Ga. Together they produced 61,000 long dry tons of ore, a 56-percent increase from 1964 output. American Cyanamid Co. and R. E. Wilson Mining Co. processed their crude ore and produced dried bauxite, and Harbison-Walker Refractories Co. produced calcined bauxite.

The Anaconda Company was considering plans to build a plant in Georgia to extract alumina from clay. If constructed, it would be the first commercial plant in the United States to use clay for the production of alumina. At present Anaconda purchases alumina from other producers for its reduction plant at Columbia Falls, Mont.

Consolidated Chemical Division of Stauffer Chemical Co. started operation of an aluminum sulfate plant at Baton Rouge, La. The output will add to the supply of sulfate for the increased demands of Louisiana and Mississippi Gulf Coast areas. Two other plants are under construction in Alabama: one at Neheola by Stauffer and the other at Coosa Pines by American Cyanamid Co.

The refractory division of H. K. Porter Co. Inc. purchased 45 acres of land near Fulton, Mo., for a proposed alumina refractories plant. Kaiser Aluminum & Chemical Corp. announced plans to construct a refractory specialty plant at Frostburg, Md., using various raw materials—bauxite, alumina, graphite, and others. Kaiser also announced plans to increase capacity of the Chalmette, La., plant to produce synthetic cryolite required for the production of alumina. Cryolite in the natural state is found only in Greenland. Kaiser's alumina plants at Baton Rouge and Gramercy were severely damaged by a storm but were back in production within a few days.

Several companies including Harbison-Walker Refractories Co., Walsh Refractories Corp., and Kaiser announced production of new higher grade alumina refractory brick.

Reynolds Aluminum Co. started operation of a low-soda alumina plant at Bauxite, Ark., to increase production of alumina.

Table 3.—Mine production of bauxite and shipments from mines and processing plants to consumers in the United States

(Thousand long tons and thousand dollars)

State and year	Mine production			Shipments from mines and processing plants to consumers		
	Crude	Dry equivalent	Value [1]	As shipped	Dry equivalent	Value [1]
Alabama and Georgia:						
1956–60 (average)	82	64	$608	63	60	$657
1961	60	49	475	40	43	498
1962	120	99	1,003	50	53	609
1963	60	47	533	54	62	747
1964	51	39	444	57	57	809
1965	79	61	658	57	56	792
Arkansas:						
1956–60 (average)	1,875	1,569	15,317	1,822	1,559	16,487
1961	1,419	1,179	13,462	1,244	1,080	13,220
1962	1,523	1,270	14,606	1,715	1,481	17,535
1963	1,771	1,478	16,701	1,725	1,483	17,543
1964	1,864	1,562	17,431	1,773	1,531	17,859
1965	1,911	1,593	17,974	2,008	1,729	20,293
Total United States:						
1956–60 (average)	1,957	1,634	15,925	1,885	1,619	17,144
1961	1,479	1,228	13,937	1,284	1,123	13,718
1962	1,643	1,369	15,609	1,765	1,534	18,144
1963	1,831	1,525	17,234	1,779	1,545	18,290
1964	1,915	1,601	17,875	1,830	1,588	18,668
1965	1,990	1,654	18,632	2,065	1,785	21,085

[1] Computed from selling prices and values assigned by producers and estimates of the Bureau of Mines.

Table 4.—Recovery of dried, calcined, and activated bauxite in the United States

(Long tons)

Year	Crude ore treated	Processed bauxite recovered			
		Dried	Calcined or activated	Total	
				As recovered	Dry equivalent
1956–60 (average)	192,714	93,431	38,782	132,213	152,402
1961	153,321	30,202	55,242	85,444	124,992
1962	172,262	37,776	57,232	95,008	141,969
1963	170,641	35,727	61,853	97,580	137,946
1964	166,884	W	W	93,235	128,347
1965	193,076	W	W	99,765	140,713

W Withheld to avoid disclosing individual company confidential data.

CONSUMPTION AND USES

Domestic consumption of bauxite increased 8 percent. Foreign sources supplied 87 percent of the total consumption. Jamaican-type ore (from Jamaica, Haiti, and the Dominican Republic) comprised 56 percent of the total consumption; Surinam-type ore (from Surinam and British Guiana) made up 31 percent. Domestic sources supplied the remainder.

Shipments of domestic ore (an index of the grade of ore consumed) containing less than 8 percent silica were 5 percent of the total, a decrease from the 6 percent shipped in 1964. The proportion of ore containing 8 to 15 percent silica increased from 63 to 64 percent, and the proportion of the ore containing more than 15 percent silica remained at 31 percent of the total.

The eight domestic alumina plants operated by the aluminum companies produced 5,771,000 short tons of calcined alumina and aluminum oxide products calculated on the basis of calcined equivalent. This was 5 percent more than in 1964. The gross weight of the calcined alumina and aluminum oxide products was 5,864,-

Table 5.—Bauxite consumed in the United States, by industries
(Long tons, dry equivalent)

Year and industry	Domestic	Foreign	Total
1964:			
Alumina	1,576,145	10,193,109	11,769,254
Abrasive [1]	W	240,469	[2] 240,469
Chemical	96,133	158,600	254,733
Refractory	31,174	187,909	219,083
Other	22,745	39,297	62,042
Total [1]	1,726,197	10,819,384	12,545,581
1965:			
Alumina	1,630,021	10,991,592	12,621,613
Abrasive [1]	W	266,115	[2] 266,115
Chemical	97,791	162,769	260,560
Refractory	29,562	268,410	297,972
Other	44,930	42,499	87,429
Total [1]	1,802,304	11,731,385	13,533,689

W Withheld to avoid disclosing individual company confidential data; included with "Other."
[1] Includes consumption by Canadian abrasives industry.
[2] Excludes domestic.

000 tons, of which 5,538,000 tons was calcined alumina and 248,000 tons was trihydrate alumina. The remainder was activated, tabular alumina, or light hydrate. Shipments of alumina and aluminum oxide products totaled 5,756,000 tons, of which 94 percent, or 5,411,000 tons, went to the aluminum industry. The remaining 345,000 tons was shipped as commercial trihydrate, light hydrate, or as activated, calcined, or tabular alumina for use chiefly by the chemical, abrasive, ceramic, and refractory industries.

Table 6.—Bauxite consumed in the United States in 1965, by grades
(Long tons, dry equivalent)

Grade	Domestic origin	Foreign origin	Total
Crude	1,650,717	408,247	2,058,964
Dried	24,878	10,789,142	10,814,020
Calcined	109,185	533,996	643,181
Activated	17,524	------------	17,524
Total	1,802,304	11,731,385	13,533,689

Calcined alumina consumed at the 23 aluminum reduction plants in the United States totaled 5,210,000 short tons, 7 percent more than in 1964. An average of 2.187 long dry tons of bauxite was required to produce 1 short ton of alumina, and an average of 1.891 short tons of alumina was required to produce 1 short ton of aluminum metal. The overall ratio was 4.136 long dry tons of bauxite to 1 short ton of aluminum.

Alcoa announced plans to operate two all-aluminum unit trains to transport alumina from Mobile, Ala., to its reduction plant at Massena, N.Y., on a weekly basis. Each train will be comprised of 50 covered hopper cars weighing 24 short tons empty and capable of hauling 106 tons of alumina. A total of 110 cars including 10 cars in reserve for emergency use and normal maintenance requirements are under construction by Transco Inc. of Chicago.

A trend toward high compression ratios in automobile and airplane motors expanded the market for alumina as the ceramic insulator in spark plugs, about a 13,000-ton market in 1965. Impurities in the previously used materials caused insulating characteristics to break down under strain.[2]

Hydrated silico aluminate and sodium calcium silico aluminate may be used as a partial substitute for titanium dioxide in latex paints.

Thermosprayed powdered alumina coating on inside walls of pipe-still eductors in gasoline refineries resulted in a sixfold longer service life compared with a copper chloride treatment. The alumina is melted by an oxygen and acetylene gas mixture.[3]

[2] Chemical Week. Alumina: In "Big Time" on Its Own. V. 97, No. 24, Dec. 11, 1965, pp. 63–70.
[3] Electronic News. Metco Alumina Spray Prolongs Eductor Life. V. 84, No. 5, March 1965, p. 30.

Table 7.—Capacities of domestic alumina plants in operation and under construction

Company and plant	Capacity as of Dec. 31, 1965 (short tons per year)	
	Operating plants	Plants under construction
Aluminum Company of America:		
Mobile, Ala	880,000	
Bauxite, Ark	440,000	
Point Comfort, Tex	880,000	
Total	2,200,000	
Reynolds Metals Co.:		
Hurricane Creek, Ark	803,000	
La Quinta, Tex	876,000	220,000
Total	1,679,000	220,000
Kaiser Aluminum & Chemical Corp.:		
Baton Rouge, La	940,000	
Gramercy, La	610,000	
Total	1,550,000	
Ormet Corp.: Burnside, La	479,000	33,000
Harvey Aluminum, Inc.: St. Croix, Virgin Islands		220,000
Grand total	5,908,000	473,000

Table 8.—Production and shipments of selected aluminum salts in the United States in 1964

Type of salt	Number of plants producing	Production (short tons)	Total shipments including interplant transfers	
			Short tons	Value (thousands)
Aluminum sulfate:				
Commercial (17 percent Al_2O_3)	57	1,018,801	98,965	$36,281
Municipal (17 percent Al_2O_3)	5	3,551		
Iron-free (17 percent Al_2O_3)	14	55,877	36,568	2,142
Aluminum chloride:				
Liquid (32° Bé)	10	28,943	13,811	1,102
Crystal (32° Bé)				
Anhydrous (100 percent $AlCl_3$)	8	29,890	30,167	6,950
Aluminum flouride, technical	6	92,614	93,590	25,313
Aluminum hydroxide, trihydrate (100 percent $Al_2O_3.3H_2O$)	9	253,005	234,696	16,659
Other inorganic aluminum compounds [1]	NA	NA	NA	16,985
Total	XX	XX	XX	105,432

NA Not available. XX Not applicable.
[1] Includes sodium aluminate, light aluminum hydroxide, cryolite, and alums.

Source: Data are based upon Bureau of the Census report Form MA-28E.1, Annual Report on Shipments and Production of Inorganic Chemicals.

STOCKS

Bauxite stocks in the United States on December 31, 1965, were 87,000 long dry tons more than at yearend 1964. By dry weight, consumers' inventories of crude and processed bauxite increased 13 percent and those at mines and processing plants decreased 14 percent.

Table 9.—Stocks of bauxite in the United States [1]
(Long tons)

Year	Producers and processors: Crude	Producers and processors: Processed [2]	Consumers: Crude	Consumers: Processed [2]
1961	1,306,419	9,466	621,729	1,897,635
1962	1,121,705	9,960	542,539	1,920,051
1963	1,143,893	8,967	499,526	1,696,700
1964	1,163,770	10,264	r 402,394	r 1,399,509
1965	1,007,020	8,689	419,525	1,609,104

r Revised.
[1] Excludes strategic stockpile.
[2] Dried, calcined, and activated.

PRICES

No open market price was in effect for bauxite mined in the United States, because the output was consumed mainly by the producing companies.

The average value of bauxite shipped and delivered to domestic alumina plants was $16.84 per long ton, dry equivalent, for imported ore.

Prices per long ton quoted in E&MJ Metal and Mineral Markets for imported bauxite at yearend in 1964 and 1965 follow:

	Atlantic ports, f.o.b. cars: Dec. 28, 1964	Nov. 15, 1965
Calcined, crushed (abrasive grade) [1]	[2] $27.05—$28.80	$27.05—$28.80
Refractory grade [3]	36.25	36.25
Dried bauxite, crushed chemical grade (60 percent Al_2O_3, 6 percent silica, 1.25 percent iron)	13.95	13.95

[1] 87 percent minimum Al_2O_3.
[2] Penalties for Si content more than 7 percent.
[3] 88 percent minimum Al_2O_3.

The average value of calcined alumina, as determined from producer reports, was $0.0317 per pound. The value of imported calcined alumina classified as aluminum oxide for use in producing aluminum was $0.0299 per pound.

Table 10.—Average value of domestic bauxite in the United States [1]
(Per long ton)

Type	Shipments f.o.b. mines or plants: 1964	1965
Crude (undried)	$9.55	$9.52
Dried	W	W
Calcined	19.54	19.90
Activated	W	W

W Withheld to avoid disclosing individual company confidential data.
[1] Calculated from reports to the Bureau of Mines by bauxite producers.

Table 11.—Average value of U.S. exports and imports of bauxite
(Per long ton)

Type and country	Average value port of shipment: 1964	1965
Exports: Bauxite and bauxite concentrate	r $79.66	$73.12
Imports:		
Crude and dried:		
British Guiana	8.89	10.15
Dominican Republic [1]	14.36	9.87
Greece	10.87	14.28
Haiti [1]	14.25	9.40
Jamaica [1]	14.05	12.35
Surinam	9.80	9.46
Average	12.65	11.26
Calcined: [2]		
British Guiana	25.04	26.22
Canada	33.44	31.55
Surinam	21.13	23.94
United Kingdom	26.75	----------
Average	24.28	25.78

r Revised.
[1] Dry equivalent tons adjusted by Bureau of Mines used in computation.
[2] For refractory use.
Note: Bauxite is not subject to an ad valorem rate of duty and the average values reported may be arbitrary for accountancy between allied firms, etc. Consequently the data do not necessarily reflect market values in the country of origin.

Table 12.—Market quotations on alumina and aluminum compounds

Compound	Dec. 28, 1964	Dec. 27, 1965
Alumina, calcined, bags, carlots, works____pound__	$0.0530	$0.0530
Aluminum hydrate, heavy, bags, carlots, freight equalized____do____	.0370	.0370
Aluminum sulfate, commercial, ground, bulk, carlots, works, freight equalized____ton__	44.00	48.25
Aluminum sulfate, iron-free, bags, carlots, works, freight equalized 100 pounds__	3.80	3.80

Source: Oil, Paint and Drug Reporter.

FOREIGN TRADE

Exports.—Exports of bauxite and bauxite concentrate were about half of the 1964 amount. Canada received 58 percent; Mexico 26 percent; Australia 11 percent; and France 1 percent.

Approximately 54 percent of the 15,641 tons of aluminum sulfate exported was shipped to Venezuela; 35 percent was shipped to Canada, Mexico, and Guatemala; and 9 percent was shipped to the Philippines, Paraguay, Colombia, and Viet-Nam. Of the 317,800 tons of aluminum oxide exported, Norway received 57 percent and Canada 36 percent. Small quantities were shipped to 47 other countries. About 5,366 tons of aluminum hydroxide was exported to 47 countries; Mexico, Canada, and West Germany received 38 percent, 13 percent and 11 percent, respectively. Approximately 17,254 tons of artificial corundum was exported; Canada received 38 percent, the United Kingdom 14 percent, and Sweden and India each 11 percent. The remainder was shipped to 28 other countries. Of the 13,425 tons of other aluminum compounds exported to 54 countries, 29 percent was shipped to Australia; 14 percent to India; 13 percent to Brazil; 9 percent to Canada; 8 percent to Surinam, and 5 percent each to Norway, Taiwan, and Japan.

Table 13.—U.S. exports of bauxite (including bauxite concentrates), by countries
(Long tons)

Destination	1956–60 (average)	1961	1962	1963	1964	1965
North America:						
Canada	23,959	108,104	160,811	121,044	r 191,294	84,689
Mexico	1,414	562	826	20,245	30,863	38,643
Other	196	109	239	79	353	67
Total	25,569	108,775	161,876	141,368	222,510	123,399
South America	135	559	655	455	327	547
Europe	608	39,859	62,721	24,362	16,935	7,233
Africa	38	10	51	33	207	1
Asia	549	1,327	22,861	4,059	2,104	50
Oceania	1	153	10,397	32,919	36,729	15,600
Grand total as reported	26,900	150,683	258,561	203,196	r 278,812	146,830
Dried bauxite equivalent	41,696	233,559	400,770	314,954	r 432,159	227,587
Value____thousands__	$2,212	$12,189	$19,874	$15,696	$22,211	$10,736

r Revised.

Imports.—Imports of bauxite including ores acquired by the U.S. Government totaled 12 percent more than in 1964. Of this, 58 percent came from Jamaica reaching a new high with a 14-percent increase. Imports of bauxite originating in British Guiana and Surinam increased 4 percent and constituted 30 percent of total imports. The Dominican Republic and Haiti accounted for most of the remaining imports.

By dry weight, 44 percent of the imports entered through the New Orleans, La., customs district; 34 percent through the Galveston, Tex., district; 21 percent through the Mobile, Ala., district; and 1 percent through other districts.

Table 14.—U.S. imports for consumption of bauxite (crude and dried) by country [1]
(Thousand long tons and thousand dollars)

Country	1956–60 (average)	1961	1962	1963	1964	1965
British Guiana	274	319	560	335	253	87
Dominican Republic	203	722	719	729	640	976
Haiti	257	289	437	328	396	330
Jamaica	3,908	4,933	5,986	5,239	5,792	6,602
Surinam	2,865	2,885	2,856	2,487	3,027	2,962
Trinidad [2]	--	27	2	73	43	407
Other countries	7	31	15	21	29	36
Total: Quantity	7,514	9,206	10,575	9,212	10,180	11,400
Value	$65,405	$88,814	$212,880	$114,546	$128,787	$142,989

[1] Official Bureau of Census import data for Jamaican, Haitian, and Dominican Republic bauxite have been converted to dry equivalent by deducting 13.6 percent free moisture for Jamaican; 14.6 percent for Haitian bauxite in 1957 and 13.6 percent in 1958 and subsequent years; and 17.7 percent for Dominican Republic. Other imports, which are virtually all dried, are on an as-shipped basis.
[2] Bauxite imports from Trinidad originated in British Guiana and Surinam. Bauxite is not produced in Trinidad.

Imports of aluminum oxides and compounds classified as aluminum hydroxides and oxides (alumina) totaled 24,302 tons, of which 39 percent came from Jamaica, 31 percent from British Guiana, and 26 percent from Canada. The remainder came chiefly from Australia, West Germany, United Kingdom, France, Netherlands, and Japan.

Tariff.—The duties on crude bauxite, calcined bauxite, and alumina imported for making aluminum continued to be suspended until July 15, 1966. Duties on aluminum hydroxide and alumina not used for aluminum production were 0.25 cent per pound.

WORLD REVIEW

World bauxite production increased 10 percent. Jamaica, the principal producer, with an increase of 9 percent accounted for 23 percent of the total.

The Port of Tacoma, Wash., planned to install and operate unloading facilities to handle Australian alumina for Kaiser Aluminum & Chemical Corp., aluminum plants at Tacoma and Mead, and for Intalco Aluminum Corp., a new reduction plant at Bellingham, Wash.

Intalco is a joint venture of American Metal Climax Inc. (Amax), which owns 50 percent, and Howmet Corp. and Péchiney, Compagnie de Produits Chimiques et Electrométallurgiques, which owns 25 percent each. Western Aluminum N.L., a subsidiary of Alcoa of Australia Pty. Ltd., signed an agreement with Amax to supply Intalco with Australian alumina.

A barter agreement was signed in Budapest by Guinea and Hungary; the former will receive manufactured products in exchange for agricultural commodities and minerals including bauxite and alumina.

Worldwide the ratio of bauxite to aluminum production has declined as follows:

1956–60 (average)	5.7
1961	6.3
1962	6.2
1963	5.6
1964	5.5
1965	5.5

Table 15.—World production of bauxite by countries

(Thousand long tons)

Country	1961	1962	1963	1964	1965 p [1]
North America (dried equivalent of crude ore):					
Dominican Republic	r 737	r 665	761	r 807	927
Haiti	263	370	327	373	320
Jamaica	6,663	7,495	6,903	[2] 7,811	[2] 8,514
United States	1,228	1,369	1,525	1,601	1,654
South America:					
Brazil	110	188	167	r 130	190
British Guiana	2,374	r 3,036	2,342	2,468	2,638
Surinam	r 3,398	r 3,245	r 3,384	r 3,930	4,291
Europe:					
Austria	18	17	18	4	----------
France	2,190	2,160	1,997	r 2,394	2,610
Greece	1,100	r 1,267	1,261	e 1,280	e 1,080
Hungary	1,344	1,450	1,340	1,465	1,455
Italy	322	r 305	r 264	232	241
Rumania	68	30	10	r 7	e 30
U.S.S.R. e [3]	4,000	4,200	4,300	4,300	4,700
Yugoslavia	1,213	1,311	1,265	1,273	1,549
Africa:					
Ghana	r 201	r 239	r 309	r 246	314
Guinea, Republic of	1,739	r 1,445	1,638	1,652	1,840
Rhodesia (formerly Southern)		1	2	2	e 2
Sierra Leone			e r 30	r 151	204
Asia:					
China (diasporic) e	400	400	400	400	400
India	468	568	r 560	582	695
Indonesia	413	454	485	r 638	e 690
Malaysia:					
Malaya	410	349	444	464	843
Sarawak	253	225	155	r 158	158
Turkey				4	10
Oceania: Australia	16	30	354	r 841	1,158
World total e	r 28,945	r 30,835	r 30,260	r 33,230	36,530

e Estimate. p Preliminary. r Revised.

[1] Compiled mostly from data available June 1966.

[2] Bone dry equivalent of bauxite shipments and bauxite converted into alumina.

[3] Excludes nepheline concentrates and alunite ores.

Table 16.—Production and trade of bauxite in 1964, by major countries

(Thousand long tons)

Country	Production	Exports by country of destination: Total	North America: Canada	North America: United States	Europe: France	Europe: Germany, West	Europe: Italy	Europe: Spain	Europe: U.S.S.R.[1]	Europe: United Kingdom	Europe: Other Europe	Asia (Japan)	All other countries
North America:													
Dominican Republic	r 807	909		909									
Haiti	373	[2] 396		[2] 396									
Jamaica	[3] 7,811	5,967		5,967									
United States	1,601	293	206		9	(4)	1	5		2	(4)	(4)	70
South America:													
Brazil	r 130	3											3
British Guiana	2,468	1,319	582	472	36	37	29	[5] 6		65	17	[5] 67	8
Surinam	r 3,930	3,921	595	3,318				5			1		2
Europe:													
Austria	4	2				2							
France	r 2,394	196				134	4	1		53			4
Germany, West	4	1			(4)						1		
Greece	e 1,280	1,046		29	105	[5] 366		[5] 36	429	45	25		11
Hungary	1,465	749				[5] 74			[5] 675				
Italy	232	2											2
Rumania	r 7												
Spain	r 7												
U.S.S.R.	e [6] 4,300	NA											
Yugoslavia	1,273	1,063				667	259		130	4	3		
Africa:													
Ghana	r 246	264			19					227	18		
Guinea, Republic of	1,652	164	[5] 52						[5] 112				
Mozambique	6	7											7
Rhodesia, Southern	r 2												
Sierra Leone	r 151	127				56	50		11		10		
Asia:													
China (diasporic)	e 400	NA											
India	582	198				26	30		5	1	(4)	131	5
Indonesia	r 638	[5] 657				[5] 52						[5] 605	
Malaysia:													
Malaya	464	548										499	49
Sarawak	r 158	166										121	45
Turkey	4												
Oceania: Australia	r 841	406			1	155						239	11
World total	r 33,230	18,404	1,435	11,091	170	1,569	373	53	1,362	397	75	1,662	217

e Estimate. NA Not available. r Revised.
[1] U.S.S.R. and other Communist nations of East Europe.
[2] U.S. imports.
[3] Bone dry equivalent of bauxite shipments and bauxite converted into alumina.
[4] Less than ½ unit.
[5] Imports.
[6] Excludes nepheline concentrates and alunite ore.

NORTH AMERICA

Canada.—Allied Chemical Canada Ltd., announced plans to double the capacity of its plant at Port Arthur to produce liquid aluminum sulfate. The company has six aluminum sulfate facilities either in operation or under construction in Canada. Aluminum Company of Canada Ltd. (Alcan) announced plans to construct a liquid aluminum sulfate plant in the Ottawa-Hull-Gatineau area of Ontario to supplement its plants at Arvida and Shawinigan. The chemical is used for water purification and for the manufacture of pulp used in the paper industry.

Jamaica.—As the world's major producer of bauxite, Jamaica accounted for 23 percent of the world total. Exports of 6.6 million long tons, or 78 percent, went to the United States. Alcan Jamaica Ltd. consumed the remainder and produced 828,000 short tons of alumina, about the same as in 1964.

Reynolds Jamaica Mines Ltd. announced plans to double shipments of bauxite by installing new facilities including mining, storage, handling, and a 6.5-mile conveyor system from the drying plant at Lydford to the loading pier at Ocho Rios alongside the two existing cableways.

Virgin Islands.—The 220,000-ton capacity alumina plant under construction by Harvey Aluminum, Inc. is designed to handle both monohydrate and trihydrate bauxite ores. Plans include a 22,000-kilowatt steam-electric powerplant, a substantial water distillation system, and a 70,000-gallon-per-minute cooling system using titanium tubes to circulate sea water.

SOUTH AMERICA

Brazil.—Two new mines at Catas Altas and Moro de Fraga produced bauxite for the Aluminio Minas Gerais S.A. alumina plant at Ouro Preto. Alcoa reportedly had preliminary plans for a bauxite-alumina-aluminum complex in Minas Gerais with an aluminum capacity of 25,000 tons per year subject to participation of Brazilian interests.

British Guiana.—Production of bauxite continued to increase. Demerara Bauxite Co. Ltd. (Demba), shipped 881,000 long tons of dried bauxite, a 65-percent increase from 1964 production; 486,000 tons of calcined bauxite, a 5-percent increase; and 275,000 tons of alumina, a 6-percent decrease. A plant to recover usable bauxite from waste material was installed by Demba.

Reynolds Metals Co. signed a long-term agreement with the British Guiana Government to produce 600,000 tons per year of bauxite from its three mines at Wong, Mombaka, and Bissaruni. The agreement providing for dredging of the Berbice River and insured ample reserves of bauxite. The company announced plans to build a 400-ton-per-day calcining plant at Everton.

Surinam.—Exports of bauxite from Surinam amounted to 4,330,000 long tons, 10 percent more than in 1964. Surinam Aluminum Co. (Suralco) furnished 63 percent of total 1965 exports.

Suralco started operation of two units (400,000 tons) of its alumina plant at Paramaribo designed for four units with a total capacity of 800,000 tons when completed. The first shipment of 14,000 tons of alumina to the United States was made in September 1965.

EUROPE

Germany, West.—Imports of bauxite during January to August 1965, amounted to about 1 million long tons. Of this Yugoslavia supplied 41 percent, Greece 23 percent, Australia 14 percent, France 9 percent, and Sierra Leone 7 percent.

Greece.—Although Péchiney, Compagnie de Produits Chimiques et Electrométallurgiques' contract with the Greek Government for construction of an aluminum smelter in Greece included limiting exports of bauxite to 0.98 million long tons of bauxite per year, both parties agreed that exports could be raised to 1.2 million tons.

Hungary.—Development of the Halemba II mine was started, to produce 600,000 tons of bauxite per year when fully operational. Expansion of the Ajkaalumina plant and modernization of the Almasfuzito alumina plant was in progress. The Hungarian Government agreed to supply the State-owned Vereinigte Metallwerke of Ranshoven, Austria, with 22,000 tons of alumina per year with an option to supply an additional 3,000 tons annually.

Italy.—Mineraria Montevergine S.p.A., a subsidiary of Compagnie Belge de l'Aluminum (Cobeal), started development of a bauxite mine at Montevergine, Italy.

Norway.—A joint venture of Kaiser Aluminum & Chemical Corp., with a 40-percent interest, and Norsk Spraengstofindustri, with a 60-percent interest, to build an aluminum fluroide plant on the Oslo Fiord was announced. Norsk would supply the sulfuric acid and Kaiser the alumina trihydrate and fluorspar.

Rumania.—A 120,000-ton alumina plant was under construction at Oradea on the Hungarian border as part of a Rumanian aluminum complex. Plans included recovery of bauxite from deposits in Padurea Craiuli mountains in northwest Rumania and use of Rumanian aluminum fluoride and cryolite.

U.S.S.R.—Bauxite deposits were discovered in the Kzyl-Kum desert. A member of the Central Committee of the Communist Party announced expected completion in 1965 of alumina plants at Kirovabad and Zhdanov.

AFRICA

Camaroon.—Prospecting by the Government of Camaroon outlined two bauxite deposits of 45 million and 100 million tons each.

Guinea, Republic of.—Halco Mining Inc., a wholly owned subsidiary of Harvey Aluminum Inc., received a U.S. Agency for International Development (AID) initial risk guarantee protecting its $20 million investment in Compagnie des Bauxites de Guinée against inconvertibility, expropriation, revolution, and insurrection. Bauxites de Guinée is a partnership of Halco and the Republic of Guinea to exclusively exploit the Boké bauxite deposit. Negotiations with world bauxite users were in progress to establish long-term purchasing agreements for bauxite.

Sierra Leone.—The Sierra Leone Ore & Development Co., a subsidiary of Aluminium Industrie, A.G., increased the production of its mine in the Mokanji hills.

ASIA

India.—Plans for an alumina plant at Korba in Madhya Pradesch were changed from a 120,000 to a 200,000-ton-per-year plant.

The Gujarat Mineral Development Corp. announced plans to mine the Kutch bauxite deposit and erect an alumina plant at Mandvi. Reserves in the Kutch deposit were estimated at 6 million tons with an average alumina content of 55 to 60 percent.

Preliminary surveys indicate reserves of about 2 million tons of bauxite in Jummu and Kashmir.

Indonesia.—The Government was committed to supply 1.8 million metric tons of bauxite over a 3-year period to Japan at $5.60 per metric ton f.o.b. and 200,000 tons to Taiwan.

Japan.—Nippon Light Metals Co. concluded two contracts for Australian bauxite from the Weipa deposit. One contract was with Commonwealth Aluminium Corp. Pty. Ltd. (Comalco), for 2.5 million tons over a 10-year period starting in 1967 and the other with Australian Bauxite Co. for 10 million tons over a 35-year period starting in 1977. Showa Denko K.K., financially connected with Comalco through the Hong-Kong Bauxite Co., plans to import 2.5 million tons over a 10-year period starting in 1966 from the Comalco Weipa deposit. Showa Denko K.K. increased capacity of the Yokohama plant to 200,000 tons of alumina per year.

Turkey.—Several bauxite deposits in Turkey were reassessed or proved. Bauxite reserves between Kenya and Antalias were reassessed at 30 million metric tons. About 10 million tons was discovered at Mortas; 18 million tons at Dogan Kuso, 170,000 tons at Marcukar; 40 million tons at Milas; 10 million tons at Mugla; 3 million tons at Alanya; and 4 million tons at Bolkardag.

OCEANIA

Australia.—The Government of Australia accepted a tender resubmitted March 11, 1965, by Nabalco Pty. Ltd., a consortium of Swiss Aluminium Ltd. and eight Australian companies to develop the inner bauxite lease at Gove, Northern Territory. The lease covers a deposit of 22 square miles with an estimated reserve of 100 to 200 million tons of bauxite reported to contain 48 to 50 percent alumina mostly in the form of gibbsite.

Previous tenders submitted December 1, 1964, had been rejected for revisions and resubmittal. The requested revisions included Australian participation, plans for an aluminum reduction plant, and a promise to respect the rights and interests of the local aborigines. Only Nabalco and a combine of Reynolds Metals Co. and Broken Hill Pty. Co. Ltd. resubmitted tenders.

It was announced that Nabalco would start aerial mapping before the end of the year and also start a drilling program. Costs for developing the deposit would be determined within 2 years, followed by 4 years for designing and construction. Preliminary plans include a port and mining facilities with a capacity of 1.25 million tons per year, a township for about 3,000 people, and construction of a 300,000-ton-per-year alumina plant by 1971 for a total cost of about $112 million. Plans also include an aluminum smelter when a continuous supply of low-cost electricity is available. Meanwhile the alumina will be shipped to the United States and Norway and possibly also to Iceland, Japan, and Southern Africa.

Swiss Aluminium Ltd. owns 50 percent of Nabalco, and Australian companies have agreed to provide the other 50 percent of the capital, subject to a return of at least 7.5 percent on the investment after taxes. The Australian companies with percent of investment are Colonial Sugar Refining Co. Ltd., 27.5 percent; Australian Mutual Provident Society, 5 percent; Mutual Life & Citizens Assurance Co. and Peko-Wallsend Investment Ltd. each 3.75 percent; and Bank of New South Wales, Commercial Banking Co. of Sidney, Elder Smith Goldsborough Mort Ltd. and Mount Morgan Ltd. each 2.5 percent.

An Australian Government spokesman stated that atomic power might well be the only possible source of electricity for an aluminum smelter near Gove. Reports of discovery of brown coal below bauxite beds raises a possibility for investigation of coal reserves to be considered as a possible source of power.

Péchiney, Compagnie de Produits Chimiques et Electrométallurgiques holds the peripheral leases at Gove subject to acceptable firm commitments to the Government on development plans by mid–1966.

American Metal Climax Inc. (Amax) announced discoveries of bauxite deposits covering 2,558 square miles in the northern part of Western Australia close to Secure Bay and Walcott Inlet, sites described as a source of tidal energy for electric-power generation.

Alcoa of Australia, Pty. Ltd., reported that the detailed design for expansion of its Kwinana alumina plant from 210,000 to 410,000 tons per year was almost completed. The increased production will be needed to meet export commitments.

Bauxite Exploration Pty. Ltd., reported discovery of bauxite deposits 43 miles east of Perth showing 52 percent alumina.

The Gladstone alumina plant of Queensland Alumina Ltd. is scheduled for completion of its first unit (675,000 short tons per year) early in 1965. The facility was designed for future expansion to 1,350,000 tons and eventually to 2,025,000 tons per year.

TECHNOLOGY

Research continued in development of processes and techniques for extraction of alumina from low-grade and nonbauxite materials.

Exploratory research on the composition, structure, and properties of aluminas was stimulated by the surprising strength of refractory fibers and the demand for fused refractories.

Because of the increasing depth of the overburden at the Reynolds Mining Co. open pit mine near Bauxite, Arkansas, the company planned to replace a 200-foot-boom, 13-cubic-yard-walking dragline with a 285-foot-boom, 25-cubic-yard dragline. Plans were developed to strip 160 feet of overburden from a 20-foot-thick bauxite deposit and establish a stable highwall and spoil slope. A shaped highwall was planned with three cuts 140-feet-wide at vertical intervals of 30, 80, and 50 feet, respectively, from the top on 1 to 1 slopes. A drainage ditch was to be placed at the toe of the top cut. The spoilage slope was planned with two intermediate 50-foot-wide benches at intervals of 60 feet, respectively, from the bottom of the pit and a total height of 176 feet to the leveled top. Slope ratios of 1½ to 1 for the lowest slope interval and of 1¼ to 1 for the middle and top slope intervals were planned. Similar plans were developed for overburden depths up to 200 feet with cuts of 30, 90, and 80 feet in steps from the top.[4]

A sulfuric acid process for the production of alumina from aluminum-bearing ore was patented whereby, after ferric iron in the digestion liquor was reduced to the ferrous state, reactive alumina was added

[4] Rumfelt, Henry. Recent Developments in Surface Mining. Min. Cong. J., v. 51, No. 9, September 1965, pp. 77–81.

precipitating basic aluminum sulfate for calcining to produce alumina.[5]

A nitric acid process for treating ferruginous aluminum-bearing ores was patented whereby alumina was recovered by heating the nitrate formed by leaching the ore with nitric acid. The patent also included calcining the ore at 700° to 850° C before leaching to break the aluminum silicate bonding in the ore; it also included magnetic removal of iron converted to the magnetic form when calcined in a reducing atmosphere.[6]

A patent was granted on a method to produce aluminum nitride refractory by heating a mixture of aluminum with 5 to 20 percent finely divided carbon at 1,000° to 1,500° C in an atmosphere of excess nitrogen.[7]

A patent was granted for a refractory batch to provide a dense spinel-bonded refractory product consisting of a minor proportion of essentially finely divided alumina, a major proportion of non-acid grain material compatible with a 5- to 20-percent proportion of magnesium aluminate including 1 to 5 percent titania, and a chemical bonding agent.[8]

The lime-soda sinter process is applicable to the recovery of aluminum from aluminum silicate, a major constituent of anorthosite. The recovered sinters contain, in addition to sodium aluminate, extraneous calcium-sodium-aluminum compounds which must be considered in devising optimum procedures for leaching a sinter. A laboratory investigation showed about 99 percent extraction of sodium and aluminum from synthesized $2Na_2O \cdot 3CaO \cdot 5Al_2O_3$ in solutions of $NaOH-Na_2CO_3$ at leaching temperatures of 50° C and above.[9]

In the lime process for recovery of gallium from the Bayer process liquor, CO^2 is used to precipitate a concentrate containing 0.3 to 1 percent gallium after the less soluble calcium aluminate is precipitated from the causticized solution. The carbonization process is similar except that CO_2 is introduced in the beginning together with alumina trihydrate seed and slightly higher gallium to aluminum ratio results before the final CO_2 is introduced.[10]

The Refractories Institute announced plans to establish a Refractories Industry Research and Testing Center at Columbus, Ohio, to conduct a full line of tests on heat-resistant brick and materials.[11]

Aluminous ores are a source of gallium which normally is recovered as a byproduct of the Bayer process. However, the percentage of gallium in the Bayer liquor which has a high organic content is not sufficient for recovery by electrolysis. In a solution containing less than 0.3 gram of gallium per liter, the rate of deposition at a solid cathode is less than the rate of solution from the cathode. The Breteque method in France uses an agitated mercury cathode. The rate of deposition exceeds the rate of solution because of the reduced activity of the gallium in the amalgan.

Studies were made to correlate some of the properties of the aluminate ion in caustic solutions.[12] The specific conductance of sodium hydroxide and sodium aluminate solutions, products of casutic leaching of lime-soda sinters for the recovery of alumina from aluminum ores, is directly proportional to the temperature. The density and viscosity of sodium aluminate solutions were inversely proportional to the temperature of the solution and directly proportional to the concentrations of sodium and aluminate ions. Aluminate ions did not influence the temperature dependence of pH in caustic solutions containing sodium aluminate.

In a search for inorganic fibers as a substitute for natural asbestos, aluminum borate whiskers were grown by vapor deposition and molten-bath methods. Whiskers grown by vapor deposition were superior with a maximum tensile strength of 174,-

[5] Scott, Thomas Robert (assigned to Commonwealth Scientific and Industrial Research Organization). Production of Alumina. U.S. Pat. 3,185,545, Nov. 8, 1962.

[6] Hyde, Richard W., and Stanley V. Margolin (assigned to Arthur D. Little, Inc.). Process for Treating Ferruginous Aluminum-Bearing Ores. U.S. Pat. 3,211,524, Jan. 29, 1964.

[7] Lapp, David T., and Howard J. Bartlett (assigned to Norton Co.). Method for Production of Aluminum Refractory Material. U.S. Pat. 3,194,635, July 18, 1961.

[8] Parikh, Kanalyalal N., and Merton L. Van Dresser (assigned to Kaiser Aluminum & Chemical Corp.). Refractory. U.S. Pat. 3,184,322, Sept. 7, 1961.

[9] Lundquist, R. V. Extraction of Aluminum From $2Na_2 \cdot 3CaO \cdot 5Al_2O_3$ in Water and in Solutions of NaOH and Na_2CO_3. BuMines Rept. of Inv. 6593, 1965, 9 pp.

[10] Hudson, L. K. Gallium as a By-Product of Alumina Manufacture. J. Metals, v. 17, No. 9, September 1965, pp. 948–951.

[11] American Metal Market. Refractories Institute to Establish Research Center at Ohio State University. V. 72, No. 23, Feb. 3, 1965, p. 6.

[12] Lundquist, R. V. Specific Conductance, pH, Density and Viscosity of Sodium Aluminate Solutions and Some Properties of the Aluminate Ion. BuMines Rept. of Inv. 6582, 1965, 11 pp.

000 pounds per square inch and a melting point between 1,675° and 1,795° C.[13]

A study of aluminum oxide whiskers showed that whiskers grown by oxidizing molten aluminum globules are of two types: parallel-sided ribbons of perfect crystals and solid or hollow bars of circular or hexagonal cross sections with a defect in the crystal lattice.[14]

The application and results of composites reinforced with fibers including alumina whiskers were investigated and described.[15]

Chemical and petrographic analyses and physical properties of three types of fused refractories—Alpha alumina, alpha-beta alumina, and zirconia-alumina — were described.[16] They are cast from electric-arc furnaces of temperatures ranging from 3,200° to 4,100° F. slowly cooled, and crystallized from a molten magma. This greatly differentiates these materials from the kiln-fired refractories generallly used in blast furnaces.

Development of an inorganic foam system made by treating colloidal alumina with small amounts of organic acids or their salts was announced by E. I. du Pont de Nemours & Co., Inc. The system is cationic and can be acidic, basic, or neutral.[17]

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[13] Johnson, Robert C., and John K. Alley. Synthesis and Some Properties of Aluminum Borate Whiskers. BuMines Rept. of Inv. 6575, 1965, 23 pp.

[14] Barber, D. J. Aluminum Oxide Whiskers Studied by Electron Microscopy. Tech. News Bull., v. 49, No. 3, March 1965, p. 49.

[15] Wagner, H. J. Review of Recent Developments Fiber-Reinforced Materials. Defense Metals Inf. Center, Battelle Memorial Inst., Dec. 31, 1965, 6 pp.

[16] Brown, Roy W. Fused Cast Refractories For Blast Furnace Linings. Blast Furnace and Steel Plant, v. 53, No. 4, April 1965, pp. 311–314.

[17] Chemical & Engineering News. Du Pont Unveils Inorganic Foam System. V. 43, No. 21, May 24, 1965, p. 31.

Beryllium

By Donald E. Eilertsen [1]

Domestic beryl output continued to be negligible in 1965, but the downward trend in worldwide beryl production and use was reversed. As a result of continuing research beryllium and beryllium alloys found wider use.

Table 1.—Salient beryl statistics

	1956–60 (average)	1961	1962	1963	1964	1965
United States: Beryl, approximately 11 percent BeO unless otherwise stated:						
Domestic beryl shipped from mines short tons	400	317	218	1	*W*	*W*
Other domestic low-grade beryllium ore short tons	(1)	805	760	750	----	----
Imports do	8,248	8,516	8,552	6,243	5,425	7,791
Consumption do	6,503	9,392	7,758	7,934	4,435	5,845
Price, approximate, per unit BeO imported, cobbed beryl at port of exportation	$30	$30	$31	$24	$23	$24
World: Production short tons	11,080	12,900	11,000	7,700	5,200	5,700

W Withheld to avoid disclosing individual company confidential data.
[1] Material first available in 1958; 1958, 42 short tons, 1959, 97 short tons, and 1960, 265 short tons.

Legislation and Government Programs.—Under the Agricultural Trade Development and Assistance Act of 1954, a total of 498 tons of beryl was added to the inventory of Commodity Credit Corporation (CCC). CCC asked U.S. firms to submit bids on converting beryl from India to approximately 75 tons of beryllium billets for stockpiling.

Government yearend stocks of beryl, beryllium metal, and beryllium copper are shown in table 2.

[1] Commodity specialist, Division of Minerals.

Table 2.—Government yearend stocks of beryllium-bearing materials
(Short tons)

Item	National stockpile	Defense Production Act (DPA)	Supplemental stockpile	Commodity Credit Corp. (CCC)	Total
Beryl:					
Stockpile grade, objective	15,215	----	----	----	15,215
Stockpile grade, excess	6,519	2,086	3,369	498	12,472
Nonstockpile grade, excess	----	456	----	----	456
Total	21,734	2,542	3,369	498	[1] 28,143
Beryllium-copper master alloy:					
Objective	1,075	----	3,675	----	4,750
Excess	----	----	2,637	----	2,637
Total	1,075	----	6,312	----	7,387
Beryllium metal:					
Objective	----	----	150	----	150
Excess	----	----	3	----	3
Total	----	----	153	----	153

[1] Does not include 5,501 tons of stockpile grade beryl on order by CCC.

DOMESTIC PRODUCTION

Hand-sorted beryl was produced in South Dakota, Colorado, and Wyoming. The total output was small. Data are company confidential.

The Beryllium Corp. of Reading and Hazleton, Pa., and The Brush Beryllium Co. of Elmore, Ohio, processed hand-sorted beryl into beryllium metal, alloys, and compounds. Outputs were mostly beryllium and beryllium-copper master alloy, each larger in 1965 than in 1964. Production data are company confidential.

Lithium Corporation of America, Inc., announced that its subsidiary, Beryllium Metals & Chemicals Corp., Bessemer City, N.C., encountered difficulties in the manufacture and quality control of beryllium, and that decisions were made to improve the electrorefining process and produce high-purity beryllium on a reduced basis.

The Anaconda Company, Anaconda, Mont., continued research on electrolytic beryllium and also on the extraction of beryllium from Spor Mountain, Utah ore.

CONSUMPTION AND USES

Cobbed beryl consumption by the beryllium and ceramic industries totaled 5,845 tons, most of which was processed to beryllium metal, alloys, and compounds.

Net sales of The Beryllium Corp. were $29.0 million, compared with $24.8 million in 1964. The Brush Beryllium Co. net sales were $23.2 million, compared with $22.4 million in 1964.

Other consumers of cobbed beryl were Beryl Ores Co., Arvada, Colo., which produced specialized beryl materials for the ceramic industry; Lapp Insulator Co., LeRoy, N.Y., which used ground beryl in making high-voltage electrical porcelain; and the Ceramic Division, Champion Spark Plug Co., Detroit, Mich., which used beryl as a minor constitutent in special ceramic compositions, principally spark plugs.

Beryllium continued to be used extensively in research and development applications. Most of the uses that have been developed for beryllium have been for special purposes and these applications have not included continuous large-scale outputs. The use of beryllium in inertial guidance systems increased and some beryllium powder went to the beryllium fuel development program. The use of beryllium in brakes to save weight in aircraft also increased.

Beryllium-copper alloys continued to be the principal established support of the beryllium industry. The alloys, well-known for their outstanding high strength, and high thermal and electrical conductivity, had many different industrial applications such as in electronic devices, business machines, automobile and aircraft products, household appliances, and telephone systems. New free-machining beryllium-copper rod which machines at rates comparable to brasses and bronzes appeared on the market.

Heat-treatable beryllium-nickel alloys were used in many applications requiring high strength, toughness, and hardness. The use of beryllium-nickel alloy in dies for the glass industry increased.

Beryllium was used also as an alloying constituent to improve the processing and properties of light metals.

Beryllium oxide had uses in ceramics.

STOCKS

Consumers stocks of beryl at yearend totaled 7,136 tons.

PRICES AND SPECIFICATIONS

Prices for domestic and imported cobbed beryl were on a buyer and seller basis.

The price of beryllium metal, 97-percent pure, beads, f.o.b. Reading, Pa., and Cleveland, Ohio, was quoted at $62 per pound in 1,000 to 2,000-pound quantities. A blend of beryllium powder, 200-grade, was quoted at $54 per pound in quantities of 20,000 pounds. Vacuum-cast beryllium ingot was quoted at $67 to $71 per pound. In January, beryllium-copper master alloy was quoted f.o.b. Reading, Pa., Detroit, Mich., and Elmore, Ohio, at $43 per pound of contained beryllium and at about 34 cents per pound of contained copper, but by yearend the price was $46 per pound of contained beryllium and 47 cents per pound of contained copper. In January, beryllium-copper strip, rod, and wire were quoted at $2.04 per pound, but during the year several increases in prices occurred and by yearend the prices were quoted at $2.24 per pound. In January, beryllium aluminum was quoted at $65 per pound of contained beryllium and at market price for contained aluminum, but by yearend the price of the contained beryllium was $60 per pound.[2]

[2] American Metal Market. V. 72, Nos. 1–252, January-December 1965.

FOREIGN TRADE

No data were available on exports of beryllium-copper alloy.

Table 3.—U.S exports of beryllium, beryllium alloys wrought or unwrought and waste and scrap [1]

Country	1964		1965	
	Pounds	Value	Pounds	Value
Austria	6,879	$22,126	2	$204
Australia	1,759	5,774	2	900
Brazil	18	640	----	----
Canada	18,280	45,907	29,294	79,270
Denmark	----	----	35	7,018
France	95	16,722	3,187	104,148
Germany, West	68,638	210,687	44,776	157,424
India	233	12,808	----	----
Italy	2,241	7,236	241	7,604
Ivory Coast	444	766	----	----
Japan	3,210	101,376	1,164	33,217
Mexico	2,810	2,042	220	820
Netherlands	222	1,284	5	1,493
Norway	39,981	52,598	6,684	6,595
South Africa, Republic of	90	508	8	2,641
Spain	1,105	4,272	1,107	5,325
Sweden	----	----	2	513
Switzerland	3,655	11,618	40	1,384
Turkey	426	1,290	----	----
United Kingdom	18,380	124,742	32,969	212,237
Yugoslavia	2,205	6,680	25	3,628
Total	170,671	629,076	119,761	624,421

[1] Consisting of beryllium lumps, single crystals, and powder; beryllium-base alloy powder; and beryllium rods, sheets, and wire.

Table 4.—U.S. imports for consumption of beryl, by countries and customs districts
(Short tons)

Country and customs district	1964	1965
South America:		
Argentina:		
New York	46	----
Philadelphia	383	257
Total	429	257
Bolivia: Philadelphia	----	33
Brazil:		
New York	128	83
Philadelphia	1,768	1,089
Total	1,896	1,172
Total South America	2,325	1,462
Europe:		
Belgium-Luxembourg: Philadelphia	----	190
Finland: Philadelphia	3	----
Italy: Philadelphia	----	61
Portugal: Philadelphia	----	74
Sweden: Philadelphia	49	----
Total Europe	52	325
Africa:		
Burundi and Rwandi: Philadelphia	101	167
Congo (Léopoldville): Philadelphia	224	1,178
Kenya: Philadelphia	----	254
Malagasy, Republic: Philadelphia	297	77
Malawi, Southern Rhodesia, and Zambia: Philadelphia	384	101
Mozambique: Philadelphia	716	295
South Africa, Republic of: Philadelphia	660	514
Uganda:		
New York	----	168
Philadelphia	411	245
Total	411	413
Total Africa	2,793	2,999
Asia:		
India: Maryland	----	1,507
Pakistan: Philadelphia	13	----
Total Asia	13	1,507
Oceania:		
Australia:		
New York	----	14
Philadelphia	242	1,484
Total Oceania	242	1,498
Grand total	5,425	7,791
Value	$1,372,160	$2,055,675

Table 5.—Imports of beryllium products in 1965, by countries

Country	Beryllium; unwrought, waste, and scrap		Wrought beryllium		Beryllium oxide or carbonate		Other beryllium compounds	
	Pounds	Value	Pounds	Value	Pounds	Value	Pounds	Value
Canada	----	----	39	$352	----	----	----	----
France	8,248	$458,333	51	5,587	----	----	2,037	$10,381
Italy	----	----	1	527	----	----	----	----
Japan	693	10,273	----	----	20	$407	----	----
United Kingdom	99	9,753	1	419	(1)	127	----	----
Total	9,040	478,359	92	6,885	20	534	2,037	10,381

[1] Less than ½ unit.

WORLD REVIEW

Greenland.—Two Soviet geologists reportedly discovered a new silicate mineral containing approximately 20 percent tin oxide and 7 percent beryllium oxide in the Narssaq area while on a visit in this country.

Table 6.—World production of beryl by countries

(Short tons)

Country	1961	1962	1963	1964	1965 p 1
Australia	343	250	123	r 123	14
Argentina	3 1,488	3 998	3 825	3 442	4 257
Brazil 3	3,503	3,319	r 2,170	r 1,566	1,226
Congo (Léopoldville)	184	304	235	r 136	21
India 4	885	150	----	----	1,507
Kenya	1	----	----	1	1
Korea, South	6	----	----	----	----
Malagasy Republic	836	743	453	r 234	22
Mozambique	1,073	627	613	r 451	4 295
Portugal	39	19	2	20	43
Rhodesia, Southern	396	559	249	182	e 90
Rwanda	525	394	282	328	3 756
South Africa, Republic of	192	360	425	151	53
South-West Africa	252	159	61	8	57
Swaziland	7	----	2	----	----
Sweden 4	----	26	----	49	----
Uganda	1,136	1,116	419	r 434	212
U.S.S.R. e 5	900	1,000	1,100	1,100	1,100
United States (mine shipments):					
Cobbed beryl	317	218	1	2 W	2 W
Other lower grade beryllium ore	805	760	750	----	----
World total e 1	12,900	11,000	7,700	5,200	5,700

e Estimate. p Preiminary. r Revised. W Withheld to avoid disclosing individual company confidential data.
[1] Compiled from data available May 1966.
[2] U.S. output was very small, not included in world total.
[3] Exports.
[4] United States imports.
[5] Cobbed concentrates at about 11 percent BeO.

TECHNOLOGY

Some quartz-carbonate veins in the southern part of the Gold Hill District, Utah, were reported to contain abnormal amounts of bertrandite.[3]

The pilot plant extraction of beryllium from bertrandite ore from Spor Mountain, Utah, was described.[4]

The Bureau of Mines ended its nationwide study of beryllium deposits in June, but continued its metallurgical research on beneficiation, extraction, purification, and fabrication of beryllium. Various thermal properties of beryllium fluoride were reported.[5] Three fluorescent methods were developed to quickly detect beryllium in the field. The first method was a bead test; the second, a spray method; and third, a contact-print method.[6]

A preliminary report describing Bureau of Mines diamond drilling and sampling of fluorite-beryllium deposits in the Lost River Valley, Seward Peninsula, Alaska, was placed in open files for inspection, chrysoberyl being the principal beryllium mineral.[7]

General progress on high-purity beryllium research and summaries on various aspects of U.S. Air Force research on beryllium were reported.[8]

Various reports on U.S. Air Force research on beryllium were published. The mechanical properties of zone-leveled crystals of beryllium were found to be between those of high purity and commercial crystals.[9] The properties of sheet produced from beryllium flake and beryllium lumps

[3] Griffitts, Wallace R. Recently Discovered Beryllium Deposits Near Gold Hill, Utah. Econ. Geol. v. 60, No. 6, September–October 1965, pp. 1298–1305.
[4] Chemical & Engineering News. Process Wins Beryllium From Low-Grade Ores. V. 43, No. 16, Apr. 19, 1965, pp. 70–71.
[5] Taylor, A. R. Jr., and T. Estelle Gardner. Some Thermal Properties of Beryllium Fluoride From 8° to 1,200° K, BuMines Rept. of Inv. 6664, 1965, 15 pp.
[6] Pattee, E. C. Variations on a Theme Foster —Better, Faster Field Tests for Beryllium. Min. Eng. v. 17, No. 5, May 1965, pp. 59–62.
[7] Mulligan, John J. Diamond-Drill Sampling Data, Fluorite-Beryllium Deposits, Lost River Valley, Seward Peninsula, Alaska, 1964. May 1965, 94 pp. Open-file report available for inspection at Bureau of Mines offices in Juneau and Anchorage, Alaska, and in the Department of the Interior Library (Rept. No. 29), Washington, D.C.
[8] Materials Advisory Board. Third Progress Report by The Committee on Beryllium Metallurgy of The Materials Advisory Board. Nat. Acad. Sci. Nat. Res. Council, MAB-199-M(3). June 1, 1965, 39 pp.
[9] Carrabine, J. A., and others. Investigation of the Mechanical Characteristics of Zone-Leveled Beryllium. Wright-Patterson Air Force Base, Ohio, AFML-TR-64-388, January 1965, 58 pp.

were studied.[10] Work on the elasticity of beryllium was discussed.[11] A few other reports on U.S. Air Force research on beryllium had limited distribution. Some of the discussions were on the purification of beryllium by distillation, and also by sublimation and evaporation; the inclusions in beryllium of different origins; beryllium bicrystals; beryllium technological material; effects on thermomechanical variables on high-purity beryllium sheet; and gas-pressure bonding of beryllium sheet.

The fabrication and properties of beryllium ingot sheet,[12] the machining damage to beryllium,[13] and the corrosion of beryllium [14] were discussed.

A price list of selective bibliography of Government research reports and translations on beryllium was published.[15]

Numerous patents concerning beryllium were issued.[16]

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[10] Moriceau, J. and others. Beryllium Research and Development Program—Influence of the Distribution of Oxide and of the Total Impurity Level on Recrystallization and Grain Growth of Beryllium. Wright-Patterson Air Force Base, Ohio, ASD-TDR-62-509, v. 6, February 1965, 84 pp.

[11] Dai, P. K. Mechanical Considerations in the Utilization of Beryllium in Structural Systems; Part 1: Equations for Plane Elastic Analysis of a Transversely Isotropic Medium. Wright-Patterson Air Force Base, Ohio, AFML-TR-64-395, January 1965, 13 pp.

[12] Battelle Memorial Institute, Defense Metals Information Center. Beryllium Ingot Sheet. DMIC 206, Aug. 10, 1965, 8 pp.

[13] Battelle Memorial Institute, Defense Metals Information Center. Surface Damage in Machined Beryllium. DMIC Memo 198, Jan. 4, 1965, 9 pp.

[14] Stonehouse, A. J., and W. W. Beaver. Beryllium Corrosion and How to Prevent it. Materials Protection, v. 4, No. 1, January 1965, pp. 24–28.

[15] U.S. Dept. of Commerce, Clearinghouse for Federal and Scientific Reports. Beryllium. SB-413, Supp. 1, 1965, 35 pp.

[16] Beaver, Wallace W., Robert M. Paine, and Albert James Stonehouse (assigned to The Brush Beryllium Co.). Beryllium-Niobium Composition. U.S. Pat. 3,172,761, Mar. 9, 1965.

Lane, Donald H., and Frank Emley (assigned to Westinghouse Electric Corp.). Copper-Base Alloys Containing Cobalt, Beryllium, and Zirconium. U.S. Pat. 3,196,006, July 20, 1965.

Mod, William A., and Charles W. Becker (assigned to The Dow Chemical Co.). Recovery of Beryllium From Bertrandite Ore. U.S. Pat. 3,177,068, Apr. 6, 1965.

Morana, Simon J., Gordon F. Simons, Arthur Epstein, and Robert Harry Ray (assigned to The Beryllium Corp.). Process for Producing High-Purity Beryllium Fluoride. U.S. Pat. 3,205,035, Sept. 7, 1965.

Schwenzfeier, Carl W., and Carl S. Pomelee (assigned to The Brush Beryllium Co.). Production of High-Purity Sinterable Beryllium Oxide. U.S. Pat. 3,172,728, Mar. 9, 1965.

Bismuth

By Donald E. Moulds [1]

The highlight of the year was a record consumption of nearly 3 million pounds of bismuth, 36 percent more than in 1964. Growing demand was accompanied by a price advance from $2.35 per pound to $4 per pound, in lots of 1 ton.

Disposal of 36,580 pounds of bismuth in alloy in the Government stockpile was authorized by Congress, but the material was not sold during 1965. The 22,901 pounds remaining in the Defense Production Act stockpile was transferred to the Atomic Energy Commission.

Legislation and Government Programs.—Bismuth held in Government stocks remained essentially unchanged at 3.8 million pounds. Of this total, the national stockpile held 1.3 million pounds and the supplemental stockpile 2.5 million pounds. Approximately 23,000 pounds of bismuth held in the Defense Production Act stockpile was transferred to the Atomic Energy Commission. Bismuth of stockpile grade exceeded the 3 million pound objective by some 800,000 pounds, and an additional 36,600 pounds of nonstockpile-grade bismuth alloy was held awaiting sale as authorized by Congress in August.

Table 1.—Salient bismuth statistics

(Pounds)

	1956–60 (average)	1961	1962	1963	1964	1965
United States:						
Consumption	1,499,242	1,478,423	1,909,548	2,175,038	2,160,100	2,931,673
Imports, general	805,502	798,518	816,190	1,123,466	1,238,252	1,378,147
Exports [1]	291,778	317,735	350,763	36,035	61,299	341,868
Price: New York, average ton lots	$2.25	$2.25	$2.25	$2.25	$2.30	$3.43
Stocks Dec. 31: Consumer and dealer	397,040	323,000	447,800	428,100	656,900	506,300
World: Production	5,040,000	5,700,000	6,700,000	6,800,000	8,200,000	9,400,000

[1] Includes bismuth, bismuth alloys, and waste and scrap.

DOMESTIC PRODUCTION

Bismuth from foreign and domestic base-metal ores was refined at the Omaha, Neb., and Perth Amboy, N.J., plants of American Smelting and Refining Company and at the East Chicago, Ind., plant of United States Smelting Lead Refinery, Inc. Secondary bismuth recovery from reclaimed alloy-scrap was resumed in May 1965 in the new refining facilities of United Refining & Smelting Co. at Franklin Park, Ill. The old plant of this company in Chicago, Ill., had been destroyed by fire in September 1964.

Production from primary materials currently being refined, augmented by previously accumulated foreign and domestic stocks of bismuth-rich segregates, was almost double the unusually low production of 1964, and shipments in 1965 were greater than any since 1942, when there was wartime demand. Secondary output, curtailed during construction of the Franklin Park refinery, was about 65 percent of the 1964 production.

[1] Commodity specialist, Division of Minerals.

CONSUMPTION AND USES

The growth in domestic bismuth consumption initiated in 1962 accelerated sharply during 1965 and exceeded 2.9 million pounds, an increase of 35 percent over the previous record consumption in 1963. The substantial increase resulted from the expanding use of bismuth in free-cutting steels, malleable iron and aluminum and to the mushrooming demand for the metal in the manufacture of a catalytic compound required in the production of acrylic fibre. Demand in 1965 exceeded available supply, and producer allocation was exercised to meet essential requirements.

The leading use of bismuth was again in the pharmaceutical classification. This classification covers bismuth used in industrial and laboratory chemicals, including catalytic compounds, which accounts for some 80 percent of the bismuth in this category. Use in medical compounds declined by almost 52,000 pounds in 1965 and represented only 20 percent of the total, compared with 46 percent in 1964.

Consumption in the form of fusible alloys was the largest consumption of this type since 1962. The classification "other alloys" includes use of bismuth as a metallurgical additive in steel, aluminum, and malleable iron. Consumption for this purpose accounted for 524,000 pounds, and miscellaneous multimetal and special purpose alloys required 50,000 pounds. Requirements in this category decreased 14 percent in relation to the major increase shown in 1964.

Table 2.—Bismuth metal consumed in the United States, by uses
(Pounds)

Use	1964	1965
Fusible alloys [1]	688,255	783,283
Other alloys	668,659	573,844
Pharmaceuticals [2]	756,864	1,523,904
Experimental uses	18,551	15,275
Other uses	27,771	35,367
Total	2,160,100	2,931,673

[1] Includes 127,446 pounds of bismuth contained in bismuth-lead bullion used directly in the production of an end product in 1964 and 166,906 pounds in 1965.
[2] Includes industrial and laboratory chemicals.

STOCKS

Stocks of bismuth metal held by consumers and dealers, decreased to 506,000 pounds at yearend. Additional stocks of bismuth metal as well as refinery feed materials in the form of bismuth-lead bullion, smelter residues, and electrolytic slimes were held by primary refining plants. The increased rate of production in 1965 indicated that inventories of this material declined substantially and that current output of bismuth-rich segregates was being processed as available.

PRICES

The delivered price of refined bismuth as quoted by the E&MJ Metal and Mineral Market (New York) advanced sharply from $2.35 per pound at the beginning of the year to a firm price of $4 per pound in 1-ton lots on June 21, 1965. The initial advance was on March 5 to $2.75 per pound, followed on March 23 by an increase to $3 per pound. On June 1, one of the major producers increased the domestic price to $4 per pound, and, until firmed on June 21, a range of $3 to $4 per pound existed.

The Metal Bulletin (London) quotation for bismuth metal advanced in early March to $3.08 per pound and again in late July to approximately $4 per pound. Quotations for bismuth ores were "nominal" throughout the year.

FOREIGN TRADE

Exports of bismuth in all forms were substantially above exports in 1963 and 1964 and approached the level of shipments prior to 1963. Exports data encompass waste and scrap in addition to the previously segregated bismuth metal and alloys, which in 1964 amounted to 48,000 pounds of the 61,300 pounds gross weight shown in table 3. The United Kingdom received 74 percent of the exports, and other European countries, 20 percent. Canada was the other significant importer at 4 percent.

General imports of metallic bismuth increased 11 percent in relation to 1964 imports.

Table 3.—U.S. exports of bismuth [1]

Year	Gross weight (pounds)	Value
1956–60 (average)	291,778	$377,621
1961	317,735	590,898
1962	350,763	673,905
1963	36,035	48,379
1964	61,299	101,789
1965	341,868	939,570

[1] Includes bismuth, bismuth alloys, and waste and scrap.

In addition to the import of refined bismuth, approximately 463,400 pounds of bismuth in bismuth-lead alloys containing not less than 30 percent of lead was imported. Of this, 256,100 pounds originated in Mexico and 207,300 pounds in Peru. Approximately 170,000 pounds of this bismuth-lead alloy was used directly in production of end products, and the remainder was domestically refined to metallic bismuth.

Table 4.—U.S. general imports of metallic bismuth, by countries
(Pounds)

Country	1964	1965
North America:		
Canada	80,671	50,424
Mexico	244,709	274,356
Total	325,380	324,780
South America: Peru	877,180	1,019,654
Europe:		
Germany, West	5	--------
Netherlands	4,130	5,048
Portugal	--------	4,409
Yugoslavia	31,377	22,045
Total	35,692	31,502
Asia: Japan	--------	2,211
Grand total	1,238,252	1,378,147

WORLD REVIEW

The increased production of base-metal ores throughout the world and the favorable market for bismuth have widened interest in recovery and marketing of the bismuth byproduct of various smelting operations.

Table 5.—World production of bismuth, by countries [1] [2]
(Pounds)

Country [1]	1961	1962	1963	1964	1965 [p]
Argentina (in ore)	[e] 8,600	7,100	1,345	9	------
Australia (in ore)	602	97	------	------	------
Bolivia	502,023	669,987	560,873	599,365	[e] 582,000
Canada (metal) [3]	478,118	425,102	395,125	399,958	513,213
China (in ore) [e]	660,000	660,000	660,000	660,000	660,000
France (in ore)	116,800	138,890	150,000	140,000	[e] 140,000
Japan (metal)	422,326	572,841	823,314	1,115,611	[4] 1,115,611
Korea, South (in ore)	333,000	353,000	349,000	[e] 1,100,000	[4] 1,100,000
Mexico [3]	643,700	780,000	941,400	1,040,500	[e] 1,100,000
Mozambique	38,800	13,889	24,317	14,462	[4] 14,462
Peru [3]	1,031,795	1,084,227	1,244,367	1,614,779	1,715,000
South-West Africa (in ore)	485	154	5,115	3,131	[e] 440
South Africa, Republic of (in ore)	168	130	2,619	161	[e] 285
Spain (metal)	21,427	18,799	25,836	[e] 25,800	[e] 25,800
Sweden [e]	79,000	155,000	155,000	150,000	150,000
Uganda	1,433	110	65	------	[e] [5] 615
Yugoslavia (metal)	216,348	199,765	194,657	184,660	[e] 196,000
World total (estimate) [1] [2]	5,700,000	6,700,000	6,800,000	8,200,000	9,400,000

[e] Estimate. [p] Preliminary.
[1] United States figure withheld to avoid disclosing individual company confidential data; included in world total. Bismuth is believed to be produced in Brazil, East Germany, and U.S.S.R. Production figures are not available for these countries, but estimates are included in the world total. Metallic bismuth is produced in West Germany presumably from imported raw material, as follows: 1961, 235,900 kilograms; 1962, 288,800; 1963, 277,300; 1964, 385,800; and 1965, not available.
[2] This table incorporates some revisions. Data do not add exactly to totals shown because of rounding where estimated figures are included in the detail.
[3] Bismuth content of refined metal and bullion plus recoverable content of concentrates exported.
[4] 1964 data.
[5] Exports.

Bolivia.—Bismuth output is predominantly from the Tasna copper-bismuth orebody managed by Corporación Minera de Bolivia. The bismuth flotation concentrate was exported for refining and accounted for over 90 percent of the Bolivian output. Expansion of mine and concentrator output was planned. Bismuth is also recovered in the smelting of certain tin ores.

Canada.—Four companies recover essentially all of the bismuth produced in Canada. The Consolidated Mining and Smelting Co. of Canada, Ltd., recovers and refines bismuth from lead-zinc ores at Trail, British Columbia. Molybdenite Corporation of Canada, Ltd., recovers bismuth from treatment of molybdenum ore; a bulk flotation concentrate containing about 8 percent bismuth is leached with hydrochloric acid, precipitated as bismuth oxychloride, and smelted to produce 98 percent bismuth metal. Gaspé Copper Mines, Ltd., also recovers an impure bismuth metal from treatment of flue dust obtained in smelting copper ores. The fourth producer, Anglo-American Molybdenite Mining Corp., initiated production in August at the newly constructed molybdenite-bismuth plant in Pressiac Township, Quebec. Total company reserves have been reported at 1.25 million tons of ore averaging 0.53 percent molybdenum and 0.02 percent bismuth. The bismuth is separated from the molybdenum-bismuth bulk concentrate by leaching and precipitation and is refined to 99.9 percent bismuth metal. Annual capacity of the plant is estimated at 300,000 pounds of bismuth.

Italy.—Bismuth in lead and zinc ores from mines of Monteponi e Montevecchio Societi per Azioni, located in Sardinia, is refined at the San Gavino Monreale (Sardinia) lead refinery with an estimated annual capacity of 50,000 pounds of bismuth. Expansion in capacity of the mines and smelter is presently underway.

Japan.—Five companies operate smelters and refineries recovering bismuth from base-metal ores of domestic and foreign origin. The estimated combined capacity of Mitsubishi Metal Mining Co., Ltd., Mitsui Mining and Smelting Co., Ltd., Nippon Mining Co., Ltd., Sumitomo Metal Mining Co., Ltd., and Toho Zinc Co., Ltd., is 825,000 pounds annually. The Kamioka and Taishu base-metal mines are the main sources of domestic bismuth.

Korea, South.—Bismuth is recovered as a byproduct of tungsten ore beneficiation by the Korea Tungsten Mining Co. at the Sangdong mine. The bismuth is refined to high purity metal at the mine plant.

Mexico.—The Monterrey, N.L., lead refinery of Metalurgica Mexicana Peñoles, S.A., produces refined bismuth metal from lead bullion and residues provided by the Torreon, Coah., smelter. The lead smelter of Compania Minera Asarco, S.A., also located in Monterrey, produces bismuth-lead bullion and high-bismuth smelter drosses which are mainly exported to the United States for refining and marketing.

Peru.—The La Oroya refinery complex of the Cerro Corp. in Peru is the world's largest source of bismuth. The bismuth derived from smelting and refining copper and lead concentrates from company and purchased Peruvian ores is refined to metal either of high-purity or of a specification multimetal-alloy for direct use. The capacity of the plant is estimated at 1.7 million pounds annually. The bismuth content of exported concentrates also provides a substantial byproduct production of bismuth at various smelters processing these concentrates.

Sweden.—The Ronnskar lead refinery of Boliden Gruvaktiebolag produces a bismuth-lead alloy derived from complex sulphide ores from company mines as well as from mines operated for the Government. Annual capacity is estimated at 90,000 pounds of bismuth.

Yugoslavia.—Production of bismuth at the Zevcan Lead Smelter & Refinery of the Trepca base-metal mining and refining complex increased as expanded mine and plant facilities provided an improved ore supply.

Other European.—Seven metal refining plants of major capacity, situated in Belgium, France, West Germany, and the United Kingdom, recover bismuth from imported base-metal ores. The largest of these is the Mining and Chemical Products, Ltd., plant with an estimated capacity of 2 million pounds annually at Alperton, Middlesex, United Kingdom.

TECHNOLOGY

Research has been directed recently toward the recovery and application of ultrahigh-purity single crystal bismuth. A promising use of this material is as a bismuth-antimony alloy in the field of magnetothermoelectrics where low temperatures are required in small space. The results of a study on the mechanical properties of single crystal bismuth were published,[2] and the basic thermodynamic data on bismuth oxide were reviewed and further analyzed.[3] U.S. patents were issued covering a method of manufacture of pure bismuth by variable volatilization and distillation,[4] and for an oxidation catalyst composition of bismuth and molybdenum oxides.[5]

The Bureau of Mines continued processing research on recovery and refining of bismuth through laboratory analysis of existing commercial techniques and exploration of a process for extraction of bismuth from lead with fused salts.

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[2] Slonaker, R. E., M. Smutz, H. Jensen, and E. H. Olson. Factors Affecting the Growth and the Mechanical and Physical Properties of Bismuth Single Chystals. J. Less-Common Metals (Amsterdam, Netherlands), v. 8, No. 5, May 1965, pp. 327–338.

[3] Levin, Ernest M., and Clyde L. McDaniel. Heats of Transformations in Bismuth Oxide by Differential Thermal Analysis. J. Research of the National Bureau of Standards. Section A. Physics and Chemistry, v. 69A, No. 3, May–June 1965, pp. 237–243.

[4] Champ, Roger (assigned to La Societe Les Produits Semi-Conducteurs, Paris, France). Manufacture of Pure Bismuth. U.S. Pat. 3,218,159, Nov. 16, 1965.

[5] Callahan, James L., Joseph J. Szabo, and Berthold Gertisser (assigned to The Standard Oil Co., Cleveland, Ohio). Bismuth-Molybdenum Oxidation Catalyst Promoted With a Ba-Si Oxide Mixture. U.S. Pat. 3,186,955, June 1, 1965.

Boron

By William C. Miller [1]

The upward trend in the production rate of boron minerals and compounds slowed somewhat. Nevertheless, expansions of production facilities for the manufacture of new and improved products continued.

The most significant development in boron use was the preparation of new forms of boron nitride. Research was conducted on boron nitride fibers and filaments for possible engineering and aerospace applications.

The first commercial shipment of Turkish colemanite was made to a U.S. glass manufacturer.

Table 1.—Salient boron minerals and compounds statistics in the United States

(Thousand short tons and thousand dollars)

	1956–60 (average)	1961	1962	1963	1964	1965
Sold or used by producers:						
Quantity:						
Gross weight	575	603	647	700	776	807
Boron oxide	288	313	339	369	405	425
Value	$40,573	$46,936	$49,336	$54,981	$60,871	$64,180
Imports for consumption:						
Quantity	[1] 1	(2)	(2)	(2)	(1 2)	[1] 6
Value	$198	$52	$51	$58	$21	$279

[1] Imports for 1956, 1957, 1964, and 1965 include a higher proportion of crude ore to refined products.
[2] Less than ½ unit.

DOMESTIC PRODUCTION

Boron minerals and compounds production (as measured by sales) increased 4 percent in quantity and 5 percent in value compared with that of 1964. Production of pentahydrate borax, boric acid, colemanite and kernite, and kernite increased; decahydrate borax and sodium tetraborate production decreased.

All of the production of boron minerals was in California. U.S. Borax & Chemical Corp. mined borax and kernite at the Boron open pit operation, colemanite at the DeBely open pit mine, and ulexite at the Gerstley underground mine. American Potash & Chemical Corp. and Stauffer Chemical Co. recovered boron minerals from the brines at Searles Lake. Kern County Land Co. mined colemanite at the Kern Borate underground mine.

Refineries and plants operated by the U.S. Borax & Chemical Corp. at Boron and Wilmington, Calif., the American Potash & Chemical Corp. at Trona, Calif., the Stauffer Chemical Co. at Westend and San Francisco, Calif., produced boron compounds and products containing boron.

U.S. Borax & Chemical Corp. announced that it will spend more than $5 million for a plant at Boron, Calif., to produce anhydrous boric acid. The company claimed that the process will substantially reduce the manufacturing cost of the product. A company official indicated that savings to the consumer may be realized because transportation costs, based on boric oxide, would be less for the anhydrous product than for boric acid which contains water.

Stauffer Chemical Co. completed the expansion of facilities initiated in 1964 to increase by 50 percent the boron capacity of its Westend plant.

[1] Commodity specialist, Division of Minerals.

CONSUMPTION AND USES

Glass, soap and cleaner, and porcelain enamel manufacturers were the major consumers of boron compounds. About 32 percent of the consumption was used in the manufacture of heat-resistant glass, glass wool, and fiberglass. Soaps and cleansers for industrial and household use consumed 16 percent of the domestic production. The addition of borax to detergents and the marketing of borax waterless hand cleaners contributed to the gain in the volume of borax used in household products. The market for sodium perborate for the production of detergents was active. Manufacturers of porcelain enamels for domestic appliances consumed 13 percent of the boron compounds. Borate products used in agriculture consumed 8 percent of the boron production. A new application for boron was to help prevent internal damage to some agricultural products. The remaining 31 percent was consumed in leather tanning, metallurgy, corrosion control, nuclear shielding, flameproofing, manufacture of adhesives and starches, and in other industrial and consumer uses.

Boron was consumed in the 396,817 short tons of alloy steel (other than stainless steel) ingots produced in 1964, compared with 348,085 tons produced in 1963.[2]

Two significant new products developed in 1965 were ultrafine boron and boron nitride in fiber form. Ultrafine boron was used in ramjet aircraft, incendiary explosives, materials technology for dispersion strengthening, and in powder metallurgy. Limited quantities of a pure fiber form of boron nitride were made available for research. The fibers were used as thermal insulation or as a chemical filtration material. Widespread applications as a useful engineering material were predicted for the fibers because the material has unique properties—chemical inertness, high-temperature and abrasion resistance, and good strength-to-density ratio.

Larger size boron nitride cylinders were developed to satisfy industrial requirements for scaled-up high-temperature plasma arc and magnethohydrodynamic devices.

PRICES

The price of most grades of borax and boric acid remained steady throughout the year. In December, the American Potash & Chemical Corp. announced a reduction of $10 per short ton in the price of technical-grade boric acid. The initial price of boron nitride fiber was $175 per pound and $75 for 4 ounces; however, the price is expected to lower as production increases. The prices quoted for borax and boric acid in the Oil, Paint and Drug Reporter were the same as quoted in 1964.

FOREIGN TRADE

Exports.—Effective January 1, 1965, the exports of all borates and their compounds except boric acid and refined sodium borates were classified under a blanket category. In 1964 the total exports of boric acid, borates, and compounds amounted to 383,100 tons and valued at $31,289,004. These quantities are not comparable with the summation of the total quantity and value of boric acid and sodium borates shown in table 2.

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[2] American Iron & Steel Institute. Annual Statistical Report. New York, 1964, p. 70.

Table 2.—U.S. exports of boric acid and sodium borates in 1965

Destination	Boric acid (H_3BO_3 content)		Sodium borates (refined)	
	Short tons	Value	Short tons	Value
North America:				
Canada	2,362	$334,380	8,319	$781,221
Costa Rica	4	558	109	8,213
Dominican Republic	15	2,064	9	1,276
Mexico	1,575	207,079	5,175	491,045
Nicaragua	11	1,752	20	4,062
Other	22	3,744	99	8,866
Total	3,989	549,577	13,731	1,294,683
South America:				
Brazil	843	110,268	1,523	153,756
Colombia	152	24,107	160	14,955
Peru	163	20,840	362	28,488
Uruguay	---------	---------	121	12,252
Venezuela	136	24,238	114	10,436
Other	16	2,029	91	6,188
Total	1,310	181,482	2,371	226,075
Europe:				
Austria	28	3,599	15	2,334
Belgium-Luxembourg	125	41,807	960	82,122
Denmark	154	45,327	144	10,391
Finland	---------	---------	917	78,962
France	48	12,982	8,701	874,160
Germany, West	3,158	372,693	4,758	438,232
Greece	12	1,504	165	16,758
Ireland	39	6,370	450	27,350
Italy	178	56,902	2,573	259,863
Netherlands	639	87,787	58,921	5,761,292
Norway	105	27,357	539	35,327
Portugal	28	3,337	738	44,596
Spain	20	4,240	11	1,152
Sweden	328	63,129	2,031	136,899
Switzerland	35	10,361	1,239	95,485
United Kingdom	356	59,960	7,462	645,066
Yugoslavia	---------	---------	644	61,936
Total	5,253	797,355	90,268	8,571,925
Asia:				
Ceylon	2	292	6	430
Hong Kong	167	20,188	2,946	250,701
India	451	66,249	4,154	274,909
Indonesia	9	1,093	211	12,310
Iran	---------	---------	242	16,774
Israel	4	926	394	35,688
Japan	6,368	769,139	22,478	1,826,553
Korea, South	38	6,864	1,444	87,911
Malaysia	220	32,020	422	30,862
Pakistan	110	15,323	767	52,219
Philippines	187	35,656	547	56,601
Taiwan	90	10,863	1,720	111,731
Thailand	91	11,328	579	49,944
Viet-Nam	10	1,581	660	50,779
Other	---------	---------	106	8,230
Total	7,747	971,522	36,676	2,865,642
Africa:				
Rhodesia and Malawi	12	1,636	124	16,478
South Africa, Republic of	240	34,996	2,051	206,038
United Arab Republic (Egypt)	22	4,061	23	2,193
Other	3	544	135	10,974
Total	277	41,237	2,333	235,683
Oceania:				
Australia	1,972	307,965	3,483	261,694
New Zealand	649	96,754	3,899	511,993
Other	4	1,207	54	7,553
Total	2,625	405,926	7,436	781,240
Grand total	21,201	2,947,099	152,815	13,975,248

Imports.—Crude calcium borate (colemanite) imports from Turkey totaled 6,283 tons valued at $201,600. This was the first significant quantity of borate ore imported for commercial consumption. Imports of boron carbide from West Germany, Canada, Sweden, and France were 13,801 pounds valued at $47,725 compared with 4,845 pounds valued at $19,375 in 1964. Boric acid imports from France and the United Kingdom amounted to 7,068 pounds valued at $1,616. Imports of boron metal from West Germany and the United Kingdom totaled 754 pounds valued at $27,635.

WORLD REVIEW

Production and exports of Turkish borates reached new record highs. Shipments included crushed colemanite sent to new customers in the United States and Japan.

India's first borax and boric acid plant started production; it has sufficient capacity to supply all of the Indian market. Trial production of boric acid as a byproduct of nitrate operations was started by a Chilean firm.

Plans for the construction of a boron plant in Bulgaria, a sodium perborate plant in West Germany, and a boric acid plant in Japan were announced.

Argentina.—Borgoquimica Argentina, a subsidiary of Borax (Holdings) Ltd., was reported planning a 2-year exploration program in efforts to locate borate deposits closer to railway transportation and shipping ports so that its products will be more competitive in countries outside the Latin American Free Trade Association. The company now mines calcium borate; however deposits of sodium borate were expected to be uncovered.[3]

Bulgaria.—The Bulgarian Texim State economic organization concluded a contract with two Polish trading organizations, Polish Foreign Trade Enterprise (CEKOP) and Polish Industrial Combine (CHEMAK), to construct a boron plant in Bulgaria. Construction of the plant, with an annual productive capacity of 10,100 tons, was scheduled for 1966–67.[4]

Chile.—Borax Consolidated Ltd. continued to be the only active producer of borax ore. The company mined 7,306 tons of crude ulexite ore which was upgraded to 3,638 tons of commercial-grade (33 percent borax oxide) ore. The 1963 production was 6,573 tons of crude ore and 3,285 tons of commercial-grade ore. The total sales in 1964 of 4,492 tons was used in local consumption. Anglo-Lautaro Nitrate Corp. started trial production of boric acid as a byproduct of its nitrate operations. Plans called for an annual output of 275 tons to be consumed locally for the production of high-boron fertilizer.[5]

China, mainland.—The discovery of four new borate minerals in the Salt Lake area of western China was claimed by Chinese geologists. The minerals were produced by the evaporation of salt water under extremely dry climatic conditions. Hungtsaoite, the name given to one of the minerals was in memory of the Chinese geologist, Chang Hung-Tsao. The other minerals were named carborite, hydrochlorborite, and trigonomagneborite.[6]

France.—French exports of sodium perborate rose to 8,851 tons, an increase of 40 percent over the exports in 1963. Italy was a minor market in 1963, but in 1964 it took nearly half of the French exports. The United States was the second main market with 11,111 tons. Exports to The Netherlands, the principal market in 1963, were reduced to 893 tons compared with 1,645 tons in 1963.[7]

Germany, West.—Elektrochemische Werke Muenchen A.-G. started construction of a plant at Munich to produce sodium perborate.

India.—India's first borax and boric acid plant, owned by Borax Morarji Ltd., was opened on February 12, 1965, at Ambernath, near Bombay. It was stated that the plant will have sufficient capacity to supply all the Indian market and the products will be sold by ICI (India) Private Ltd.[8]

[3] Bureau of Mines. Mineral Trade Notes. V. 60, No. 6, June 1965, p. 15.
[4] European Chemical News (London). Polish Borax Plant for Bulgaria. V. 8, No. 202, Nov. 26, 1965, p. 35.
[5] Bureau of Mines. Mineral Trade Notes. V. 61, No. 4, October 1965, p. 6.
[6] Mining Journal. Chinese Claim Discovery of New Borate Minerals. V. 265, No. 6786, Sept. 3, 1965, p. 167.
[7] Chemical Trade Journal & Chemical Engineer (London). More Sodium Perborate Exported. V. 157, No. 4083, Sept. 9, 1965, p. 26.
[8] Chemical Age (London). Production Starts at India's First Borax Facility. V. 93, No. 2380, Feb. 20, 1965, p. 286.

Italy.—Boric acid produced in 1964 from steam vents amounted to 352 tons compared with 567 tons (revised) in 1963. The chemical industry in 1964 consumed 60,072 tons of natural borates imported mostly from Turkey.

Japan.—A new company, Asahi Borax Co., a joint venture between Asahi Glass Co. Ltd. of Japan and Borax (Holdings) Ltd. of the United Kingdom, was established for the production of boric acid in Japan. Construction of a new plant, designed for an annual capacity of 5,300 tons, was started at Kita Kyushu City in northern Kyushu Island. Asahi Borax Co. announced that most of the production would be used by Asahi Glass Co. and that the raw material for the production of the boric acid would be imported from Borax (Holdings) Ltd.[9]

Turkey.—Production of boron minerals reached a record high of 154,322 tons compared with 141,374 (revised) tons in 1963. Two companies, Türk Boraks Madençilik and Etibank, produced about 80 percent of the minerals.

Exports of boron minerals also increased to a new high of 179,200 tons valued at \$4.5 million compared with 130,550 (revised) tons valued at \$3.3 million in 1964. Part of the increase in exports was attributed to the strong European demand for clean, crushed colemanite ores that can be added directly to fiber glass melts and to shipments to new customers in the United States and Japan. The first commercial shipment of boron minerals was made to an American glass manufacturer.

United Kingdom.—The activities of the research laboratories of Borax Consolidated at Chessington, Surrey, and of Hardman & Holden Ltd. at Miles Plating, Manchester, were combined under a United Kingdom research organization for the Borax group on January 1, 1965.

TECHNOLOGY

A Bureau of Mines project was conducted to determine the conditions under which the highest purity boron can be produced by electrolysis of a fused mixture of potassium fluoborate and boric oxide.

The electrical resistivity, the coefficient of electrical resistivity, the Hall coefficient, and the absolute thermoelectric power were determined in a Bureau of Mines investigation for nine compositions of the TiB_2-CrB_2 subsystem.[10]

Research conducted at Fansteel Metallurgical Corp., Richmond, Calif., showed that the addition of a small quantity of boron greatly improved the ductility of electron-beam-melted ingots of molybdenum. Boron was added to ingots in concentrations ranging from 10 to 500 parts per million by weight. The ingots were directly forged at temperatures of 2,200° to 2,400° F without cracking. This result was heretofore unattainable in the forging of molybdenum castings of commercial purity.[11]

Aerospace applications of boron nitride were reported. Mechanical properties that underline the advantages of the material for high-temperature applications were summarized. Changes of flexural strengths with temperatures from room temperature up to 3,630° F were discussed. Thermal expansion, moisture pickup, spalling, and electric characteristics for high-temperature applications were discussed.[12]

A translation of U.S.S.R. research on the possible applications of boron organosilicon polymers as components of heat-resistant adhesives was issued in booklet form. Adhesives based on boron organosilicon polymers produced from phenyltriethoxysilane or mixtures of this compound with methylphenyldiethoxysilane and boric acid gave the best results.[13]

By treating tetramethylammonium triborohydride-8 with polyphosphoric acid a new unstable boron hydride, B_8H_{18} was prepared. The highest hydrogen content of any known octaborane was contained in the new hydride. The discovery of the new boron hydride was significant because the knowledge of the structural principlas was extended. Clarification of the complex

[9] Chemical Age (London). Boric Acid Plant for New Borax Japanese Interest. V. 93, No. 2394, May 24, 1965, p. 833.

[10] Farrior, Gilbert M. Diborides in the Pseudobinary System TiB_2-CrB_2. Electrical Properties. BuMines Rept. of Inv. 6691, 1965, 26 pp.

[11] Light Metals and Metal Industry (London). Boron Raises Molybdenum Ductility. V. 28, No. 321, February 1965, p. 42.

[12] Fredrickson, James, and William H. Redanz. Boron Nitride for Aerospace Applications. Metal Prog., v. 87, No. 2, February 1965, pp. 97–101.

[13] Chemical Trade Journal and Chemical Engineer (London). Russian Research on Heat Resistant Adhesives. V. 156, No. 4057, Mar. 11, 1965, p. 297.

mechanism by which diborane (B_2H_6) is converted into higher boron hydrides was assisted by the experiment.[14]

Standard metallographic, thermoanalytic, and X-ray diffraction techniques were used to determine the general features of the boron-platinum system.[15]

A research program was conducted for the preparation of 1-isopropenylcarborane. The program included chemical process and parametric studies, product isolation investigations, and analytical research and development tests. A process was developed for laboratory and pilot plant preparation of the compound. Raw material and product specifications were established, and the physical properties of the compound were determined.[16]

Measurements were made to obtain low-frequency dielectric data of liquid boric oxide. The behavior of the material was found to be essentially like that of a non-polar liquid. Dielectric losses appeared to be due to impurities and increased with increasing temperature and decreasing frequency.[17]

The preparation of pure crystalline boron carbide was studied by the application of thermal decomposition of the mixture of pure boron trichloride and carbon tetrachloride in an atmosphere of hydrogen. Boron carbide crystals 3 to 4 millimeters in length and in the form of needles or plates were obtained.[18]

Physical, optical, and chemical properties, X-ray data, and the chemical composition of a new hydrous magnesium borate mineral were reported.[19]

The U.S. Air Force conducted studies to evaluate the application of boron fibers and borides as reinforcement materials for use in space aircraft. Research was conducted on dielectric materials required for high-temperature applications. Boron phosphide (in two forms, BP or $B_{13}P_2$) was evaluated for use as a semiconductor.[20]

To facilitate direct instrument viewing of a nuclear propulsion engine, a lead-boron carbide composite was used for a collimator. The boron carbide suppressed the production of hard gamma rays which resulted from neutron capture in the lead. Neutron capture in the boron carbide was more than 99 percent.[21]

Boron nitride was used for a heat shield around the combustion chamber in an aircraft's auxiliary power unit. An insert fitted inside the injector dome of the unit and a flame deflector lip were made of boron nitride.[22]

Comparisons between the specific strength, specific modulus, stiffness, and temperature-strength relationship of boron and other aeronautical construction materials were reported. The uses of the superior physical properties of boron filament and composites for industrial and civilian applications were presented.[23]

Important process variables in the production of high-purity, fine particle elemental boron were studied. The thermal decomposition of diborane in a high-temperature nitrogen stream was used in a laboratory scale unit to prepare elemental boron.[24]

Construction was started on a $600,000 vapor-deposition pilot plant at Wilmington, Mass., for the production of boron filaments by Avco Corp. The plant was designed to have four production lines and two development lines; however, the exact conditions and the equipment design were classified. Techniques to improve the over-

[14] Chemical & Engineering News. New Boron Hydride Synthesized. V. 43, No. 15, Apr. 12, 1965, pp. 46–47.

[15] Wald, F., and A. J. Rosenberg. Constitutional Investigations in the Boron-Platinum System. Trans. AIME, v. 233, 1965, pp. 796–799.

[16] Fein, Marvin M., and John E. Paustian. Carboranes. Process Development and Scale-Up of 1-Isopropenylcarborane. Ind. and Eng. Chem., Process Design and Development, v. 4, No. 12, April 1965, pp. 129–133.

[17] Stern, Kurt H. Low-Frequency Dielectric Properties of Liquid Boric Oxide. NBS J. Res., v. 69A (Phys. and Chem.), No. 3, May–June 1965, pp. 281–285.

[18] Mierejewska, S., and T. Niemyski. Preparation of Crystalline Boron Carbide by Vapour Phase Reaction. J. Less-Common Metals (Amsterdam, Netherlands), v. 8, No. 6, June 1965, pp. 368–374.

[19] Schaller, Waldemar T., Angelina C. Vlisidis, and Mary E. Mrose. Macallisterite, $2MgO \cdot 6B_2O_3 \cdot 15H_2O$, A New Hydrous Magnesium Borate Mineral from the Death Valley Region, Inyo County, California. Am. Miner., v. 50, Nos. 5 and 6, May–June 1965, pp. 629–640.

[20] Untersee, Phillip A., and Paul Remirez. Air Force Zeros in on Space-Age Materials. Chem. Week, v. 97, No. 8, Aug. 8, 1965, pp. 82–83, 92.

[21] Materials in Design Engineering. Lead Composite Shields Radiation in Nuclear Engine Program. V. 62, No. 3, September 1965, pp. 150, 152, 154.

[22] Materials In Design Engineering. Boron Nitride Resists Heat in Turbine Combustion Chamber. V. 62, No. 3, September 1965, pp. 23, 25.

[23] Mullen, James W. Realizing the Potentials of Boron Whiskers. Research/Development, v. 16, No. 9, September 1965, pp. 38–41.

[24] Cherenko, J. P. High Purity, Fine Particle Elemental Boron. Technical Rept. AFAPL-TR-65-88, Wright-Patterson Air Force Base Defense Documentation Center, AD 469442, September 1965, 50 pp.

all process through the testing of automation approaches, additives, and other research approaches were incorporated in the development lines. The production units were designed so that a constant effort can be made to optimize cost and production consistent with acceptable boron filaments.[25]

Narmco Research and Development Division of Whittaker Corp., Los Angeles, Calif., was awarded contracts of over a half million dollars for research with boron fibers by the U.S. Air Force Materials Laboratory of Wright-Patterson Air Force Base. The contracts covered the advancement of material development on boron fiber prepegs, fiber finishes, and high-modulus, high-strength composites.

A procedure used and apparatus developed for a laboratory process for making boron carbide whiskers was described. Critical problems encountered in the growing of whiskers were noted.[26]

The use of boron filaments in organic matrices was investigated in the initial component development programs sponsored by the U.S. Air Force. The primary purpose of these programs was to define the most urgent engineering problems of composite materials.[27]

A method was described for the synthesis of dichloroborane, $BHCl_2$, in quantitative yields by the thermal hydrogenation of boron trichloride. Investigations were conducted to determine the reaction conditions for hydrogenation of boron trichloride, the rate of the back reaction, and the disproportionate of dichloroborane. Thermodynamic data were calculated. A diagram of the apparatus used in the experiments was shown.[28]

A technique that permits rigid control of the properties of an expanded form of hydrated sodium tetraborate was developed by the American Potash & Chemical Corp. The company claimed that because of the high-void volume, the product has a high absorbance for liquid and solid organics. Plans were announced for a pilot plant to supply development quantities of the compound to producers of detergents, laundry rinses, and industrial hand soaps.[29]

A structural material was developed from a combination of boron filament and epoxy resins. United Aircraft Corp. claims that the material has twice the stiffness of steel but is lighter than either glass fiber or aluminum. A rocket case was fabricated from the material as part of a study to determine the aerospace potential of the boron-epoxy blend.[30]

Certain binary boron-metal systems were investigated by the usual X-ray analysis, optical metallography, and thermal analysis. The procedure and apparatus used for reacting liquid boron with molten metals were described. The results support the findings of previous investigations of the formation of borides and the tendency of binary systems to form miscibility gaps in the liquid state.[31]

A patent was issued for a method of bonding steel components together using borosilicate glasses. A ceramic composition containing approximately 57 parts of B_2O_3 was fused to the components. Heat and pressure were applied to bond the components together to form a structure that withstood temperature changes of several hundred degrees.[32]

A method for improvement in the manufacture of boron nitride was patented. A substantially pure crystalline boron nitride was obtained.[33]

A patent was issued for a method of growing large composite cubic boron nitride crystals. The composite cubic boron nitride crystal consisted essentially of at least one after-grown layer of cubic boron nitride that was distinguishable from, completely enveloped by, and securely bonded

[25] Judge, John F. Avco Building Boron Filament Plant. Missiles and Rockets, v. 17, No. 20, Nov. 15, 1965, pp. 22–23, 27.

[26] Chemistry. Boron Carbide Whiskers. V. 38, No. 11, November 1965 p. 26.

[27] Stone, Irving. Boron Research Focusing on Components. Aviation Week and Space Technol., v. 28, No. 25, Dec. 20, 1965, pp. 49, 51.

[28] Murib, Jawad H., David Horvitz, and Charles A. Bonecutter. Hydrogenation of Boron Trichloride to Dichloroborane. Ind. and Eng. Chem., Product Res. and Development, v. 4, No. 4, December 1965, pp. 273–280.

[29] Chemical & Engineering News. An Expanded Form of Hydrated Sodium Tetraborate Has Been Developed. V. 43, No. 50, Dec. 13, 1965, p. 45.

[30] Steel. Boron, Resin Provide Strong Rocket Case. V. 157, No. 25, Dec. 20, 1965, p. 80.

[31] Wald, Fritz, and Richard W. Stormont. Investigations on the Constitution of Certain Binary Boron-Metal Systems. J. Less-Common Metals (Amsterdam, Netherlands), v. 9, No. 6, December 1965, pp. 423–433.

[32] Bayer, Joseph, and William A. Patterson (assigned to Aeronca Manufacturing Corp., Middletown, Ohio). Method of Bonding Metals Using Borosilicate Glasses. U.S. Pat. 3,175,937, Mar. 30, 1965.

[33] Wood, Anthony, Arthur Robinson, and Eric Campbell Shears (assigned to United States Borax & Chemical Corp.). Method of Manufacturing Boron Nitride. U.S. Pat. 3,189,412, June 15, 1965.

to a core of cubic boron nitride crystal.[34]

A patent was granted for a method of producing a rigid, porous, fire-retardant fiberboard. An excess of finely divided particles of a composition of boron oxide was added to combustible vegetable fibers.[35]

A herbicidal composition that contained a predominate proportion of borate was patented. The composition was nonpacking in spreaders, dustless, and free-flowing.[36]

A crystalline structure of boron nitride that was substantially equal in hardness to a diamond was developed by a patented method. Hexagonal boron nitride was converted, in the absence of a catalyst, to a new structure.[37]

A patent was issued for a cyclic process for the manufacture of boric acid. An aqueous alkali metal borate solution was used in the process.[38]

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[34] Wentrof, Robert H., Jr. (assigned to General Electric Co.). Growth of Large Cubic Form of Boron Nitride Crystals. U.S. Pat. 3,192,015, June 29, 1965.

[35] Videen, Otis R. (assigned to Wood Conversion Co., St. Paul, Minn.). Method of Forming a Fiberboard Containing a Fire-Retardant Hydrated Borate and Product Thereof. U.S. Pat. 3,202,570, Aug. 24, 1965.

[36] Luvisi, George W., and Thomas C. Nohejl. (assigned to Nalco Co.). Herbicidal Compositions and Method for the Manufacture Thereof. U.S. Pat. 3,203,780, Aug. 31, 1965.

[37] Bundy, Francis P. (assigned to General Electric Co.). Method for Converting Hexagonal Boron Nitride to a New Structure. U.S. Pat. 3,212,852, Oct. 19, 1965.

[38] Brown, Michael Peter, and William Jeffers (assigned to United States Borax & Chemical Corp.). Manufacture of Boric Acid. U.S. Pat. 3,216,795, Nov. 9, 1965.

Bromine

By William C. Miller [1]

New plant facilities were put into production to meet the increased demand for bromine and bromine products. The shortage in the supply of bromine in the United Kingdom and Continental Europe increased. New record levels in the production and sales of bromine and bromine compounds were reached in the United States.

DOMESTIC PRODUCTION

Bromine production rose 15 percent as sales of elemental bromine, potassium sodium and ammonium bromide, and ethylene dibromide increased. The gain in total sales of bromine and bromine compounds was attributed chiefly to new uses of bromine in fire retardant compounds for textiles and plastics and to the increased use of ethylene dibromide.

Table 1.—Sales of bromine and bromine compounds by primary producers in the United States

(Thousand pounds and thousand dollars)

Year	Quantity		Value
	Gross weight	Bromine content	
1956–60 (average)	220,755	187,118	$47,661
1961	212,497	180,798	44,517
1962	223,972	190,747	46,617
1963	238,583	203,333	48,558
1964 r	283,530	238,019	66,064
1965	328,115	274,569	77,259

r Revised.

Bromine was extracted from sea water, sea-water bittern, natural brines, and oil-field brines. The Ethyl-Dow Chemical Co. recovered bromine from sea water at Freeport, Tex., and the FMC Corp. from sea-water bittern at Newark, Calif. Plants of The Dow Chemical Co. at Midland and Ludington, Mich., Great Lakes Chemical Corp. at Filer City, Mich., Michigan Chemical Corp. at St. Louis and Manistee, Mich., and Morton International, Inc., at Manistee, Mich., recovered bromine from natural well brines. Arkansas Chemicals, Inc., Michigan Chemical Corp., and Great Lakes Chemical Corp. extracted bromine from oil well brines near El Dorado, Ark.

In June, the new plant near El Dorado, Ark., of the Great Lakes Chemical Corp. started production of bromine and bromine compounds. The facilities at the plant included units for the production of ethylene dibromide and methyl bromide.

The exclusive license to the U.S. patents for the production of sodium bromite was acquired by the Olin Mathieson Chemical Corp. from the Sté. d'Etudes Chimiques pour l'Industrie et l'Agriculture.

Production and sales by the Ethyl-Dow Chemical Co. of ethylene dibromide reached record levels. Equipment changes and modifications completed in 1965 improved process operations and economics at its Freeport, Tex., plant.

CONSUMPTION AND USES

The manufacture of ethylene dibromide consumed the largest portion of the bromine production. A component of gasoline antiknock fluids and fumigates for grain and soils were the principle outlets for this compound.

Elemental bromine was second in the consumption of bromine. It was used for sanitizers, bleaching and disinfecting agents, laboratory reagents, and organic

[1] Commodity specialist, Division of Minerals.

Table 2.—Bromine and bromine compounds sold by primary producers in the United States

(Thousand pounds and thousand dollars)

Product	Quantity: Gross weight	Quantity: Bromine content	Value
1964:			
Elemental bromine r	30,435	30,435	$5,096
Ethyl bromide	955	823	383
Methyl bromide	14,381	12,553	6,524
Other, including ethylene dibromide, sodium bromide, ammonium bromide, and potassium bromide	237,759	194,208	r 54,061
Total r	283,530	238,019	66,064
1965:			
Elemental bromine	35,118	35,118	7,477
Ethyl bromide	794	681	322
Methyl bromide	10,992	9,577	4,931
Other, including ethylene dibromide, sodium bromide, ammonium bromide, and potassium bromide	281,211	229,193	64,529
Total	328,115	274,569	77,259

r Revised.

and inorganic compounds. Applications for high-purity bromine continued to increase.

Methyl bromide the next largest consumer of bromine was used primarily for soil and grain fumigates, pesticides and flame-proofing compounds. New fumigate products were added to the markets.

The alkali bromides, sodium, potassium, and ammonium bromide, showed increases in the consumption of bromine. They were used in the preparation of pharmaceutical sedatives and photographic plates, films, and emulsions, and as process and laboratory reagents.

Production of sodium bromate was increased to satisfy the demand for the use of the compound in cosmetics, bleaching flour, and steam boiler compounds.

An inorganic textile desizing compounds, sodium bromite, was placed on the U.S. market. Other new products include fire control compounds and vinyl bromide for use as an oven cleaner. Although the number of new products placed on the market were not as numerous as in past years, new applications for products being produced were increased.

PRICES

Prices for bromine and bromine compounds remained steady and were virtually the same as in 1964. The following prices were quoted by the Oil, Paint and Drug Reporter:

	Cents per pound
Bromine, purified:	
Cases, carlots, ton lots, delivered east of Rocky Mountains	33
Drums, carlots, ton lots, delivered east of Rocky Mountains	29
Tanks, carlots, same basis	21.5
Ammonium bromide, National Formulary (N.F.) granular, drums, carlots, ton lots, freight equalized	44
Bromochloromethane:	
Drums, carlots, freight equalized	48
Tanks, same basis	47
Ethylene dibromide:	
Drums, carlots, freight equalized	30.5
Tanks, freight equalized	28.5
Potassium bromate, 200-pound drums, carlots, freight allowed	49
Potassium bromide, U.S.P., granular, barrels, keys	40
Sodium bromide, U.S.P., granular, barrels, drums, works	40

FOREIGN TRADE

The only transactions involving bromine and bromine compounds reported under the existing tariff schedules (TSUS) were the importation of 2,200 pounds of potassium bromide valued at $618 from Israel and of 25,397 pounds of sodium bromide valued at $5,462 from France. No transactions were reported for bromine and ethylene dibromide. All other classes of bromine compounds are part of a blanket category and are no longer classified separately.

Effective January 1, 1965, exports of bromine, bromides, and bromates were no longer separately classified.

WORLD REVIEW

The short supply of elemental bromine in the United Kingdom and in Continental Europe became more acute at the beginning of 1965. The increase in the production of ethylene dibromide for use as a gasoline additive was the major reason for the shortage of elemental bromine.

EUROPE

France.—Société Octel-Kuhlmann announced that new facilities would be constructed to double the present capacity of about 6,600 tons a year for the production of ethylene dibromide. Most of the production from the company's plant at Port-de-Bouc, close to Levéra in southern France, was used captively. The company hoped that an increase in the consumption of ethylene dibromide at its own plants and a substantial rise in export sales would result from the completion of the new facilities in late 1965 or early 1966.[2]

Germany, Federal Republic of.—The short supply of bromine became more acute after mid-1965. Production of elemental bromine in 1964 was 2,465 tons valued at $1.2 million.

Rumania.—Geologic work was undertaken to identify oil field brines that may contain sufficient bromine for commercial extraction.

United Kingdom.—The increased captive demand by the sole producer of bromine in the United Kingdom for the production of ethylene dibromide reduced the quantity of elemental bromine the company sold on the open market. A secondary reason for the shortage of bromine was a reduction of imports from France. No import duty was levied on bromine as it was classified as a vital raw material. In May, an increase of $14 raised the price of bromine to $700 a ton.

ASIA

Israel.—Because of the current heavy demand by United Kingdom customers for bromine and bromine compounds, Dead Sea Bromine Ltd. announced that the production capacity of its bromine plant at Sedom would be increased from 9,900 to 14,300 tons a year. The company contemplated that upon completion of these facilities, its ethylene dibromide unit would work at full capacity of 6,600 tons. The research department of the company was particularly active in the development and production of new bromine compounds. Investigations of facilities for the bulk shipment of liquid bromine were continued.

Bromine Compounds Ltd., an affiliated company of Dead Sea Bromine Ltd. that produces organic and inorganic bromides, put into operation a plant that has a capacity of 265 tons a year for the production of sodium bromate.

TECHNOLOGY

The Institute for Fibers and Forest Products Research of the Israel Ministry of Commerce and Industry, Jerusalem, Israel, developed and patented a new process for making wood highly fire resistant. Claims were made that the process reduced the cost of fireproofing by $10 to $15 per ton of wood and produced better results than existing methods.[3]

A process for absorbing bromine from an aqueous acidic chlorine brine was patented. The process was an improvement

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[2] European Chemical News (London). Octel-Kuhlmann Doubles Dibromide Capacity. V. 7, No. 170, Apr. 16, 1965, p. 24.

[3] European Chemical News (London). Wood Fire-Proofing with Bromine. V. 7, No. 155, Jan. 1, 1965, p. 29.

over other processes because the adsorption was effected in the presence of excess chlorine.[4]

The procedure used in and the results of laboratory studies of the solvent effects of certain bromine compounds were reported. Solvent effects of previous studies were reported and compared.[5]

A satisfactory reagent for the reduction of perfluoroaryl bromides was found to be zinc powder and acetate acid. High yields were achieved for the reduction of some compounds, and the reagent proved useful for the preparation of other compounds.[6]

A patent was issued for a process to recover bromine by the catalytic oxidation of bromide ion in an acid medium. Free bromine formed by the oxidation of the bromide ion was separated from the reaction media.[7]

An extraction process using three steps was patented for the recovery of elemental bromine from an aqueous brine solution. The first step was the preparation of an effluent consisting essentially of chlorine, unreacted hydrogen chloride, and other inert gases. The second step was the mixing of the effluent with the brine solution to liberate elemental bromine. The third step was the stripping out and recovery of elemental bromine.[8]

The development section of a brochure describing research and development products included a discussion of bromine with terpens.[9]

Bromination reactions on enol derivatives of 3-oxo-5α-steroids of the androstane and cholestane series were investigated. When enol ethers or enol esters were used the results of the reactions differed.[10]

An investigation was conducted to establish the stoichiometry for the reaction of bromine with phenols and to demonstrate the rapid and quantitative nature of the reaction of bromine and enols. Procedures and results of the investigation were reported.[11]

A process was patented that improved the production of an aqueous bromine solution from aqueous bromide-bromate salts and mineral acid. The five-step process produced a substantial yield.[12]

A lead lined bulk storage unit for bromine, the first in the United Kingdom, was installed at the Kirkby, Liverpool, plant of Pure Chemicals Ltd. The storage tanks enabled the delivery of bromine to the plant from road tankers instead of in small bottles.[13]

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[4] Hein, Rowland Frank (assigned to E. I. du Pont de Nemours & Co., Inc., Wilmington, Del.). Sorption of Bromine on Anion Exchange Resins in the Presence of Excess Chlorine. U.S. Pat. 3,174,828, Mar. 23, 1965.

[5] Fuller, G., and D. A. Warwick. Solvent Effects Tetrahydrofuran in the Reaction of Pentafluorophenylmagnesium Bromide With Ethylene Oxide. Chem. and Ind. (London), No. 15, Apr. 10, 1965, p. 651.

[6] Tilney-Bassett, J. F. Use of Zinc Powder and Acetic Acid for Reduction of Perfluoroaryl Bromides. Chem. and Ind. (London), No. 16, Apr. 17, 1965, pp. 693–694.

[7] Harding, William A., and Saul Gerald Hindin (assigned one-half to Air Products and Chemicals, Inc., Philadelphia, Pa., and one-half to Northern Natural Gas Company, Omaha, Nebr.). Recovery of Bromine by the Nitrite Catalytic Oxidation of Bromide Ion in an Acid Medium. U.S. Pat. 3,179,498, Apr. 20, 1965.

[8] Davis, Wayne T. (assigned to Ethyl Corp., New York). Process for Recovery of Elemental Bromine from an Aqueous Bromine Solution. U.S. Pat. 3,181,934, May 4, 1965.

[9] Chemical Age (London). Fine Chemicals from Revai. V. 93, No. 2392, May 15, 1965, p. 778.

[10] Di Gioacchino, D., M. Giorgi, and A. Romeo. The Bromination of Enol Derivatives of 3-keto Steroids by means of N-Bromosuccinimide. Chem. and Ind. (London), No. 38, Sept. 18, 1965, p. 1633.

[11] Lockwood, K. L. Stoichiome try of the Reaction of Bromine with Phenols. J. Chem. Education, v. 42, No. 9, September 1965, p. 482.

[12] Belohlav, Leo Rudolf, and James Robert Underhill (assigned to Great Lakes Corp., West Lafayette, Ind.). Bromination Process. U.S. Pat. 3,222,276, Dec. 7, 1965.

[13] Chemical Trade Journal and Chemical Engineer (London) Bulk Storage and Handling of Bromide, v. 157, Nos. 4098 and 4099, Dec. 23, 1965, p. 749.

Cadmium

By Harold J. Schroeder [1]

The domestic cadmium industry in 1965 experienced lower production, a large increase in imports, and an increase in apparent consumption. Total new supply was in excess of consumption, and industrial stocks increased by 60 percent to the highest yearend level since 1959.

LEGISLATION AND GOVERNMENT PROGRAMS

No sales of cadmium were made against the 5 million pounds of Government stockpiled cadmium authorized for disposal by legislation enacted in 1964, and all but the 23,400 pounds disposed of in 1964 remained available for sale. Increasing availability of cadmium through commercial channels since passage of the legislation and undesirability of shapes in the stockpile have been the principal reasons for the lack of sales of Government stockpiled cadmium.

Government stockpiles remained unchanged at 15.1 million pounds, of which 7.7 million was in the strategic stockpile and 7.4 million in the supplemental stockpile. The stockpile objective was 5.1 million pounds.

Table 1.—Salient cadmium statistics

(Thousand pounds)

	1956–60 (average)	1961	1962	1963	1964	1965
United States:						
Production [1]	10,005	10,466	11,137	9,990	10,458	9,671
Shipments by producers [2]	10,350	10,222	12,057	10,124	9,689	8,128
Value ....thousands..	$13,595	$14,218	$18,481	$21,880	$27,412	$19,153
Imports for consumption, metal	1,657	1,079	1,117	991	1,104	2,121
Exports	1,181	702	717	1,313	1,439	73
Consumption	9,738	10,184	12,146	11,482	r 9,364	10,431
Price: Average [3] ......per pound..	$1.56	$1.68	$1.72	$2.26	$3.00	$2.58
World: Production	21,900	25,700	26,300	26,800	28,900	27,800

r Revised.
[1] Primary and secondary cadmium metal. Includes equivalent metal content of cadmium sponge used directly in production of compounds.
[2] Includes metal consumed at producer plants.
[3] Average quoted price for cadmium sticks and bars in lots of 1 to 5 tons.

DOMESTIC PRODUCTION

Production of cadmium metal from primary and secondary sources was the smallest quantity since 1959.

About 14 percent of the metal output was derived from imported cadmium flue dust. Except for a relatively small quantity recovered from scrap, the balance was obtained from processing domestic and imported zinc and other base metal concentrates, with the foreign source estimated to be the largest item. The main sources of imported zinc concentrates were Mexico, Canada, and Peru. Secondary cadmium was recovered mainly from scrap alloys.

Production of cadmium sulfide, cadmium lithopone, and cadmium sulfoselenide totaled 1.6 million pounds of contained cadmium, a record quantity. Two

[1] Commodity specialist, Division of Minerals.

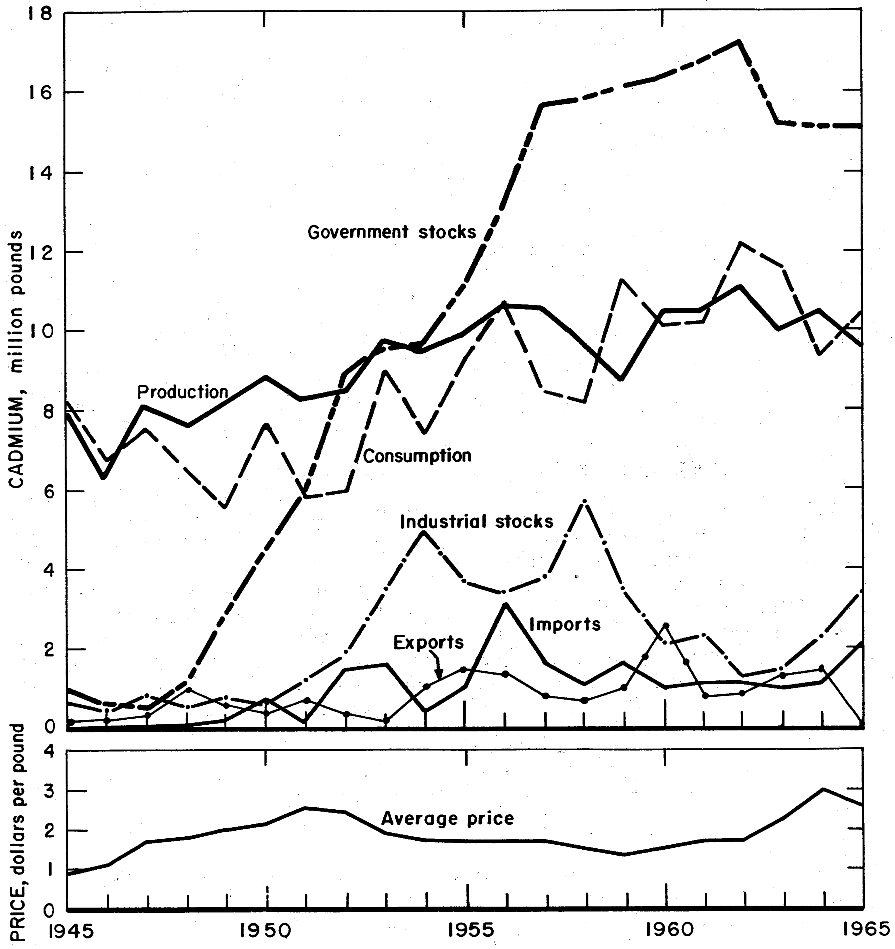

Figure 1.—Trends in production, consumption, yearend stocks, imports, exports, and average price of cadmium metal in the United States.

firms continued production of cadmium oxide. Cadmium compounds are prepared from the metal or from intermediate compounds.

The list of plants producing cadmium metal, published in the Cadmium chapter of the 1964 Minerals Yearbook, was unchanged except for the Sherwin-Williams Co. plant which did not operate during 1965.

Table 2.—Cadmium oxide and cadmium sulfide produced in the United States
(Thousand pounds)

Year	Oxide		Sulfide [1]	
	Gross weight	Cadmium content	Gross weight	Cadmium content
1956–60 (average)	W	W	3,341	1,122
1961	1,229	1,075	3,355	1,115
1962	1,694	1,481	4,250	1,329
1963	W	W	4,560	1,542
1964	W	W	4,514	1,531
1965	W	W	4,666	1,575

W Withheld to avoid disclosing individual company confidential data.
[1] Includes cadmium lithopone and cadmium sulfoselenide.

CONSUMPTION AND USES

Plating continued to be the largest use for cadmium, and was estimated to have consumed 55 to 60 percent of the total. Applications for cadmium plating include parts for automobiles, household appliances, aircraft, industrial machines, radio and television sets, electrical and electronic equipment, hardware fittings, instruments, and numerous fastening items such as nuts, bolts, and screws.

Other principal uses of cadmium were as the sulfide, sulfoselenide, and lithopones for industrial color pigments, the stearate for vinyl plastics, the nitrate for nickel-cadmium batteries, phosphors for television tubes, and the metal for solders, low-melting point fusible alloys, and other alloys.

STOCKS

Stocks of cadmium metal at producers, compound manufacturers, and distributors increased to the highest yearend level since 1959.

Table 3.—Industry stocks, December 31
(Thousand pounds)

	1964		1965	
	Cadmium metal	Cadmium in compounds	Cadmium metal	Cadmium in compounds
Metal producers	1,523	W	3,066	W
Compound manufacturers	311	r 609	177	598
Distributors	r 327	81	206	37
Total	r 2,161	r 690	3,449	635

r Revised.
W Withheld to avoid disclosing individual company confidential data; included with 'Compound manufacturers."

PRICES

Cadmium on the London market was quoted at the beginning of the year at 22s. per pound ($3.07). Price quotations changed on March 5 to 18s. ($2.52) and on July 23 to 16s. ($2.24).

In Italy the quoted price was 3,800 lire ($2.76) at the beginning of the year; it declined in increments to 3,400 lire ($2.47) by yearend.

The French quotation for metal was 28 francs ($2.59) at the start of the year; it declined to 27 francs ($2.50) in April and to 23.50 francs ($2.17) in October.

Table 4.—Prices quoted for cadmium in the United States in 1965
(Per pound)

Date	Producer to consumer: 1-ton lots	Producer to consumer: Less than 1-ton lots	Distributor to consumer
January 1	$3.00	$3.05	$2.90–$3.15
March 2	2.65–3.00	2.70–3.05	2.65– 3.00
March 8	2.65	2.70	2.65– 2.75
June 17	2.40–2.65	2.45–2.70	2.40– 2.75
June 23	2.40	2.45	2.40– 2.50
August 2 to Dec. 31	2.40	2.45	2.40– 2.45

FOREIGN TRADE

Imports.—General imports of cadmium metal nearly doubled to 2.1 million pounds, a record high. Imports of cadmium in flue dust, all from Mexico, increased to the

Table 5.—U.S. imports of cadmium metal and cadmium in flue dust, by countries
(Thousand pounds and thousand dollars)

Country	General imports [1]				Imports for consumption [2]			
	1964		1965		1964		1965	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
CADMIUM METAL								
North America:								
Canada	428	$1,084	615	$1,129	428	$1,084	615	$1,129
Mexico	96	293	12	37	94	286	12	37
Total	524	1,377	627	1,166	522	1,370	627	1,166
South America:								
Argentina	2	6	----	----	3	8	3	6
Peru	152	342	337	865	152	342	337	865
Total	154	348	337	865	155	350	340	871
Europe:								
Belgium-Luxembourg	78	204	60	153	78	204	60	153
France	----	----	9	18	----	----	9	18
Germany, West	----	----	46	114	----	----	46	114
Italy	----	----	22	52	----	----	22	52
Netherlands	4	11	56	138	4	11	56	138
Poland-Danzig	----	----	7	29	----	----	7	29
United Kingdom	----	----	79	150	----	----	79	151
U.S.S.R.	----	----	53	103	----	----	53	103
Total	82	215	332	757	82	215	332	758
Africa:								
Angola (Portuguese)	----	----	35	75	----	----	35	75
Congo (Leopoldville)	223	591	287	681	218	575	287	681
Mozambique	----	----	8	17	----	----	8	17
Total	223	591	330	773	218	575	330	773
Asia: Japan	102	288	264	540	86	247	288	609
Oceania: Australia	44	122	204	492	41	113	204	492
Total cadmium metal	1,129	2,941	2,094	4,593	1,104	2,870	2,121	4,669
FLUE DUST (CADMIUM CONTENT)								
North America: Mexico	1,272	$1,543	1,531	$1,521	1,272	$1,543	1,531	$1,521
Europe: Belgium-Luxembourg	(3)	2	----	----	(3)	2	----	----
Total flue dust	1,272	1,545	1,531	1,521	1,272	1,545	1,531	1,521
Grand total	2,401	4,486	3,625	6,114	2,376	4,415	3,652	6,190

[1] Comprises cadmium imported for immediate consumption plus material entering bonded warehouses.
[2] Comprises cadmium imported for immediate consumption plus material withdrawn from bonded warehouses.
[3] Less than ½ unit.

Table 6.—U.S. exports of cadmium metal and cadmium in alloys, dross, flue dust, residues, and scrap

(Thousand pounds and thousand dollars)

Year	Quantity	Value
1956–60 (average)	1,181	$1,560
1961	702	983
1962	717	1,139
1963	1,313	3,070
1964	1,439	4,033
1965 [1]	73	195

[1] Not strictly comparable to preceding years.

largest quantity since 1961.

Exports.—Exports of cadmium as metal, dross, flue dust, residues, and scrap declined to a record low of 73,000 pounds.

Tariff.—The import duty on cadmium metal remained at 3.75 cents per pound in 1965—the rate effective January 1, 1948, as established at the Geneva Trade Conference in 1947. Cadmium contained in flue dust remained duty free.

WORLD REVIEW

World production of cadmium metal decreased 4 percent to 27.8 million tons. Five countries—United States, U.S.S.R., Canada, Japan, and the Congo (Léopoldville)—accounted for about 74 percent of total production.

Mexico.—A zinc reduction plant at Saltillo, Coahuila, built for Zincamex, S.A., a company formed by the Mexican Government, began operating in late 1964. Facilities included a cadmium recovery unit operated in conjunction with the refinery.

United Kingdom.—"The World Non-Ferrous Metal Statistics" published by the British Bureau of Non-Ferrous Metal Statistics reports production of 485,000 pounds and imports of 3.2 million pounds of cadmium for the United Kingdom during 1965. Cadmium consumption was 2.8 million pounds and was used for the following purposes (in thousand pounds): Plating anodes, 851; plating salts, 253; cadmium-copper alloys, 114; other alloys, 101; batteries, 262; solder, 185; colors, 914; and miscellaneous, 165.

Table 7.—World production of cadmium metal by countries [1] [2]

(Thousand pounds)

Country	1961	1962	1963	1964	1965 p
North America:					
Canada (all forms)	r 2,222	2,605	2,475	r 2,773	3,009
Honduras	10	r 31	r 192	r 231	194
Mexico (exports)	104	63	326	r 260	3 260
United States	10,466	11,137	9,990	10,458	9,671
South America: Peru (refined metal)	232	235	382	r 435	e 475
Europe:					
Austria	42	49	41	r 43	3 43
Belgium (exports)	1,988	1,854	1,943	r 1,858	e 830
France	560	567	r 655	r 849	882
Germany:					
East e	-----	7	11	22	3 22
West	952	560	492	705	723
Italy	r 767	r 536	r 622	r 597	3 597
Netherlands e	88	88	88	88	88
Norway	231	254	243	r 254	e 187
Poland e	880	880	930	930	930
Spain	76	133	119	r e 119	e 119
U.S.S.R. e	3,300	3,500	3,700	3,900	4,200
United Kingdom	217	237	r 247	r 435	485
Yugoslavia e	88	88	88	90	90
Africa:					
Congo (Léopoldville)	1,173	677	871	r 1,038	3 1,038
Zambia	42	37	33	r 32	e 44
Asia: Japan	1,596	1,948	2,231	r 2,678	3 2,678
Oceania: Australia	697	791	1,089	r 1,107	e 1,197
World total	25,700	26,300	26,800	28,900	27,800

e Estimate. p Preliminary. r Revised.

[1] Data derived in part from bulletins of the World Non-Ferrous Metal Statistics (London) and annual issues of Metal Statistics (Metallgesellschaft).

[2] Data do not add exactly to totals shown because of rounding where estimated figures are included in the detail. No estimate included for Bulgaria, but it is reported to be producing cadmium.

[3] 1964 data.

TECHNOLOGY

A patent was granted on a method of imparting a black surface on cadmium by means of immersion in a bath containing chromium and silver ions and phosphate and sulfate radicals.[2]

Patents were granted on a cadmium sulfide pigment incorporating zinc and selenium in the crystal lattice [3] and on a complex basic cadmium compound.[4] Other patents provide for growth of cadmium oxide single crystals by sublimation [5] and use of cadmium sulfate in making a heat-sensitive reproduction material.[6]

The behavior of individual positive and negative electrodes of the sintered-plate nickel-cadmium battery system in the presence of foreign ions has been investigated.[7]

Several papers were published regarding research on the photoconductivity properties of cadmium-containing compounds.[8] Patents were granted on the use of cadmium in semiconductor devices.[9]

Reports on research related to atomic energy described the plutonium-cadmium phase equilibria system.[10] Basic research was reported on strain patterns surrounding cadmium-gold phase precipitates in cadmium sulfide crystals.[11] Heat of formation of the anhydrous sulfate of cadmium was determined.[12]

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[12] Adami, L. H., and E. G. King. Heats of Formation of Anhydrous Sulfates of Cadmium, Cobalt, Copper, Nickel, and Zinc. BuMines Inf. Circ. 6617, 1965, 10 pp.

Calcium and Calcium Compounds

By Ronald C. Briggs [1]

Calcium metal was produced in two plants in North America—one in Canaan, Conn., and one in Haley, Ontario, Canada. Various forms of calcium chloride and calcium-magnesium chloride were produced by 11 companies in the United States. Continuing the trend of recent years, domestic production of all forms of calcium chloride reached a record high. The greatest use of calcium chloride continued to be for deicing highways.

DOMESTIC PRODUCTION

Nelco Metals, Inc., a division of Chas. Pfizer & Co., Inc., continued as the only domestic producer of calcium metal in 1965. Calcium was produced by the alumino-thermal reduction of calcium oxide in vacuum retorts at its Canaan, Conn., plant. The quantity of calcium produced in 1965 was reported to be about the same as in 1964.

Calcium chloride and calcium-magnesium chloride were important calcium compounds in both quantity and value for 1965. The demand for these compounds continued to increase, chiefly because of the quantity required for construction and maintenance of the expanding network of highways. Production reached a record high, continuing the trend of recent years.

In 1965, 11 companies reported production of some form of calcium chloride or calcium-magnesium chloride. The companies producing synthetic calcium chloride, recovered as a byproduct of the ammonia-soda process, were Solvay Process Division of Allied Chemical Corp., Syracuse, N.Y.; Pittsburgh Plate Glass Co., Barberton, Ohio; and Wyandotte Chemicals Corp., Wyandotte, Mich. Natural calcium chloride, including natural calcium-magnesium chloride, was produced in nine plants operated by the remaining eight companies. Hill Bros. Chemical Co., Leslie Salt Co., and National Chloride Co. of America, were the only California producers, and obtained their material from Bristol Dry Lake near Amboy. Natural brines from under-ground saline formations provided the raw materials for producers in Michigan and West Virginia. The sole West Virginia producer was Inorganic Chemical Division of FMC Corp. Michigan producers included The Dow Chemical Co. with two plants, Michigan Chemical Corp., Morton Chemical Co., and Wilkinson Chemical Corp.

Total domestic production in 1965 was 790,000 short tons of both natural and synthetic solid and solid flake forms, calculated as 75-percent chloride equivalent. Production of calcium chloride and calcium-magnesium chloride brines (about 40 percent chloride), excluding those used to produce granular forms, totaled 325,000 tons. Most of the reported granular and brine production was natural calcium chloride and calcium-magnesium chloride. Michigan continued as the leading producing State.

Production of all forms of natural calcium and calcium-magnesium chlorides, calculated as 75-percent chloride equivalent, averaged 494,000 tons annually for the years 1961–65. The annual average value was $9.8 million ($19.84 per ton) for the same 5-year period.

Shipments of natural and synthetic solid and flake calcium chloride (73 to 80 percent $CaCl_2$) in 1964 were 700,000 tons, valued at $21 million ($30 per ton) f.o.b. plant. Brine (40 to 45 percent $CaCl_2$) shipments for the same year were 278,000 tons, valued at $3 million ($11 per ton). Corresponding 1964 production totals were

[1] Commodity specialist, Division of Minerals.

722,000 tons and 296,000 tons, respectively.[2]

U.S. Calcite Co. reported production of optical-grade calcite from a deposit near Convict Lake, Calif. The quantity produced was greater than that reported in 1964, but the value was substantially lower.

CONSUMPTION AND USES

Metallic calcium was used as a deoxidizer, a sulfide former, and a scavenger to clean melts. Various other applications for this highly reactive metal ranged from refractory metals reductant to alloying agent and gas absorbent in chemical processing. It was also used in the production of calcium pantothenate and numerous organo-metallic compounds.

Highway deicing continued as the principal use of calcium chloride. Other major uses included dust control, concrete treatment, tire weighting, brine refrigeration, and a variety of industrial uses.

One of the new developments in the calcium chloride industry was shipment and application of the material in bulk. Bulk calcium chloride was either applied directly to roads or stored for ready application for dustlaying or winter maintenance. Construction of facilities for storing calcium chloride continued to be important. Although practical production capacity for both natural and synthetic material exceeds demand, the salt is usually in short supply during periods of heavy snowfall or of cold weather.

The use of calcium chloride solution for tire weighting continued to grow steadily. Farmers and heavy equipment manufacturers and operators have long known that liquid ballast in tires gives more maneuverability, greater pulling power, and better treadwear. The use of liquid ballast dates back to about 1930 when pneumatic tires were first used on farm tractors. Calcium chloride is a suitable tire-weighting material. It is about 30 percent heavier than plain water, is freezeproof to minus 59° F, is relatively inexpensive, easily available, and not harmful to tires or valve stems.[3]

PRICES AND SPECIFICATIONS

Reportedly, prices and specifications for calcium metal have remained the same as those quoted in the 1963 and 1964 Minerals Yearbooks.

Most calcium chloride prices did not change in 1965. Powdered calcium chloride, 77 percent minimum $CaCl_2$ (paper bags, carlots, at works, freight equalized), was $40 per ton. Solid calcium chloride, 73 to 75 percent $CaCl_2$ (carlots, freight equalized), was $32.50 per ton. Calcium chloride liquor or brine, about 40 percent $CaCl_2$, a supersaturated solution shipped in heated tank cars (tank cars, freight equalized), was $14 per ton. Concentrated flake or pellet chloride, 94 to 97 percent $CaCl_2$ (paper bags, carlots, at works, freight equalized), was $41.70 to $43 per ton. Regular flake calcium chloride, 77 to 80 percent $CaCl_2$ (paper bags, carlots, at works, freight equalized), was $34 to $35 per ton.[4]

FOREIGN TRADE

All imports of calcium metal were from Canada. Countries supplying calcium chloride imports for consumption were Canada, 48 percent; Belgium-Luxembourg, 37 percent; West Germany, 11 percent; and United Kingdom, 4 percent.

Other calcium compounds imported during 1965 included 12.6 million pounds of crude calcium borate from Turkey; 20.9 million pounds of calcium carbide from Canada (99.8 percent), and the Canal Zone (0.2 percent); and 35.8 million pounds of calcium cyanide from Canada.

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[2] U.S. Department of Commerce, Bureau of the Census, Industry Division. Inorganic Chemicals and Gases, 1964, Current Ind. Rept. Ser. M28A (64)–13, Jan. 28, 1966, p. 11.

[3] Calcium Chloride Institute News. Report on Liquid Tire-Weighting. V. 15, No. 1. First Quarter 1965, p. 10.

[4] Oil, Paint and Drug Reporter. V. 187, Nos. 1–26; v. 188, Nos. 1–26; Jan. 4-Dec. 27, 1965.

Table 1.—U.S. imports for consumption of calcium, and calcium chloride and exports of calcium chloride

Year	Imports				Exports	
	Calcium		Calcium chloride		Calcium chloride	
	Pounds	Value	Short tons	Value	Short tons	Value
1956–60 (average)	13,666	$19,277	1,681	$62,221	36,968	$1,290,945
1961	17,266	22,892	3,022	102,680	22,047	1,090,583
1962	43,962	51,669	1,896	59,753	43,830	1,686,819
1963	26,343	31,648	2,234	67,225	36,984	1,527,243
1964	42,439	42,238	2,718	91,933	39,893	1,513,479
1965	28,219	27,616	3,658	99,751	(1)	(1)

[1] Beginning Jan. 1, 1965 no longer separately classified.

WORLD REVIEW

Canada.—Production of calcium in 1965 was estimated at 123,487 pounds, valued at Can$123,391. Compared with 1964 figures, quantity and value were 11 percent and 19 percent less, respectively. Dominion Magnesium Ltd. in Ontario was the only Canadian producer of calcium.[5]

Commercial shipments of calcium metal in 1964 were consigned mainly to export markets, as Canadian demand continued to be low. World demand was also low, but an increase in consumption is likely as more diversified uses are developed and widely adopted. Canadian calcium exports in 1964 totaled 210,800 pounds, valued at Can$137,681. Countries receiving these exports were the United States, 64 percent; Belgium-Luxembourg, West Germany, and India, 7 percent each; Netherlands, 6 percent; Great Britain, 5 percent; Japan, 3 percent; and other countries, less than 1 percent.[6]

India.—Travancore Electro-Chemical Industries applied to the Indian Government for permission to double its present calcium carbide capacity to 24,000 tons per year. The company is currently producing at well below its capacity at about 7,000 tons per year, because of an inadequate power supply. It hopes that this fault will be corrected soon.[7]

TECHNOLOGY

A process for producing calcium by the thermal dissociation of commercial calcium carbide was described in a newly issued patent. The process comprises heating a charge consisting of a lower bed of calcium carbide, which contains calcium oxide and an upper layer of carbon particles having a large surface area. A temperature range of 1,500° to 1,800° C is maintained. Initially the pressure is held above the equilibrium pressure of the calcium carbide dissociation reaction, but below the equilibrium pressure for the reaction of calcium carbide with calcium oxide. After a sufficient time period with the charge temperature held within the required range, the pressure is reduced allowing the dissociation of calcium carbide. Calcium metal is recovered from the process by condensing that which evaporates.[8]

Another patent granted was for a method of making graphite free calcium cyanamide. This process involves reacting urea and calcium oxide in a molar ratio of about 3:1 in a closed kettle at about 300° C. The reaction products are a solid and gaseous ammonia. Crushing the solid and reheating in a kiln to about 700° C results in the formation of calcium cyanamide and carbon dioxide.[9]

Recent developments involving improvements in the operations and techniques for the use of continuous self-baking electrodes in a 20,000-kva electric furnace for making

[5] Canadian Mining Journal. The Canadian Mineral Industry in 1965 and Its Position in Provincial Economies, 1950–1964. V. 87, No. 2, February 1966, pp. 82–83.

[6] Jackson, W. H. Calcium 1964. Canada Dept. Mines and Tech. Surveys, Min. Res. Div., Ottawa, March 1965, 5 pp.

[7] European Chemical News (London). V. 8, No. 197, Oct. 22, 1965, p. 24.

[8] Kaess, Franz, and O. A. Heinrich Rock (assigned to Suddeutsche Kalkstickstoff-Werke Aktiengesellschaft, Trostberg, West Germany). Production of Calcium Metal. U.S. Pat. 3,208,845, Sept. 28, 1965.

[9] Picard, Jean P., and Marcel Blais (assigned to the U.S. Army). Synthesis of Calcium Cyanamide. U.S. Pat. 3,173,755, Mar. 16, 1965.

calcium carbide were reported. Following current trends, these developments have been fostered by the need for a better self-baking electrode at a lower cost. Many other technological changes in furnace practice have taken place at this plant since it was built in 1954.[10]

Noteworthy analytical procedures developed included methods for determining the calcium content of sea water and for determining water content of solid materials by reaction with calcium carbide. The concentration of dissolved calcium in sea water is of particular interest since it is the prime participant in calcium carbonate formation by shell-forming marine organisms and by inorganic precipitation. Calcium concentration bears directly on the question of the solubility of calcium carbonate in sea water, and on the factors that control precipitation and solution. The analysis of a solution containing magnesium, calcium, and strontium, however, has traditionally posed a problem, particularly where a high degree of accuracy and precision is required. The new experiment described employs radiotracer, ion exchange, complexometric titration, and spectrophotometric techniques for the determination of calcium in sea water.[11]

Reliable estimates of water content are important to users of a large group of organic materials such as leather, paper, and grains whose properties are greatly influenced by water content. Usually the moisture content is arbitrarily defined as the weight loss on drying under specified conditions. To establish the drying conditions, moisture determinations by independent methods are needed. The specificity and speed of the reaction of calcium carbide with water to give acetylene make it an ideal basis for an analytical method. An improved calcium carbide method is examined as a way around some of the difficulties in eliminating variability of previous methods.[12]

New products developed during 1965 added to the growing list of calcium compounds and alloys available. A New York based company expanded its line of synthetic sweetners for sale through supermarket and drug chains. The new product is made by a recently patented process for producing calcium cyclamate tablets without the use of liquids or heat. Separate mixtures of sodium bicarbonate and calcium cyclamate and tartaric acid, insoluble saccharin, and polyethylene glycol are prepared under controlled conditions then combined, granulated, and pressed into tablets. These tablets are said to effervesce rapidly and completely, even in iced drinks or beverages, without leaving any residue.[13]

Another new product was described in a newly granted patent. The subject of the patent was a feed additive containing rennet and calcium chloride in the ratio of 1:5. This growth accelerating additive is combined with animal feed, principally composed of proteins and carbohydrates, in the amount of 0.05 to 0.2 percent by weight.[14]

An English firm developed a new process for the production of calcium silicate-type insulation. Calcium silicate thermal insulation is a material of increasing importance for service in the medium-to-high temperature range. The manufacturing process does not involve steam induration in autoclaves which represents a considerable saving in the capital cost of the plant required. The process is basically a reaction in boiling water between selected siliceous material and lime in the presence of aluminum ions. This process can employ as raw materials synthetic silicas or silicates, as well as selected siliceous materials of natural origin available in many parts of the world.[15]

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[10] Scherrer, R. E., and M. L. Stott. Recent Developments in Soderberg Electrode Practice in Carbide Operation. J. Metals, v. 17, No. 2, February 1965, pp. 193–196.

[11] Corless, James T. Determination of Calcium in Sea Water, Analytical Experiment Using the Radionculide Ca^{45}. J. Chem. Education, v. 42, No. 8, August 1965, pp. 421–423.

[12] Dahl, Sverre. Determining Moisture in Solid Materials by Reaction with Calcium Carbide. Mat. Res. and Standards, v. 5, No. 9, September 1965, pp. 446–453.

[13] Chemical and Engineering News. Forest Expands Cyclamate Tablet Sweetener Line. V. 43, No. 13, Mar. 29, 1965, pp. 45, 47.

[14] Schoner, Stefan (assigned to Aktiengesellschaft Fuu, Schaan, Liechtenstein, a corporation of Leichtenstein, Munich, West Germany). Feed Additive Containing Rennet and Calcium Chloride. U.S. Pat. 3,222,179, Dec. 7, 1965.

[15] Chemistry and Industry (London). Calcium Silicate Insulation. No. 29, July 17, 1965, p. 1303.

Cement

By Paul L. Allsman[1]

For the third consecutive year, record production and shipments of cement were reported in 1965. As a result of the growth of the national economy and new construction, domestic production of cement was 2 percent greater than in 1964.

Portland cement plant capacity at yearend was reported to be 482.4 million 376-pound barrels, compared with 479.6 million barrels at the end of 1964. Despite the increased capacity operating levels increased to 76.8 percent, compared with 76.5 percent in 1964 and 73.4 percent in 1963. The declining price trend of recent years was continued with average 1965 mill values reported at $3.18 per barrel, compared with $3.22 in 1964. Continued intense competition among building products and materials has largely precluded general price increases. The greater efficiency inherent in larger plants and automation as plants are modernized and enlarged has enabled producers to meet price competition from other building products.

[1] Commodity specialist, Division of Minerals.

Table 1.—Salient cement statistics

	1956–60 (average)	1961	1962	1963	1964	1965
United States:						
Production [1] thousand 376-pound barrels	327,622	332,558	345,567	361,235	377,475	381,578
Capacity used at portland cement mills [1] ...percent	79.7	73.1	71.5	73.4	76.5	76.8
Shipments from mills [1] thousand 376-pound barrels	321,234	329,443	340,770	358,024	375,340	384,402
Value [1] [2] ...thousands	$1,044,682	$1,105,537	$1,129,387	$1,156,890	$1,209,470	$1,221,454
Average value [1] ...per barrel	$3.25	$3.36	$3.31	$3.23	$3.22	$3.18
Stocks Dec. 31: At mills [1] thousand 376-pound barrels	29,784	36,415	39,003	[r] 39,496	[r] 39,761	35,248
Exports ...do	883	286	380	460	713	748
Imports for consumption do	4,329	3,621	5,633	4,030	3,633	5,505
Consumption, apparent [3] do	324,680	332,778	346,023	361,594	378,260	389,159
World: Production	1,593,340	1,956,384	2,102,236	2,216,180	2,434,019	2,544,723

[e] Estimate. [r] Revised.
[1] Excludes Puerto Rico.
[2] Value received f.o.b. mill, excluding cost of containers.
[3] Quantity shipped plus imports minus exports.

Legislation and Government Programs.—The Federal Trade Commission (FTC) continued to investigate acquisitions by producers of cement, ready-mixed concrete, and concrete products companies. The FTC will also probe the causes underlying such acquisitions and the probable effects of such acquisitions on competitive conditions of the markets and industries involved.

Lone Star Cement Corp. agreed to divest itself of 25 of the 31 concrete plants obtained through acquisition of Pioneer Sand & Gravel Co. of Seattle and Southern Materials Co. of Norfolk. The FTC told Mississippi River Fuel Corp. to divest itself of three ready-mixed concrete firms acquired recently. Kaiser Cement & Gypsum Corp. agree to dispose of Olympic Portland Cement Co., and two ready-mixed concrete operations, Pacific Building Materials Co. and Ready-Mix Concrete Co.

United States Steel Corp. denied charges by the FTC that its acquisition of Certified Industries, Inc., Hicksville, Long Island, N.Y., violates the Federal antimerger law. The FTC ruled that the acquisition of Bessemer Limestone & Cement Co. by Diamond Alkali Co. was illegal.

Two clauses in the recent Appalachian Regional Development Act were opposed by trade groups. The law encourages the use of portland cement in place of asphalt, and the use of coal tar as a binder instead of petroleum asphalt, to stimulate use of materials indigenous to the Appalachian region. A bill to tighten U.S. antidumping laws for the relief of the steel and cement industries was introduced into Congress. Action was not expected before 1966.

The Colorado Supreme Court upheld the change in Boulder County zoning regulations to permit construction of a cement plant near Lyons, for Rocky Mountain Cement Co., a division of Martin Marietta Corp.

PORTLAND CEMENT

PRODUCTION AND SHIPMENTS

Three new plants announced the beginning of commercial production. These were the River Cement Co. at Selma, Mo., G. & W. H. Corson Inc. at Plymouth Meeting, Pa., and Capitol Cement Division of Capitol Aggregates Inc. at San Antonio, Tex.

Plants under construction included a $20 million plant at Lyons, Colo., Martin Marietta Corp. (Rocky Mountain Cement Co.); a plant at Catskill, N.Y., by Marquette Cement Manufacturing Co.; and a $20 million plant at Charlevoix, Mich., scheduled by Medusa Portland Cement Co., for completion in mid-1967. Lone Star Cement Corp. was building a new $20 million plant at Greencastle, Ind. Dundee Cement Co. planned completion of a $55 million, 7-million-barrel plant at Clarksville, Mo., in 1967. Gifford-Hill Portland Cement Co. was to start building a 1-million-barrel plant at Midlothian, Tex.

Plans were announced for 10 new production plants. Louisville Cement Co. decided on a $20 million, 2.5-million-barrel plant at Roanoke, Va. Ideal Cement Co. announced its largest plant, a 6-million-barrel, $40 million plant at Redwood City, Calif. Lone Star Cement Corp. decided to replace existing plants at Concrete and Seattle, Wash., with a 4-million-barrel plant at Anacortes, Wash. Ideal Cement Co. planned a $20 million, 2.5-million-barrel plant on Duwamish Waterway, Seattle, Wash. Pacific Western Industries Inc., announced a $21 million, 3-million-barrel plant in Lebec, Calif., for completion in 1966. Martin Marietta Corp. announced a new $30 million plant, to employ 125 workers, at Milan, Mich. Santee Portland Cement Co. announced a 2-million-barrel, $10 million plant at Holly Hill, S.C., to be completed in 1966. Better Roads, Inc., announced a 1-million-barrel plant at Artesia, Miss. Rochester Portland Cement Corp. decided to locate its new $11 million plant on the Lake Ontario side of Stoney Point, N.Y. Kaiser Cement & Gypsum Corp. proposed a new plant on Duwamish Waterway, Seattle, Wash.

Thirteen major plant expansions or modernizations were either underway or due to begin shortly in 1965: Arkansas Cement Co., Foreman, Ark.; Bessemer Cement Co., Division of Diamond Alkali Co., Bessemer, Pa.; Kaiser Cement & Gypsum Corp., Montana City, Mont.; Alpha Portland Cement Co., Orange, Tex.; Puerto Rican Cement Co., Inc., Ponce, Puerto Rico; National Gypsum Co., (Huron Portland Cement Co.), Alpena, Mich.; Marquette Cement Manufacturing Co., Catskill, N.Y.; Mississippi Valley Portland Cement Co., Redwood, Miss.; Northwestern States Portland Cement Co., Mason City, Iowa; Southwestern Portland Cement Co., Victorville, Calif.; Riverside Cement Co., Riverside, Calif.; Century Cement Manufacturing Co., Rosendale, N.Y.; Capitol Cement Co. (Division of Martin Marietta Corp.), Martinsburg, W.Va.

Lehigh Portland Cement Co. announced the closure of its Bunnell, Fla., plant. Production will be concentrated in the firm's Miami, Fla., plant. Penn-Dixie Cement Corp. announced shutdown of its Buffalo, N.Y., plant. Production will be concentrated in their Howes Cave, N.Y., plant. Alpha Portland Cement Co. closed their plant at Martins Creek, Pa., and Peninsular Portland Cement Division of General Portland Cement Co. discontinued production at their Cement City, Mich., plant. Both plants were converted to use as terminals.

Research is becoming an important part of the cement industry, as indicated by the fact that three companies announced plans for new research centers. The $1.5 million site of American Cement Corp., next to the Crestmore plant of its Riverside Division east of Los Angeles, will be completed in 1966.

Medusa Portland Cement Co. began development of a unique underground technical research center at Wampum, Pa. Completion of the $250,000 center was expected by early 1966. Alpha Portland Cement Co. completed research and testing facilities at an 8,000-square-foot complex at Martins Creek, Pa., for its eight cement plants.

The trend continued toward larger plants and increased automation to achieve greater production efficiencies and reduced costs. A new mill installed in the Foreman, Ark., plant of Arkansas Cement Corp. is 13 by 46 feet. The Dundee Cement Co. at Clarksville, Mo., has ordered the world's largest cement kiln and grinding mills. The kiln is 760 feet long, and one 15- by

Table 2.—Finished portland cement produced, shipped, and in stock in the United States,[1] by districts

District	Active plants		Production (thousand 376-pound barrels)		Shipments from mills						Stocks at mills Dec. 31 (thousand 376-pound barrels)	
					1964			1965				
					Thousand 376-pound barrels	Value		Thousand 376-pound barrels	Value			
	1964	1965	1964	1965		Total (thousands)	Average per barrel		Total (thousands)	Average per barrel	1964 [2]	1965
New York, Maine	13	13	27,869	29,622	28,155	$86,607	$3.08	30,410	$82,219	$2.70	3,785	2,939
Eastern Pennsylvania	16	16	29,014	29,262	28,861	84,526	2.93	29,765	83,890	2.82	3,815	3,156
Western Pennsylvania	5	5	8,949	10,078	8,802	28,883	3.28	10,388	33,035	3.18	1,921	1,454
Maryland, West Virginia	4	4	10,686	10,401	10,384	32,198	3.10	10,561	32,776	3.10	1,105	945
Ohio	10	9	15,606	14,599	15,553	50,647	3.26	14,786	47,499	3.21	1,787	1,600
Michigan	9	8	26,802	27,018	26,745	84,316	3.15	27,565	86,996	3.16	2,737	2,190
Indiana, Kentucky, Wisconsin	8	8	20,704	20,374	19,696	64,114	3.26	20,088	65,445	3.26	2,474	1,890
Illinois	4	4	9,978	9,235	9,790	32,191	3.29	9,358	30,622	3.27	1,470	1,238
Tennessee	6	6	8,471	8,829	8,343	26,791	3.21	8,724	27,535	3.16	737	832
Virginia, North Carolina, South Carolina	5	5	10,672	11,876	10,666	32,428	3.04	11,944	35,980	3.01	1,060	992
Georgia, Florida	7	7	12,028	11,497	12,090	39,165	3.24	12,044	39,550	3.28	1,074	526
Alabama	8	8	13,059	14,089	12,870	40,108	3.12	13,765	42,604	3.10	1,025	910
Louisiana, Mississippi	6	6	9,049	9,022	9,025	28,365	3.14	9,258	29,695	3.21	982	746
Minnesota, South Dakota, Nebraska	4	4	7,730	6,951	7,649	26,516	3.47	7,021	23,922	3.41	1,278	1,208
Iowa	5	5	13,651	13,575	13,607	46,398	3.41	13,643	46,273	3.39	1,409	1,340
Missouri	5	6	12,399	13,975	12,378	42,618	3.44	13,334	46,034	3.45	1,374	2,015
Kansas	6	6	8,335	8,877	8,483	25,959	3.06	8,801	26,972	3.06	1,350	1,427
Oklahoma, Arkansas	6	5	11,408	12,098	11,765	34,641	2.94	12,397	35,319	2.85	1,110	778
Texas	17	18	29,792	30,771	30,030	94,492	3.15	30,820	97,598	3.17	2,816	2,747
Wyoming, Montana, Idaho	4	4	3,659	3,601	3,601	12,568	3.49	3,476	12,038	3.46	562	675
Colorado, Arizona, Utah, New Mexico	7	7	12,838	11,822	12,745	43,242	3.39	11,809	39,824	3.37	1,016	1,029
Washington [3]	---	6	---	6,080	---	---	---	6,258	22,351	3.57	---	758
Oregon, Washington	9	---	8,244	---	8,219	29,525	3.59	---	---	---	1,147	---
Oregon, Nevada [3]	---	4	---	3,745	---	---	---	3,671	13,122	3.57	---	285
Northern California	6	6	18,999	19,402	18,418	59,834	3.25	19,619	63,804	3.25	1,727	1,511
Southern California	7	7	28,982	25,770	28,786	90,099	3.13	25,733	81,048	3.15	1,707	1,744
Hawaii	2	2	1,798	1,584	1,717	8,877	5.17	1,564	8,297	5.30	217	237
Puerto Rico	2	2	7,911	7,269	7,926	23,879	3.01	7,284	23,415	3.21	164	149
Total	181	181	368,633	371,422	[4] 366,304	1,168,987	3.19	[4] 374,086	1,177,863	3.15	39,849	35,321

[1] Includes Puerto Rico.
[2] Incorporates some revisions.
[3] Newly created districts: Oregon combined with Washington, 1964; Oregon combined with Nevada, 1965.
[4] Does not include finished cement used in manufacturing prepared masonry cement as follows: 1964, 2,621,000 barrels; 1965, 1,864,000.

Table 3.[1]—Portland cement produced and shipped in the United States, by types

Type and year	Active plants	Production (thousand 376-pound barrels)	Shipments: Thousand 376-pound barrels	Shipments: Value: Total (thousands)	Shipments: Value: Average per barrel
General use and moderate heat (types I and II):					
1956–60 (average)	167	294,827	289,205	$920,388	$3.18
1961	174	[2] 302,107	298,616	980,371	3.28
1962	177	[2] 313,888	309,784	1,004,793	3.24
1963	180	[2] 329,929	326,918	1,032,809	3.15
1964	181	[2] 347,954	346,052	1,090,712	3.15
1965	181	[2] 348,665	352,431	1,095,639	3.11
High-early-strength (type III):					
1956–60 (average)	119	13,111	12,817	47,248	3.69
1961	135	[3] 13,530	14,305	53,000	3.71
1962	141	[3] 14,958	14,597	53,576	3.67
1963	145	[3] 14,592	14,559	51,167	3.51
1964	144	[3] 12,873	12,530	44,124	3.52
1965	153	[3] 13,388	12,757	44,621	3.50
Low-heat (type IV):					
1956–60 (average)	2	12	7	28	3.94
1961	2	18	14	60	4.23
1962	2	---	9	37	4.45
1963	3	---	---	---	---
1964	1	(4)	(4)	(4)	---
1965	---	---	---	---	---
Sulfate-resisting (type V):					
1956–60 (average)	10	232	220	840	3.80
1961	13	931	416	1,608	3.87
1962	11	236	244	1,048	4.29
1963	18	349	324	1,267	3.91
1964	16	446	398	1,443	3.63
1965	19	512	425	1,648	3.88
Oil-well:					
1956–60 (average)	15	1,298	1,297	4,475	3.45
1961	14	1,015	1,235	4,181	3.39
1962	13	1,281	1,215	4,140	3.41
1963	15	1,239	1,158	3,878	3.35
1964	12	1,347	1,306	4,329	3.31
1965	13	1,645	1,613	5,571	3.45
White:					
1956–60 (average)	4	1,333	1,259	8,143	6.46
1961	5	[5] 1,647	1,532	10,387	6.78
1962	5	[5] 1,726	1,668	11,690	7.01
1963	5	[5] 2,050	1,935	13,547	7.00
1964	5	[5] 2,139	2,111	14,821	7.02
1965	5	[5] 2,241	2,128	14,517	6.82
Portland-slag and portland pozzolan:					
1956–60 (average)	10	4,707	4,672	15,348	3.28
1961	8	[6] 3,586	3,316	11,179	3.37
1962	7	[6] 2,848	2,868	9,524	3.32
1963	8	[6] 2,470	2,620	8,681	3.31
1964	10	[6] 1,047	1,057	3,656	3.46
1965	6	[6] 967	913	2,878	3.15
Miscellaneous: [7]					
1956–60 (average)	23	1,367	1,160	4,364	3.76
1961	19	[5] 1,280	1,317	4,992	3.79
1962	19	[5] 1,551	1,438	5,581	3.88
1963	23	[5] 1,914	1,739	6,625	3.81
1964	22	[5] 2,827	2,850	9,902	3.47
1965	34	[5] 4,004	3,819	12,989	3.40
Grand total:					
1956–60 (average)	168	316,887	310,638	1,000,834	3.22
1961	[8] 175	324,114	320,751	1,065,778	3.32
1962	[8] 178	336,488	331,823	1,090,389	3.29
1963	[8] 181	352,543	349,253	1,117,974	3.20
1964	[8] 181	368,633	366,304	1,168,987	3.19
1965	[8] 181	371,422	374,086	1,177,863	3.15

[1] Includes Puerto Rico.
[2] Includes air-entrained portland cement as follows (in thousand 376-pound barrels): 1961, 36,373; 1962, 38,096; 1963, 40,649; 1964, 43,950; 1965, 46,118.
[3] Includes air-entrained portland cement as follows (in thousand 376-pound barrels): 1961, 4,140; 1962, 5,078; 1963, 4,879; 1964, 2,754; 1965, 2,677.
[4] Less than ½ unit.
[5] Includes a small amount of air-entrained portland cement.
[6] Includes air-entrained portland cement as follows (in thousand 376-pound barrels): 1961, 1,996; 1962, 1,617; 1963, 1,369; 1964, 343; 1965, none.
[7] Includes hydroplastic, plastic, and waterproofed cements.
[8] Includes number of plants making air-entrained portland cement as follows: 1961, 120; 1962, 121; 1963, 121; 1964, 130; 1965, 132.

54-foot slurry mill and two 15- by 49-foot cement mills are being manufactured.[2]

Descriptions were published of equipment and operations at a number of modern plants.[3] The number of portland cement plants in the United States (including Puerto Rico) in 1965, by size group was—

Estimated annual capacity Dec. 31, million barrels	*Number of plants*	*percent of total capacity*
Less than 1	8	1.3
1 to 2	57	17.4
2 to 3	56	28.0
3 to 4	36	24.5
4 to 5	13	11.3
5 and over	11	17.5
Total	181	100.0

TRANSPORTATION

New cement distribution and service centers were completed by Dundee Cement Co. at Youngstown, Ohio, and Rock Island, Ill; Ideal Cement Co. at Port of Palm Beach, Fla., and Lyons, Colo; Marquette Cement Manufacturing Co., at Bloomington, Minn.; Atlantic Cement Co. in Syracuse, N.Y.; Universal Atlas Cement Co. in Bettendorf, Iowa; and Calaveras Cement Co. at Sparks, Nev.

[2] Pit and Quarry. Dundee's New Missouri Plant to Have 760-ft. Long Kiln. V. 57, No. 9, March 1965, p. 25.

[3] Bergstrom, J. H. Columbia Cement Completes Zanesville Modernization. Rock Products, v. 68, No. 8, August 1965, pp. 50–58.

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Utley, H. F. Riverside's Expansion at Crestmore (American Cement Co.) Pit and Quarry, v. 58, No. 1, July 1965, pp. —130–138, 143.

Table 4.—Portland-cement-manufacturing capacity of the United States,[1] by districts

District	Capacity Dec. 31 (thousand 376-pound barrels)		Percent utilized	
	1964	1965	1964	1965
New York, Maine	39,776	39,776	70.1	74.5
Eastern Pennsylvania	40,186	38,736	72.2	75.5
Western Pennsylvania	12,208	12,208	73.3	82.6
Maryland, West Virginia	11,880	11,880	89.9	87.6
Ohio	22,400	19,700	69.7	74.1
Michigan	32,654	34,500	82.1	78.3
Indiana, Kentucky, Wisconsin	25,327	26,300	81.7	77.5
Illinois	11.950	11,400	83.5	81.0
Tennessee	10,194	10,559	83.1	83.6
Virginia, North Carolina, South Carolina	14,110	14,910	75.6	79.7
Georgia, Florida	20,427	20,493	58.9	56.1
Alabama	16,140	15,993	80.9	88.1
Louisiana, Mississippi	11,275	11,600	80.3	77.8
Minnesota, South Dakota, Nebraska	9,117	9,100	84.8	76.4
Iowa	15,630	15,100	87.3	89.9
Missouri	16,043	18,803	77.3	74.3
Kansas	13,106	12,822	63.6	69.2
Oklahoma, Arkansas	15,184	14,359	75.1	84.3
Texas	43,160	43,574	69.0	70.6
Wyoming, Montana, Idaho	5,100	5,100	71.7	70.6
Colorado, Arizona, Utah, New Mexico	15,750	15,800	81.5	74.8
Washington [2]	---	6,975	---	87.2
Oregon, Washington	10,750	---	76.7	---
Oregon, Nevada [2]	---	4,900	---	76.4
Northern California	21,150	21,150	89.8	91.7
Southern California	35,400	36,000	81.9	71.6
Hawaii	2,700	2,700	66.6	58.7
Puerto Rico	8,001	8,001	98.9	90.9
Total	479,618	482,439	76.9	77.0

[1] Includes Puerto Rico.
[2] Newly created districts: Oregon combined with Washington, 1964; Oregon combined with Nevada, 1965.

Table 5.—Capacity of portland cement plants in the United States,[1] by processes

Process	Capacity, Dec. 31: Thousand 376-pound barrels 1963	1964	1965	Capacity, Dec. 31: Percent of total 1963	1964	1965	Percent of capacity utilized 1963	1964	1965	Percent of total finished cement produced 1963	1964	1965
Wet	284,601	294,767	291,276	59.6	61.5	60.4	74.0	75.7	77.0	59.8	60.5	60.4
Dry	192,984	184,851	191,163	40.4	38.5	39.6	73.5	78.7	77.0	40.2	39.5	39.6
Total	477,585	479,618	482,439	100.0	100.0	100.0	73.8	76.9	77.0	100.0	100.0	100.0

[1] Includes Puerto Rico.

Table 6.—Portland cement clinker produced and in stock at mills in the United States,[1] by process

Clinker	Number of plants 1964	1965	Thousand 376-pound barrels: Production 1964	1965	Stocks on Dec. 31— 1964	1965
Wet	110	112	218,141	223,198	r 9,151	8,171
Dry	71	69	154,029	152,004	r 9,458	10,345
Total	181	181	372,170	375,202	18,609	18,516

r Revised.
[1] Includes Puerto Rico.

Table 7.—Production and percentage of total output of portland cement in the United States,[1] by raw materials used

(Quantities in thousand 376-pound barrels)

Year	Cement rock and pure limestone: Quantity	Percent	Limestone and clay or shale [2] [3]: Quantity	Percent	Blast-furnace slag and limestone: Quantity	Percent
1956-60 (average)	75,000	23.7	222,829	70.3	19,058	6.0
1961	70,824	21.9	230,376	71.1	22,914	7.0
1962	75,042	22.3	238,160	70.7	23,286	7.0
1963	85,741	24.3	251,068	71.2	15,734	4.5
1964	85,884	23.3	260,376	70.6	22,373	6.1
1965	84,360	22.7	266,148	71.7	20,914	5.6

[1] Includes Puerto Rico.
[2] Includes output of 4 plants using marl and clay in 1956-60 (average); 3 plants in 1961; 1 plant in 1963; 1 plant using marl only in 1963; 2 plants in 1962 and 1964; and 2 plants in 1965.
[3] Includes output of 9 plants using oystershells and clay in 1956-60 (average); 9 plants in 1961; 10 plants in 1962; 11 plants in 1963; 12 plants in 1964; and 11 plants in 1965.

Table 8.—Raw materials used in producing portland cement in the United States[1]

(Thousand short tons)

Raw materials	1963	1964	1965
Cement rock	17,354	18,853	19,879
Limestone (including oystershell)	77,663	80,759	81,943
Marl	452	391	611
Clay and shale [2]	10,650	11,593	11,397
Blast-furnace slag	1,040	950	935
Gypsum	2,929	3,299	3,274
Sand and sandstone (including silica and quartz)	1,811	1,376	1,834
Iron materials [3]	572	617	755
Miscellaneous [4]	200	84	125
Total	112,671	117,922	120,753

[1] Includes Puerto Rico.
[2] Includes fuller's earth, diaspore, and kaolin.
[3] Includes iron ore, pyrite cinders and ore, and mill scale.
[4] Includes flourspar, pumicite, calcium chloride, soda ash, borax, staurolite, air-entraining compounds, and grinding aids.

Table 9.—Finished portland cement produced and fuel consumed by the portland-cement industry in the United States,[1] by processes

Year and process	Finished cement produced			Fuel consumed		
	Plants	Thousand 376-pound barrels	Percent of total	Coal (thousand short tons)	Oil (thousand 42-gallon barrels)	Natural gas (thousand cubic feet)
1964:						
Wet	115	223,077	60.5	4,644	3,484	137,099,330
Dry	66	145,556	39.5	4,180	818	64,573,144
Total	181	368,633	100.0	[2] 8,824	4,302	[3] 201,672,474
1965:						
Wet	113	224,321	60.4	5,143	3,648	133,520,997
Dry	68	147,101	39.6	3,993	815	64,985,952
Total	181	371,422	100.0	[4] 9,136	4,463	198,506,949

[1] Includes Puerto Rico.
[2] Comprises 152,595 tons of anthracite and 8,671,122 tons of bituminous coal.
[3] Includes 263,707 thousand cubic feet of coke-oven gas.
[4] Comprises 268,759 tons of anthracite and 8,867,701 tons of bituminous coal.

Table 10.—Portland cement produced in the United States,[1] by kinds of fuel

Year and fuel	Finished cement produced			Fuel consumed		
	Plants	Thousand 376-pound barrels	Percent of total	Coal (thousand short tons)	Oil (thousand 42-gallon barrels)	Natural gas (thousand cubic feet)
1964:						
Coal	59	[2] 123,203	33.4	5,981	---	---
Oil	8	[2] 16,273	4.4	---	2,870	---
Natural gas	44	[2] 73,431	19.9	---	---	88,937,219
Coal and oil	18	38,998	10.6	1,661	761	---
Coal and natural gas	27	50,954	13.8	1,085	---	[3] 39,172,137
Oil and natural gas	18	52,819	14.4	---	651	58,853,368
Coal, oil, and natural gas	7	12,955	3.5	97	20	14,709,750
Total	181	368,633	100.0	[4] 8,824	4,302	201,672,474
1965:						
Coal	61	[2] 128,936	34.7	6,262	---	---
Oil	8	[2] 14,760	4.0	---	2,891	---
Natural gas	38	[2] 66,544	17.9	---	---	81,165,498
Coal and oil	16	37,940	10.2	1,590	717	---
Coal and natural gas	25	43,811	11.8	1,016	---	33,845,231
Oil and natural gas	24	60,767	16.4	---	705	65,945,018
Coal, oil and natural gas	9	18,664	5.0	268	150	17,551,202
Total	181	371,422	100.0	[5] 9,136	4,463	198,506,949

[1] Includes Puerto Rico.
[2] Average consumption of fuel per barrel of cement produced as follows: 1964—coal, 97.1 pounds; oil, 0.1764 barrel; natural gas, 1,211 cubic feet; 1965—coal, 97.2 pounds; oil, 0.1956 barrel; natural gas 1,220 cubic feet.
[3] Includes 263,707 thousand cubic feet of coke-oven gas.
[4] Comprises 152,595 tons of anthracite and 8,671,122 tons of bituminous coal.
[5] Comprises 268,759 tons of anthracite and 8,867,701 tons of bituminous coal.

Huron Portland Cement Co. christened its seventh cement carrier, the largest bulk cement freighter on the Great Lakes, in Cleveland. The Steamer J.A.W. Iglehart is 501 feet long. Universal Atlas Cement Co. put the "Tom Sawyer," a 245-foot, self-unloading cement barge, into service at Hannibal, Mo.

Inflatable rubber dunnage bags used to protect bagged mortar cement during freight haulage were described by National Portland Cement Co.[4] Oceangoing barges and dock facilities used by Oregon Portland Cement Co. at Lake Oswego, Oreg., were described.[5]

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[4] Brong, Sherwood C. Rubber Dunnage Bags Save Cement Shipments at National Portland. Rock Products, v. 68, No. 6, June 1965, pp. 66–67.

[5] Mining and Minerals Engineering (London). Material Handling at Oregon Portland Cement. V. 1, No. 9, May 1965, pp. 351–352.

Table 11.—Electric energy used at portland cement plants in the United States,[1] by processes

Year and process	Electric energy used: Generated at portland cement plants: Active plants	Generated at portland cement plants: Million kilowatt-hours	Purchased: Active plants	Purchased: Million kilowatt-hours	Total: Million kilowatt-hours	Total: Percent	Finished cement produced (thousand 376-pound barrels)	Average electric energy used per barrel of cement produced (kilowatt-hours)
1964:								
Wet	22	466	111	4,635	5,101	58.0	223,077	22.9
Dry	20	1,074	69	2,620	3,694	42.0	145,556	25.4
Total	42	1,540	180	7,255	8,795	100.0	368,633	23.8
Percent of total electric energy used	---	17.5	---	82.5	100.0	---	---	---
1965:								
Wet	18	389	109	4,691	5,080	57.3	224,321	22.6
Dry	18	994	69	2,794	3,788	42.7	147,101	25.8
Total	36	1,383	178	7,485	8,868	100.0	371,422	23.9
Percent of total electric energy used	---	15.6	---	84.4	100.0	---	---	---

[1] Includes Puerto Rico.

Table 12.—Shipments of portland cement from mills in the United States,[1] in bulk and in containers by types of carriers

Year and type of carrier	In bulk: Thousand 376-pound barrels	In bulk: Percent	In paper bags[2]: Thousand 376-pound barrels	In paper bags[2]: Percent	Total shipments: Thousand 376-pound barrels	Total shipments: Percent
1964:						
Truck	206,714	64.4	34,754	76.5	241,468	65.9
Railroad	106,425	33.2	10,316	22.7	116,741	31.9
Boat	7,349	2.3	302	.7	7,651	2.1
Used at the plant	386	.1	58	.1	444	.1
Total	320,874	100.0	45,430	100.0	366,304	100.0
Percent of total	87.6	---	12.4	---	100.0	---
1965:						
Truck	224,105	67.6	32,693	76.7	256,798	68.6
Railroad	100,379	30.3	9,579	22.5	109,958	29.4
Boat	6,616	2.0	361	.8	6,977	1.9
Used at the plant	350	.1	3	---	353	.1
Total	331,450	100.0	42,636	100.0	374,086	100.0
Percent of total	88.6	---	11.4	---	100.0	---

[1] Includes Puerto Rico.
[2] Cloth bags and other containers included with paper bags to avoid disclosing individual company confidential data.

CONSUMPTION

The Department of Commerce estimated the value of new construction put in place at about 3 percent greater than for 1964, as of midyear. Private construction was 6 percent above the 1964 level; new private nonfarm residential buildings were up 3 percent; and new public construction put in place was down 3 percent. The Reinforced Concrete Association in London announced the use of reinforced concrete in 1964 was up 70 percent from the figure of 5 years previously.

Spalling and expansion in major concrete structures continued to cause serious damage. A 710-foot-long highway bridge in Massillon, Ohio, was closed to traffic in December 1964, and was on the verge of col-

Table 13.—Destination of shipments of all types of finished portland and high-early-strength cement from mills in the United States, by States

(Thousand 376-pound barrels)

Destination	Finished portland 1964	Finished portland 1965	High-early-strength 1964	High-early-strength 1965
Alabama	6,216	6,057	56	56
Alaska [1]	W	W	W	W
Arizona	4,313	3,333	W	W
Arkansas	3,807	4,519	40	30
Northern California	17,141	18,394	42	45
Southern California	26,874	23,800	184	199
Colorado	4,355	5,033	19	23
Connecticut [1]	4,695	4,942	286	271
Delaware [1]	881	1,342	36	34
District of Columbia [1]	1,647	1,482	82	59
Florida	[2] 13,035	[2] 12,367	687	724
Georgia	8,660	8,980	141	147
Hawaii	1,296	1,518	---	---
Idaho	1,141	1,447	29	48
Illinois	18,528	17,683	621	626
Indiana	10,033	9,934	430	345
Iowa	7,629	8,090	181	144
Kansas	5,132	5,041	58	86
Kentucky	4,234	4,976	156	148
Louisiana	10,405	11,294	104	82
Maine	926	1,064	82	41
Maryland	7,284	7,207	220	412
Massachusetts [1]	6,126	5,961	370	503
Michigan	15,569	16,943	971	1,000
Minnesota	6,894	7,286	417	245
Mississippi	4,108	4,212	15	12
Missouri	10,266	10,414	284	371
Montana	1,613	1,493	13	8
Nebraska	4,460	4,318	194	172
Nevada [1]	1,807	1,699	17	30
New Hampshire [1]	733	911	97	49
New Jersey [1]	9,507	10,625	546	581
New Mexico	2,759	2,825	260	157
New York	18,137	17,714	990	1,033
North Carolina [1]	6,175	6,969	194	261
North Dakota [1]	1,895	1,209	38	32
Ohio	18,456	18,505	593	521
Oklahoma	6,163	6,884	28	44
Oregon	3,055	4,275	95	82
Eastern Pennsylvania	9,869	10,219	501	508
Western Pennsylvania	5,979	6,607	268	260
Rhode Island [1]	885	1,009	73	88
South Carolina	2,998	3,450	39	54
South Dakota	1,578	1,461	48	47
Tennessee	6,727	6,717	157	180
Texas	26,156	26,371	1,493	1,503
Utah	2,529	2,610	65	54
Vermont [1]	464	484	23	37
Virginia	8,418	8,728	419	480
Washington	5,368	5,909	435	536
West Virginia	2,160	2,509	40	37
Wisconsin	8,402	8,405	313	282
Wyoming	1,273	1,062	2	4
Total United States	358,761	366,287	12,452	12,691
Other countries	[3] 7,543	[3] 7,799	[4] 77	[4] 66
Total shipped from cement plants	366,304	374,086	12,529	12,757

W Withheld to avoid disclosing individual company confidential data; included with "Other countries."

[1] Noncement producer.

[2] Includes shipments from Puerto Rican mills.

[3] Direct shipments by producers to foreign countries, the State of Alaska, and to Puerto Rico, including distribution from Puerto Rican mills.

[4] Direct shipments by producers to other countries and the States of Alaska and Arizona.

lapse. The damage resulted from excessive expansion of the concrete deck owing to a reaction between the cement and aggregates in the deck concrete.[6]

[6] Engineering News-Record. Growth Destroys a Bridge Deck. V. 174, No. 24, June 17, 1965, pp. 163, 165.

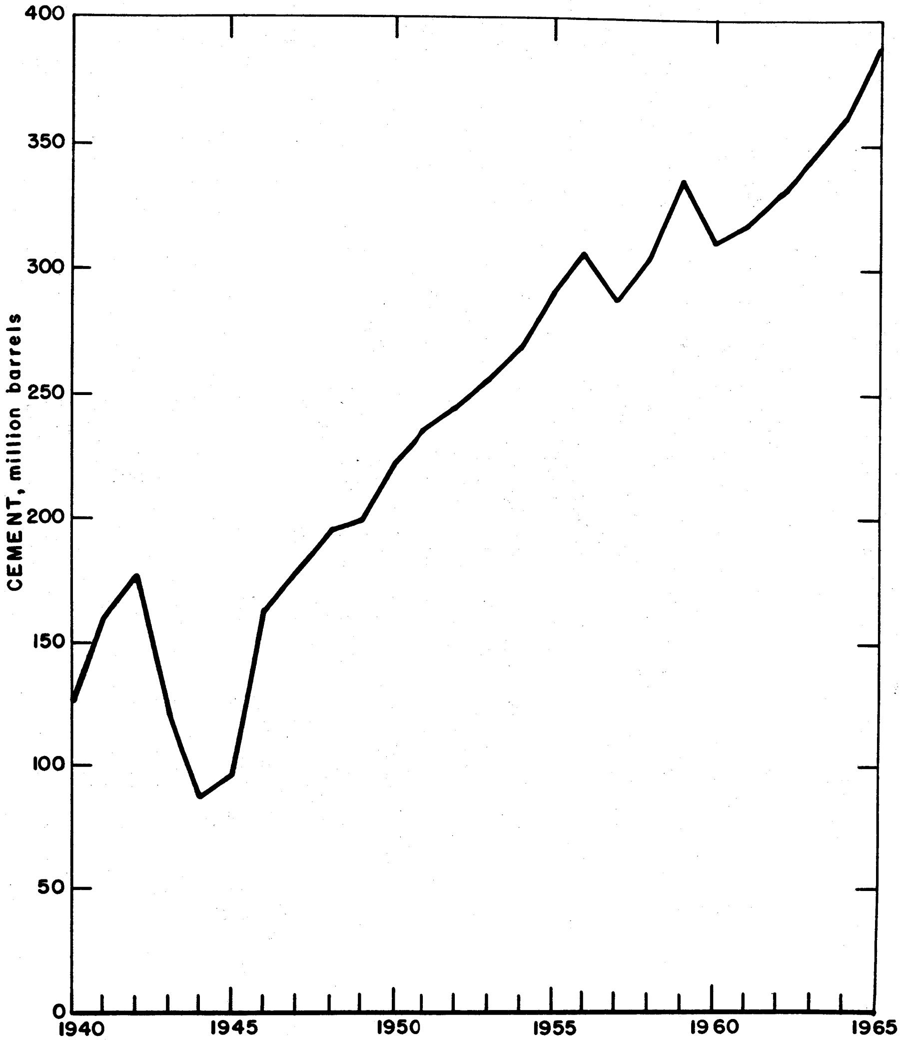

Figure 1.—Apparent consumption of finished portland cement in the United States.

Table 14.—Cement shipments by types of customers in 1965

(Quantities in thousand 376-pound barrels)

District	Number of plants in district	Building material dealers		Concrete product manufacturers		Ready-mixed concrete		Highway contractors		Other contractors		Federal, State and other Government agencies		Miscellaneous including own use		Total
		Percent	Quantity	Percent	Quantity	Percent	Quantity	Percent	Quantity	Percent	Quantity	Percent	Quantity	Percent	Quantity	
New York, Maine	13	8.6	2,614	12.1	3,685	66.3	20,152	7.3	2,224	2.8	857	.1	27	2.8	851	30,410
Eastern Pennsylvania	16	11.9	3,553	22.6	6,727	57.4	17,051	6.6	1,952	.6	189	---	14	.9	279	29,765
Western Pennsylvania	5	7.2	745	13.8	1,436	61.6	6,396	12.9	1,343	3.4	355	---	2	1.1	111	10,388
Maryland, West Virginia	4	5.4	572	21.4	2,264	65.6	6,924	6.8	718	.4	45	.1	7	.3	31	10,561
Ohio	9	5.8	859	16.2	2,392	64.7	9,568	9.8	1,443	.9	137	---	2	2.6	385	14,786
Michigan	8	8.1	2,236	15.5	4,277	58.7	16,184	11.6	3,201	4.6	1,266	---	2	1.5	399	27,565
Indiana, Kentucky, Wisconsin	8	6.1	1,223	12.8	2,563	65.5	13,166	12.8	2,569	1.3	266	---	3	1.5	298	20,088
Illinois	4	5.1	480	24.8	2,318	55.8	5,216	12.3	1,154	---	3	---	---	2.0	187	9,358
Tennessee	6	5.9	515	19.0	1,659	60.4	5,267	7.9	691	4.3	375	1.7	146	.8	71	8,724
Virginia, North Carolina, South Carolina	5	5.9	699	17.0	2,028	64.8	7,743	6.8	812	4.5	542	.6	74	.4	46	11,944
Georgia, Florida	7	12.0	1,444	20.3	2,446	47.9	5,770	7.7	928	7.5	899	3.0	359	1.6	198	12,044
Alabama	8	5.8	794	14.7	2,026	57.1	7,860	17.5	2,411	1.9	260	1.2	167	1.8	247	13,765
Louisiana, Mississippi	6	5.3	489	11.7	1,082	51.9	4,805	15.7	1,454	4.8	448	.3	27	10.3	953	9,258
Minnesota, South Dakota, Nebraska	4	12.8	897	8.5	596	48.5	3,404	24.6	1,724	4.6	323	.4	31	.6	46	7,021
Iowa	5	6.8	925	17.0	2,322	59.2	8,070	14.4	1,967	1.8	251	.3	35	.5	73	13,648
Missouri	6	7.4	993	34.3	4,571	38.5	5,130	14.8	1,966	1.3	176	.3	42	3.4	456	13,334
Kansas	6	8.7	767	6.3	557	67.3	5,919	13.7	1,208	1.1	99	.2	15	2.7	236	8,801
Oklahoma, Arkansas	5	9.2	1,135	5.8	725	49.8	6,171	24.6	3,055	9.5	1,174	.1	7	1.0	130	12,397
Texas	18	7.7	2,374	7.0	2,161	52.7	16,233	14.8	4,578	3.2	985	1.5	455	13.1	4,034	30,820
Wyoming, Montana, Idaho	4	7.2	250	11.2	388	51.7	1,797	8.1	281	20.0	694	.1	5	1.7	61	3,476
Colorado, Arizona, Utah, New Mexico	7	9.4	1,114	10.8	1,272	60.5	7,144	12.2	1,440	4.0	480	.2	20	2.9	339	11,809
Washington	6	5.1	322	11.8	738	57.2	3,577	11.0	687	14.2	889	.6	36	.1	9	6,258
Oregon, Nevada	4	5.6	207	10.4	382	66.1	2,425	1.0	36	16.3	600	.2	6	.4	15	3,671
Northern California	6	7.2	1,404	7.8	1,526	65.2	12,791	6.2	1,223	12.5	2,454	.2	36	.9	185	19,619
Southern California	7	12.8	3,307	10.7	2,766	65.8	16,943	4.1	1,054	4.9	1,250	.6	142	1.1	271	25,733
Hawaii	2	12.5	195	11.6	182	69.9	1,094	.1	2	3.6	56	2.2	34	.1	1	1,564
Puerto Rico	2	---	---	---	---	57.3	4,171	---	---	---	---	---	---	42.7	3,113	7,284
Total	181	8.0	30,113	14.2	53,089	59.1	220,971	10.7	40,121	4.0	15,073	.5	1,694	3.5	13,025	374,086

PREPARED MASONRY CEMENT

Table 15.—Shipments of prepared masonry cement from mills in the United States, by States
(Thousand 280-pound barrels)

Destination	1964	1965
Alabama	664	705
Alaska [1]	W	---
Arizona	W	W
Arkansas	350	363
Southern California	11	---
Colorado	219	186
Connecticut [1]	137	142
Delaware [1]	59	55
District of Columbia [1]	410	491
Florida	1,235	1,148
Georgia	1,265	1,292
Hawaii	---	---
Idaho	11	11
Illinois	678	706
Indiana	723	849
Iowa	201	224
Kansas	180	188
Kentucky	595	640
Louisiana	363	420
Maine	73	77
Maryland	744	791
Massachusetts [1]	288	295
Michigan	1,369	1,528
Minnesota	409	408
Mississippi	353	377
Missouri	222	233
Montana	24	25
Nebraska	87	87
Nevada	W	W
New Hampshire [1]	72	72
New Jersey [1]	652	684
New Mexico	109	120
New York	1,068	1,012
North Carolina	1,563	1,618
North Dakota [1]	56	47
Ohio	1,451	1,510
Oklahoma	321	328
Oregon	1	1
Eastern Pennsylvania	554	541
Western Pennsylvania	615	627
Puerto Rico	W	---
Rhode Island [1]	29	30
South Carolina	807	909
South Dakota	54	78
Tennessee	1,071	1,142
Texas	926	922
Utah	11	14
Vermont [1]	40	43
Virginia	1,338	1,337
Washington	43	45
West Virginia	234	237
Wisconsin	504	541
Wyoming	18	14
Total United States	22,207	23,113
Other countries [2]	190	147
Total shipped from cement plants	22,397	23,260

W Withheld to avoid disclosing individual company confidential data; included with "Other countries."
[1] Noncement producer.
[2] Direct shipments by producers to other countries and to Alaska, Arizona, Nevada, and Puerto Rico.

Table 16.—Prepared masonry cement produced and shipped in the United States, by districts

District	Active plants		Production (thousand 280-pound barrels)		Shipments from mills					
					1964			1965		
	1964	1965	1964	1965	Thousand 280-pound barrels	Value (thousands)	Average per barrel	Thousand 280-pound barrels	Value (thousands)	Average per barrel
New York, Maine	11	11	1,102	1,146	1,154	$2,918	$2.53	1,173	$2,993	$2.55
Eastern Pennsylvania	15	11	1,766	1,943	1,918	4,868	2.54	2,004	5,192	2.59
Western Pennsylvania	5	5	904	977	900	2,727	3.03	1,002	2,799	2.79
Maryland, West Virginia	5	5	1,199	1,208	1,207	3,046	2.52	1,204	2,961	2.46
Ohio	8	7	1,040	1,047	1,068	3,127	2.93	1,050	3,004	2.86
Michigan	6	6	1,889	2,170	1,865	4,954	2.66	2,108	5,373	2.55
Indiana, Kentucky, Wisconsin	7	6	3,061	3,105	3,068	8,170	2.66	3,258	9,838	3.02
Illinois	4	4	593	648	596	2,038	3.42	615	1,907	3.10
Tennessee	5	5	1,209	1,241	1,212	3,228	2.66	1,185	3,140	2.65
Virginia, North Carolina, South Carolina	5	5	1,754	1,915	1,734	5,074	2.93	1,938	5,577	2.88
Georgia, Florida	5	5	1,007	1,008	1,042	2,952	2.83	1,002	2,881	2.88
Alabama	9	9	2,513	2,628	2,574	7,794	3.03	2,598	7,853	3.02
Louisiana, Mississippi	4	4	438	265	386	1,018	2.64	435	1,147	2.64
Minnesota, South Dakota, Nebraska	4	4	284	268	277	874	3.16	268	834	3.11
Iowa	4	4	605	654	585	1,847	3.15	608	1,867	3.07
Missouri	5	5	322	380	334	1,046	3.13	377	1,173	3.11
Kansas	7	7	377	449	384	1,173	3.05	404	1,178	2.92
Oklahoma, Arkansas	5	5	582	576	575	1,675	2.91	578	1,710	2.96
Texas	12	12	897	912	930	2,805	3.02	968	3,011	3.11
Wyoming, Montana, Idaho	W	3	W	27	W	W	W	29	96	3.31
Colorado, Arizona, Utah, New Mexico	5	6	507	389	497	1,676	3.37	394	1,294	3.28
Washington [1]	---	5	---	68	---	---	---	62	201	3.24
Oregon, Washington	W	---	W	---	W	W	W	---	---	---
Undistributed	7	---	78	---	91	295	3.24	---	---	---
Total	138	134	22,127	23,024	22,397	63,305	2.83	23,260	65,979	2.84

W Withheld to avoid disclosing individual company confidential data; included with "Undistributed."
[1] Oregon combined with Washington in 1964.

NATURAL AND SLAG CEMENTS

Natural cement was produced at two plants, and slag cement was produced at two others. These four plants reported an annual capacity of approximately 1 million barrels.

Because masonry cements prepared at these plants contained some portland cement, they are included in the tabulations of masonry cements prepared at portland cement plants (tables 15 and 16). Production figures from 1957 to 1965 are not strictly comparable with those of earlier years because of changes in methods of reporting by some producers.

Table 17.—Natural, slag, and hydraulic-lime cements produced, shipped, and in stock at mills in the United States

Year	Production		Shipments		Stocks Dec. 31 (thousand 376-pound barrels)
	Active plants	Thousand 376-pound barrels	Thousand 376-pound barrels	Value (thousands)	
1956–60 (average)	5	657	643	$2,130	90
1961	4	225	269	968	40
1962	4	440	402	1,611	78
1963	4	357	352	1,407	83
1964	4	275	283	1,057	76
1965	4	279	279	1,027	76

PRICES

The price of cement in 1965 continued the moderate decline experienced in recent years. Average net value of shipments from all cement plants was $3.18 per barrel, compared with $3.22 in 1964. Overcapacity became slightly less a problem, and imports increased. At the same time larger and more efficient plants were able to produce cement at lower cost.

Portland cement values at plant changed from $3.16 per barrel in the last quarter of 1964 to $3.20 per barrel in the first quarter of 1965 and by the fourth quarter were down to $3.13. The average value of types I and II cement was $3.11 in the fourth quarter of 1964, $3.15 in the first quarter of 1965, and $3.09 in the fourth quarter of 1965. Type III cement was valued at $3.50 in the fourth quarter of 1964, $3.53 in the first quarter of 1965, and $3.44 in the fourth quarter of 1965. The average price of prepared masonry cement in 280-pound barrels was $2.81 in the fourth quarter of 1964, $2.89 in the first quarter of 1965, and $2.84 in the fourth quarter of 1965. The average value of natural, slag, and hydraulic-lime cement shipments was $3.68 in 1965, compared with $3.74 per barrel in 1964.

Engineering News-Record gives f.o.b. base prices per barrel for portland cement in carload lots in 20 cities across the Nation. In bulk, during 1965, cement sold for an average of $3.89 and ranged from a high of $4.95 in Pittsburgh to a low of $3.17 in New York. In paper bags, during 1965, the average price quoted was $4.59, ranging from a high of $5.65 in Pittsburgh to a low of $3.42 in New York. Mortar cement sold for an average $4.25 per barrel and ranged from a high of $5.68 in Los Angeles to a low of $3.04 in Detroit.

Table 18.—Average mill value in bulk, of cement in the United States[1]
(Per barrel)

Year	Portland cement [2]	Natural, slag, and hydraulic-lime cements [2]	Prepared masonry cement [3] [4]	All classes cement [5]
1956–60 (average)	$3.22	$3.31	$2.84	$3.25
1961	3.32	3.60	2.89	3.35
1962	3.29	4.01	2.87	3.31
1963	3.20	3.99	2.84	3.23
1964	3.19	3.74	2.83	3.22
1965	3.15	3.68	2.84	3.18

[1] Includes Puerto Rico.
[2] 376-pound barrels.
[3] Includes masonry cements made at portland, natural, and slag cement plants.
[4] 280-pound barrels.
[5] Includes masonry cement converted to 376-pound barrels.

FOREIGN TRADE

United States exports of cement increased 5 percent in 1965. Imports were at the second highest level on record in 1965, ending a declining trend of the last 3 years. The higher import figure was largely due to shipments from a new cement plant in the Bahama Islands.

Table 19.—U.S. exports of hydraulic cement, by countries

Destination	1963		1964		1965	
	376-pound barrels	Value	376-pound barrels	Value	376-pound barrels	Value
North America:						
Bermuda	1,869	$11,138	27,112	$90,133	346	$6,818
Canada	110,753	607,512	132,633	818,342	281,293	1,915,534
Central America:						
Costa Rica	19,126	37,918	3,894	19,593	1,201	11,192
El Salvador	57	598	---	---	149	4,355
Guatemala	500	2,475	782	4,518	556	4,310
Honduras	394	4,326	20	496	100	1,136
Nicaragua	5,798	25,676	2,748	12,735	6,912	32,679
Panama	42	846	2,164	12,133	1,581	20,954
Mexico	59,786	238,451	62,268	309,358	94,564	436,088
West Indies:						
British:						
Bahamas	132,904	482,965	170,112	678,446	41,480	200,445
Barbados	---	---	8,040	18,850	7,981	21,126
Jamaica	1,360	9,130	1,275	5,157	1,864	9,867
Leeward and Windward Islands	28,748	82,374	33,789	85,237	34,986	102,757
Trinidad and Tobago	252	1,873	1,527	9,638	515	6,935
Dominican Republic	186	1,020	9,613	24,748	1,398	9,481
French West Indies	---	---	9,795	23,338	75,656	154,890
Haiti	3,602	15,556	1,200	3,360	628	2,680
Netherlands Antilles	885	7,016	66	1,112	247	2,414
Other	---	---	573	8,362	29	228
Total	366,262	1,528,874	467,611	2,125,556	551,486	2,943,889
South America:						
Bolivia	2,684	25,310	5,250	44,742	1,526	14,794
Brazil	1,913	18,016	---	---	1,585	14,693
Chile	5,391	36,485	1,405	14,929	3,472	57,448
Colombia	275	3,991	1,229	12,120	298	3,673
Peru	2,080	11,548	3,633	21,255	9,286	92,928
Venezuela	292	2,929	569	3,042	2,082	20,464
Other	458	2,133	282	3,347	595	8,120
Total	13,093	100,412	12,368	99,435	18,844	212,120
Europe:						
Belgium-Luxembourg	30	744	---	---	1,543	14,009
France	---	---	1,740	9,084	1,105	8,826
Germany, West	218	834	509	6,776	1,999	43,669
Italy	282	2,134	2,530	19,615	2,948	26,356
Netherlands	788	10,787	616	7,819	1,784	21,774
Norway	---	---	28	888	2,366	21,574
Spain	23	224	---	---	2,397	28,773
Sweden	---	---	---	---	2,499	23,942
Switzerland	2,263	10,676	---	---	133	1,062
Other	1,052	3,750	600	8,919	2,523	31,265
Total	4,656	29,149	6,023	53,101	19,297	221,250
Africa:						
British West Africa	2,363	10,058	120	500	3,973	18,522
Gabon	---	---	2,018	7,550	2,750	35,345
Liberia	99	860	9,438	35,102	102,804	403,253
Libya	2,280	11,491	---	---	---	---
Western Equatorial Africa, n.e.c.	4,085	18,203	---	---	---	---
South Africa, Republic of	168	736	470	3,450	457	3,652
Other	---	---	2,249	11,729	3,749	33,850
Total	8,995	41,348	14,295	58,331	113,733	494,622

Table 19.—U.S. exports of hydraulic cement, by countries—Continued

Destination	1963 376-pound barrels	1963 Value	1964 376-pound barrels	1964 Value	1965 376-pound barrels	1965 Value
Asia:						
India	78	$917	91	$1,807	1,023	$8,570
Indonesia	2,610	23,698	75	675	2,177	16,670
Iran	---	---	---	---	5,001	46,835
Japan	5,112	47,341	7,996	73,643	11,869	126,435
Korea, South	28,347	149,018	148,722	616,151	2,871	21,875
Pakistan	12,613	50,817	31,030	113,709	3,602	13,917
Philippines	7,510	44,647	17,963	86,210	5,435	53,721
Saudi Arabia	109	2,086	249	3,274	1,238	11,964
Taiwan	563	8,127	158	3,075	1,878	21,978
Thailand	5,518	25,996	34	228	220	1,411
Turkey	1,969	6,668	154	1,577	2,077	12,642
Viet-Nam	1,147	4,733	321	3,620	2,412	13,857
Other	1,461	7,633	3,989	40,178	1,655	25,917
Total	67,037	371,681	210,782	944,147	41,458	375,792
Oceania	45	653	1,599	9,480	3,622	40,215
Grand total	460,088	2,072,117	712,678	3,290,050	748,440	4,287,888

Table 20.—U.S. imports for consumption of cement
(Thousand 376-pound barrels and thousand dollars)

Year	Roman, portland, and other hydraulic cement Quantity	Roman, portland, and other hydraulic cement Value	Hydraulic cement clinker Quantity	Hydraulic cement clinker Value	White nonstaining portland cement Quantity	White nonstaining portland cement Value	Total Quantity	Total Value
1956-60 (average)	3,889	$10,463	124	$286	316	$1,806	4,329	$12,555
1961	3,359	7,858	---	---	262	1,367	3,621	9,225
1962	4,842	10,464	472	883	319	1,508	5,633	12,855
1963	3,668	8,582	52	226	310	1,394	4,030	10,202
1964	3,208	7,433	116	382	309	1,413	3,633	9,228
1965	4,838	11,307	378	962	289	1,254	5,505	13,523

WORLD REVIEW

NORTH AMERICA

Bahamas.—The modern 4.8-million-barrel plant of Bahama Cement Co. was described. The plant contains two 575-foot kilns and is fully automated and computerized. Principal raw materials are coral limestone and bauxite.[7]

Canada.—Cement production increased by 6 percent in 1965, reflecting new construction and a growing economy. Particularly evident were booming developments along the west coast. New plants totaling $65 million were either put on stream or announced, while announced expansions and modernizations of existing plants totaled $64 million.

Inland Cement Co. completed its new cement plant in Tuxedo, Winnipeg, Manitoba. Lake Ontario Cement Ltd. planned expansion which will double the capacity of its Picton, Ontario, plant. St. Lawrence Cement Co. installed a new $7 million kiln which will double capacity of its Villeneuve, Quebec, plant. Ocean Cement Ltd. will spend $4.6 million on expansion of its British Columbian facilities. Ciments Lafarge Quebec Ltd., was constructing a new 3.5-million-barrel-per-year plant at St. Constant, Quebec. Miron Co. Ltd., will spend $9 million on an expansion at its Montreal, Quebec plant.

Canada Cement Co. Ltd., undertook four major projects during 1965. A $5.5 million addition to the firm's Floral, Saskatoon, Saskatchewan plant was announced. The subsidiary Maritime Cement Co. Ltd., put its $14 million Brookfield, Nova Scotia, plant on stream. A $20 million expansion of the firm's Woodstock, Ontario, plant was announced. The company announced a $4 million expansion to double the capacity of its subsidiary Maritime Cement Co. Ltd., at Havelock, New Brunswick.

Costa Rica.—Camara del Cemento del Istmo Centroamericano was formed in

[7] Rock Products. Bahama Cement. V. 68, No. 5, May 1965, pp. 79–83.

Table 21.—U.S. imports for consumption of hydraulic cement in 1965, by countries and customs districts

(376-pound barrels)

Customs district	Bahamas	Belgium-Luxembourg	Canada	Colombia	Denmark	France	Germany, West	Japan	Mexico	Norway	Sweden	United Kingdom	Venezuela	Yugoslavia	Total
Alaska	---	---	123,655	---	---	---	---	443	---	---	---	---	---	---	124,098
Buffalo	---	---	10,310	---	---	---	---	---	---	---	---	---	---	---	10,310
Connecticut	---	---	---	---	---	---	---	---	---	501,045	---	---	---	---	501,045
Dakota	---	---	139,374	---	---	---	---	---	---	---	---	---	---	---	139,374
Florida	1,523,799	95,710	---	53,118	---	---	---	---	---	---	---	---	---	---	1,672,627
Galveston	---	---	---	---	---	---	---	---	---	---	---	160	---	---	160
Georgia	---	---	---	81,189	---	---	---	---	---	---	---	8,641	---	---	89,830
Hawaii	---	---	---	---	410	---	---	1,653	---	---	---	---	---	---	2,063
Laredo	---	---	---	---	---	---	---	---	10,179	---	---	---	---	---	10,179
Los Angeles	---	---	---	---	---	---	---	20,763	---	---	---	5,152	---	---	25,915
Maine and New Hampshire	---	---	8,221	---	---	---	---	---	---	---	---	---	---	---	8,221
Massachusetts	---	---	247	---	---	---	625	---	---	---	---	---	---	---	872
Michigan	---	---	263,851	---	---	---	1,000	---	---	---	---	---	---	---	264,851
Montana and Idaho	---	---	14,720	---	---	---	---	---	---	---	---	---	---	---	14,720
New Orleans	---	5,943	---	---	---	---	---	---	---	---	---	324	---	---	6,267
New York	69,041	1,298	234	---	---	160	---	---	---	453,260	---	3,233	---	---	527,226
North Carolina	---	604	---	---	---	---	---	---	---	---	---	---	---	---	604
Ohio	---	251	43,822	---	---	---	---	---	---	---	---	---	---	---	44,073
Oregon	---	---	---	---	---	---	---	343	---	---	---	---	---	---	343
Philadelphia	---	---	---	---	---	146	11,937	---	---	---	170	184	---	17,057	29,444
Puerto Rico	---	35,586	---	465,433	15,496	3,495	997	31,000	---	---	---	---	7,040	---	559,047
Rhode Island	---	---	---	51,550	---	---	---	---	---	---	---	---	---	---	51,550
Rochester	---	---	1,095,244	---	---	---	---	---	---	---	---	---	---	---	1,095,244
St. Lawrence	---	---	59,708	---	---	---	---	---	---	---	---	---	---	---	59,708
San Diego	---	---	---	---	---	---	---	2,238	---	---	---	---	---	---	2,238
San Francisco	---	---	---	---	---	---	600	254	---	---	---	600	---	---	1,454
Vermont	---	---	6,574	---	---	---	---	---	---	---	---	88	---	---	6,662
Virginia	233,512	---	---	---	---	---	---	---	---	---	---	---	---	---	233,512
Washington	---	---	15,131	---	---	---	---	8,220	---	---	---	233	---	---	23,584
Wisconsin	---	---	124	---	---	---	---	---	---	---	---	---	---	---	124
Total:															
Quantity	1,826,352	139,387	1,780,710	651,290	15,906	3,801	15,159	64,914	10,179	954,305	170	18,570	7,040	17,057	5,504,840
Value	$4,445,810	$601,330	$4,358,570	$1,346,922	$85,163	$25,722	$130,634	$277,428	$48,565	$1,946,114	$3,589	$132,252	$30,500	$90,379	$13,522,978

June 1965 to promote greater utilization of cement and establish a basis for cooperation among cement manufacturers in Central American countries. Countries represented were Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama.

Dominican Republic.—Fabrica Dominicana de Cemento planned to increase annual production from 7 million to 13 million bags in 1965. A private company planned to construct a plant in the Santiago area.

El Salvador.—Cementos de El Salvador has been moved from the depleted limestone area near Acajutla to Metapan, where deposits are expected to last for 160 years at the rate of 3.5 million bags of cement per year.

Mexico.—Twenty-three plants operated at high rates of production. Expansion programs underway were expected to increase annual capacity of the industry to 6.2 million tons by late 1965. Establishment of seven new plants is expected to bring the country's total cement capacity to 6.8 million tons per year by early 1967, and 8 million tons per year by 1968.

Private industrialists are financing plans for a $2.8 million cement plant in Ciudad Juarez. Production is targeted at 350 metric tons daily.

Panama.—Cemento Panama planned to increase production by the installation of new equipment. The Cemento Atlantico, S.A., plant being erected near Colon is expected to begin operating in early 1966. This $5 million plant will use coral as the basic raw material.

Puerto Rico.—The Puerto Rican Cement Co. began a 3-year, $12 million expansion program. Production capacity by the end of 1967 is expected to reach 12 million barrels. A $500,000 computer system was added to the Ponce plant.

SOUTH AMERICA

Bolivia.—A cement shortage was reported to be seriously curtailing construction activities. The price of cement nearly doubled. The Fabrico Nacional de Cementos plant near Sucre was planning to increase capacity to 170 tons per day.

Brazil.—A 50,000-ton plant at Sobral, Ceara, began operating in 1965. Four new plants, with a planned annual capacity of 40,000 to 60,000 tons, were in the planning stages. These are to be at Mossoro and Natal, Rio Grande do Norte; Crato, Ceara; and Maceio, Alagoas.

Cia. de Cemento Portland Itau upped production by 500 tons per day with the installation of a fourth kiln. Plans were underway for construction of five cement plants near Rio de Janeiro. A new portland cement plant with an initial capacity of 50,000 tons per year in Rio Grande do Norte was announced. Paraiba Cement Co. announced a $1.15 million expansion to 2.1 million U.S. barrels per year.

Cement production was scheduled to reach 7 million tons per year in 1965.

Colombia.—Cementos del Caribe, S.A., was expanding operations with the addition of a semiportable crushing plant at Barranquilla. Two new cement plants were in the advanced planning stages, at Toluviejo, Department of Bolivar, and at Moniquira, Department of Boyaca. Capacities are 1,000 and 600 tons per day, respectively.

Ecuador.—The new (1964) Guapan cement plant will have an annual capacity of 66,000 metric tons. The two other cement plants in Ecuador, Cemento Nacional and Chimborazo, had annual capacities of 300,000 and 54,000 metric tons.

Peru.—The consrtuction of a 500-ton-per-day cement plant near Arequipa, Peru, was announced.

EUROPE

Belgium.—Ciments d'Obourg installed a new furnace with an output of 2,800 tons of cement daily, claimed to be the biggest in Europe.

Finland.—A new plant was being built at Kalari in northern Finland by the Paraisten Kalkkivuari Oy. Annual output of the new plant, scheduled to begin operating in mid-1968, will be 200,000 tons.

France.—Lafarge Cement Co., France's largest cement manufacturer, was described. The plant uses the modern lepol kiln and the technique of prehomogenization.[8]

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[8] Le Bel, Francois. Prehomogenization: Giant Step Forward for Lafarge Cement. Rock Products, v. 68, No. 5, May 1965, pp. 94–99.

Table 22.—World production of hydraulic cement by countries

(Thousand barrels)

Country	1961	1962	1963	1964	1965 [p] [1]
North America:					
Canada (sold or used by producers)	33,010	36,587	37,314	42,075	44,432
Costa Rica	---	---	---	193	698
Cuba	[r] 5,107	[r] 4,568	[r] 4,761	[e] 4,691	[e] 4,691
Dominican Republic	1,390	[r] 1,425	[r] 1,343	[r] 1,747	1,243
El Salvador	440	381	[2] 457	[r] [2] 528	[2] 475
Guatemala	733	[r] 704	921	1,090	[e] 1,354
Haiti	258	299	270	328	246
Honduras	246	322	352	428	551
Jamaica	1,266	1,173	1,179	1,648	1,835
Mexico	17,795	19,654	[r] 22,058	[r] 26,174	24,620
Nicaragua	229	270	317	358	387
Panama	668	715	833	733	967
Trinidad	575	967	950	1,032	1,114
United States (including Puerto Rico)	338,628	351,932	368,406	[r] 385,386	388,842
Total	[r] 400,345	[r] 418,997	[r] 439,161	[r] 466,411	471,455
South America:					
Argentina	17,021	[r] 17,162	[r] 14,863	[r] 16,875	18,856
Bolivia	264	293	364	375	352
Brazil	27,622	29,739	30,395	32,623	32,700
Chile	5,177	5,992	6,837	[r] 7,429	6,966
Colombia	9,334	10,237	10,759	11,521	12,213
Ecuador	1,284	1,255	1,513	1,689	1,906
Paraguay	94	94	106	135	170
Peru	3,483	4,110	4,421	4,855	5,998
Uruguay	2,281	2,193	1,993	2,416	2,527
Venezuela	8,871	9,000	[r] 9,264	10,947	12,160
Total	75,431	[r] 80,075	[r] 80,515	[r] 88,865	93,848
Europe:					
Albania	704	698	[r] 762	[r] 745	879
Austria	18,082	17,924	19,419	[r] 22,093	23,635
Belgium	27,874	28,073	27,610	34,277	34,623
Bulgaria	10,255	11,099	12,929	15,162	15,720
Czechoslovakia	31,328	33,479	30,360	32,207	40,005
Denmark	9,287	9,569	8,918	[r] 11,129	11,433
Finland	7,910	7,956	[r] 8,373	[r] 9,217	10,290
France	90,183	98,984	[r] 106,325	[r] 126,278	132,417
Germany:					
East	[r] 30,929	[r] 31,849	[r] 32,002	[r] 33,814	35,672
West	159,153	167,649	171,308	[r] 197,195	200,126
Greece	10,771	11,275	13,450	15,667	18,833
Hungary	9,387	10,161	10,542	13,233	14,002
Iceland	440	569	575	633	668
Ireland	[r] 3,500	4,456	[r] 4,697	5,705	6,168
Italy	105,721	118,274	129,509	133,918	118,638
Luxembourg	1,354	1,349	1,190	[r] 1,196	1,302
Netherlands	11,158	11,815	12,202	16,845	17,432
Norway	7,470	8,279	[r] 8,431	[r] 9,035	9,053
Poland	43,177	44,233	[r] 44,995	51,368	56,129
Portugal	7,294	8,214	8,402	9,510	9,258
Rumania	19,396	20,457	25,617	27,862	31,697
Spain (includes Canary Islands)	38,862	42,767	45,429	[r] 49,838	57,695
Sweden	[r] 17,848	[r] 18,024	[r] 19,343	20,914	21,806
Switzerland	21,114	21,847	20,996	25,341	23,682
U.S.S.R.	298,231	336,131	357,767	[r] 378,142	424,479
United Kingdom	84,291	83,587	[r] 82,438	99,488	99,488
Yugoslavia	13,697	14,764	[r] 16,693	17,819	18,188
Total	[r] 1,079,416	[r] 1,163,482	[r] 1,220,282	[r] 1,358,631	1,433,318
Africa:					
Algeria	6,285	[r] 5,113	5,183	4,280	[e] 4,345
Angola	921	991	1,137	1,255	1,437
Cape Verde Islands	41	41	[r] 64	[r] 70	[e] 70
Congo, Republic of the (Leopoldville)	821	1,155	1,442	[r] 1,319	1,454
Ethiopia	176	[r] 258	[r] 188	258	563
Kenya	1,935	2,029	[r] 2,011	[r] 2,474	2,961
Malawi	217	193	147	182	182
Morocco	3,694	4,093	4,450	5,435	4,362
Mozembique	1,243	1,050	979	1,067	1,290
Nigeria	2,134	[r] 2,838	[r] 3,084	[r] 3,887	5,764
Rhodesia, Southern	1,636	[e] 1,466	[e] 1,466	[e] 1,466	[e] 1,466
Senegal	1,067	1,073	1,114	1,202	1,061

Table 22.—World production of hydraulic cement by countries—Continued

(Thousand barrels)

Country	1961	1962	1963	1964	1965 p [1]
Africa—Continued					
South Africa, Republic of	15,233	15,591	16,910	r 20,410	22,755
Sudan	487	498	r 680	r 534	469
Tunisia	1,929	2,128	2,117	2,668	2,662
Uganda	369	328	322	r 428	768
United Arab Republic (Egypt)	12,073	r 13,087	r 14,711	r 14,781	13,603
Zambia	715	r 698	r 680	r 985	985
Total	50,976	r 52,630	r 56,685	r 62,701	66,467
Asia:					
Afghanistan [3]	240	352	604	733	997
Burma	235	311	727	768	e 704
Ceylon	481	498	440	440	504
China	46,906	46,906	58,633	e 61,565	e 64,496
Cyprus	557	r 569	563	r 410	563
Hong Kong	1,079	1,243	1,272	1,261	1,413
India	48,343	r 50,342	54,851	56,815	62,198
Indonesia	2,609	r 2,961	1,935	r 2,574	e 2,140
Iran [3]	4,368	e 4,368	e 4,368	e 4,368	e 4,368
Iraq	5,494	5,400	5,283	6,303	7,534
Israel	4,960	5,594	5,992	r 6,438	7,376
Japan	144,448	168,787	175,594	r 193,377	191,665
Jordan	1,308	1,378	1,671	1,805	1,788
Korea:					
North	13,263	13,931	14,834	15,303	14,072
South	3,067	4,632	4,562	7,282	9,463
Lebanon	5,125	5,048	5,254	5,259	5,805
Malaysia	1,941	1,911	2,123	r 2,732	4,333
Pakistan	7,288	8,179	8,783	r 9,065	10,009
Philippines	5,975	5,635	5,576	r 7,042	e 8,895
Saudi Arabia	616	891	1,091	1,407	1,548
Singapore	---	715	1,137	e r 1,173	1,190
Syrian Arab Republic	3,166	3,559	4,016	r 3,723	4,896
Taiwan	8,848	10,970	13,169	13,808	14,330
Thailand	r 4,749	5,646	5,840	r 6,215	7,323
Turkey	11,891	13,620	15,819	r 17,238	19,021
Viet-Nam:					
North	2,685	2,709	r 2,879	3,805	4,397
South	---	---	---	440	1,143
Total	r 329,642	r 366,155	r 397,016	r 431,349	452,171
Oceania:					
Australia	16,757	17,197	18,288	21,260	22,292
Fiji Islands	---	---	---	182	235
New Zealand	3,817	3,700	4,233	4,620	4,937
Total	20,574	20,897	22,521	26,062	27,464
World total (estimate)	r 1,956,384	r 2,102,236	r 2,216,180	r 2,434,019	2,544,723

e Estimate. p Preliminary. r Revised.
[1] Compiled mostly from data available August 1966.
[2] Sales, including imported clinker.
[3] Year ended March 20 of year following that stated.

Greece.—The Greek Ministry of Industry approved establishment of a $5.8 million cement plant on the island of Crete. American Cement Corp. negotiated a $13 million joint venture to construct a new cement plant in Greece. General Cement Co., S.A., obtained a loan of $2.5 million from the Export-Import Bank of Washington to expand annual capacity from 7 to 10.5 million barrels per year. Titan Cement Co. announced a $7.5 million expansion and modernization program.

Italy.—Cementir Co. opened its new cement plant near Taranto. The $19.2 million plant was planned to be expandable to a capacity of 11.7 million barrels per year.

Netherlands.—The two cement manufacturing companies, N.V. Eerste Nederlandsche Cement Industrie at Maasstricht and N.V. Cementfabriek Ijmuiden at Ymuiden, were described. Total capacity of the Dutch cement industry will in a few years be 3 million tons per year.[9] A new operation at Roxenburg near Rotterdam will manufacture refractory cement at a rate of 330,000 tons per year.

Norway.—A/S Dalen Portland Cementfabrik ordered a 23-foot-diameter Aerofall mill for its cement plant in Brevick. The mill was to be shipped from Great Britain.

[9] Corper, M. Dutch Cement Production and Use. Cement, Lime and Gravel (London), v. 40, No. 2, February 1965, pp. 63–64.

Poland.—It was expected that the Polish cement industry would be turning out 11.5 million tons of cement annually by 1970. A big cement plant to be built near Barcia will have an annual capacity of 1.2 million tons.

United Kingdom.—The Cement Division of Vickers Ltd. ordered equipment needed for doubling the capacity at Whitehaven, bringing the capacity to 400,000 tons per year each of sulfuric acid and cement clinker. The first asbestos cement factory in Northern Ireland was announced by Turners Asbestos Cement Co. Ltd.

U.S.S.R.—A huge cement works was commissioned in Kemerovo. It will produce 2.4 million tons of high-grade cement a year.

Yugoslavia.—Production was expected to be maintained at the 3-million-ton level in 1965, with imports rising to 550,000 tons. A new cement works was to be erected at Usje, near Skopje. The plant will have a capacity of 1,000 tons per day and is expected to cost 10,000 million dinars.

AFRICA

Dahomey.—Dahomean Government sources indicated possible establishment of a 200,000-metric-ton cement plant at Yamaïgo Onigbolo, near Pobe in southeastern Dahomey, to supply cement requirements of Dahomey and Togo.

Ethiopia.—A new 70,000-ton cement plant near Massawa was completed in 1965. The new 70,000-ton plant at Addis Ababa was in operation during 1965.

Ghana.—Tema Cement Works began operating in 1965. When completed, this $980,000 plant will be capable of producing 200,000 long tons of cement per year.[10]

Mali.—A protocol agreement was signed for construction of a Soviet-financed cement works. The plant will have an annual capacity of 270,000 barrels and cost about $6 million.

South Africa, Republic of.—An expansion program costing $840,000 was underway by White's South Africa Portland Cement Co. Ltd., to increase productive capacity from 800,000 to 1.1 million tons per year. Eastern Province Cement Co. announced a $2.8 million expansion at the Port Elizabeth plant. With the completion of these projects, annual capacity of the South African cement industry will be nearly 5 million tons.

Tanzania.—A cement plant being constructed near Dar es Salaam was scheduled to begin operating in early 1966 with an initial output of 150,000 long tons, expandable to 300,000 tons.

Zambia.—Chilanga Cement Ltd., announced plans to erect a cement plant at Ndola, in addition to its existing facilities near Lusaka. The new plant will represent an investment of $5.6 to $8.4 million eventually.

ASIA

China.—China's cement production was estimated at 10 to 11.25 million tons in 1965, a 25-percent increase over that of 1964. About 80 small plants and 10 large and medium-sized plants, have been set up in various localities.

India.—The Indian cement industry currently consists of 37 plants (34 privately owned and 3 in the public sector) with a combined installed capacity of 10.5 million tons and an annual production of about 9.5 million tons.

Iraq.—A cement plant, to be established as a joint Iraqi-Kuwaiti venture, was being planned for erection at Safwan near the Iraq-Kuwait border.

Israel.—The Nesher Works of Israel Portland Cement Ltd. at Ramle was described. A fourth kiln was added to the company's Haifa plant. Combined output of the Haifa and Ramle plants was expected to reach 1.5 million metric tons in early 1966.[11]

Japan.—A new plant was being built by Chichibu Cement Co. Ltd. at Kumagaya, near Tokyo. The $27.8 million plant was scheduled to have a production capacity of 150,000 tons per month. The modern Fujiwara plant of the Onoda Cement Co. Ltd. was described. The capacity of this plant in 1965 was 35,180 barrels per day.[12]

Korea, South.—The Korean cement industry requested permission from the Government in early 1965 to increase the local price of cement from $.65 to $.85 per bag.

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[10] Mining and Minerals Engineering (London). Cement Grinding Plant at Tema. V. 1, No. 15, November 1965, p. 597.

[11] Crombie, Philip. Israel's Nesher Works. Miner. Processing, v. 6, No. 5, May 1965, pp. 52–53.

[12] Asano, Todashi. Onoda Cement Company's Lime Calcination Process In Cement Manufacture. Pit and Quarry, v. 58, No. 1, July 1965, pp. 184–192.

Three of Korea's five cement plants had temporarily suspended operations. Korean cement manufacturers protested a shipment of 88,000 tons of American cement for Eighth Army use, part of a 500,000-ton contract with Kaiser Cement & Gypsum Corp.

Malaysia.—Pan-Malaysia Cement Works Ltd., began full production at an annual estimated capacity of 400,000 long tons. Tosek Cement Ltd., at Ipoh, planned a $3.3 million expansion that will more than double present output of 500 long tons per day. Other Malaysian plants are Malayan Cement Ltd., 240,000 tons; Malaya Industrial & Mining Corp. Ltd., 60,000 tons; and Singapore Cement Ltd., 200,000 tons.[13]

Pakistan.—International Finance Corp. announced that it would help finance a $4.8 million expansion program planned by Ismail Cement Industries Ltd., in West Pakistan. Pan-Malaysia Cement Works Ltd., was planning a 300,000-ton grinding plant at Chittagong.

Philippines.—Eight new cement plants will be operating in the Philippines within 2 years, an increase in annual capacity of over 62 million bags. The new plants are Mindanao Portland Cement Corp., Pacific Cement Corp., Diamond Cement Corp., Island Cement Corp., BCI Davano Cement Corp., Hi Cement Corp., Luzon Cement Corp., and Marinduque Mining & Industrial Corp.

Taiwan.—The Taiwan cement industry set a production target of 2.5 million tons for 1965, of which at least 880,000 tons was to be exported.

Turkey.—The Nigde cement plant was in operation, increasing the number of producing units in Turkey to 19, and the annual capacity of the industry to 3.1 million metric tons.

Yemen.—The U.S.S.R. was contemplating the construction of an 80,000-metric-ton-per-year cement plant near Bodjil on the Hodeida-Sanaa road.

OCEANIA

Australia.—Cement manufacture in Queensland had increased to 620,000 tons in 1964 and was expected to reach 1 million tons per year by 1969. Queensland Cement & Lime Co. Ltd. announced a $4 million expansion program aimed at bringing capacity up to 750,000 tons per year by 1969.

Goliath Portland Cement Co. Ltd. planned a new 300,000-tons-per-year cement plant at the Railton Works, Tasmania. An Australian contract for £2 million was awarded to Humphreys & Glasgow Ltd., Sydney.

TECHNOLOGY

CEMENT MANUFACTURE AND PLANTS

Automation and computer control of cement plants continued to be an important feature of cement technology. A static control system used for cement transfer equipment was described at the Lone Star Cement Corp. plant at Nazareth, Pa.[14]

Digital control systems for proportioning raw mill feeds were compared with analog instrumentation. Both systems are considered reliable.[15] A digital computer installation for controlling raw materials, feeds, and calculating kiln settings was described at the Penn-Dixie Cement Co. plant at Petoskey, Mich.[16]

A complete digital computer control method for operating a rotary cement kiln was described. Programs were developed from experience with an International Business Machines Corp. IBM 1720 system at Northwestern States Portland Cement Co., Mason City, Iowa.[17] Cement automation system fundamentals were described. These functions are (1) kiln feed mix composition, (2) kiln and cooler control, (3) alarms and production logs, (4) quarry rock mix blending, and (5) control of grinding mill load.[18]

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[13] Tao, H. S. A New Portland Cement Plant in Malaysia. Pit and Quarry, v. 58, No. 5, November 1965, pp. 82–90.

[14] Hoy, R. B. Operating Experience with a Static Control System for Cement Transfer. Miner. Processing, v. 6, No. 1, January 1965, pp. 15–19.

[15] McEnvoy, Leo D. Digital vs. Analog Proportional Feed Control. Miner. Processing, v. 6, No. 4, April 1965, pp. 19–22.

[16] Peirce, J. W. The Computer and the Cement Plant. Pit and Quarry, v. 57, No. 10, April 1965, pp. 125, 127, 147.

[17] Johnson, R. L., and R. J. Lyle. Installation of a Computer for Kiln Control (A Method). Miner. Processing, v. 8, No. 8, August 1965, pp. 14–30.

[18] Rich, E. A. E. Cement Automation 1965. Miner. Processing, v. 6, No. 12, December 1965, pp. 16–24.

The gamma-ray density gage and optical and two-color pyrometer have been applied to cement kiln control, measuring the specific gravity and free lime content. Kiln exit gas and shell radiation temperatures are also measured.[19] Maintenance of a computer control room was described at Southern Cement Co. in Atlanta, Ga.[20]

A complete survey of cement kiln refractories was published. Subjects covered included high temperature calcination, early kilns, early refractory linings, sintering and solid state reactions, requirements of cement kiln refractories, slag action, and refractory engineering problems.[21]

The performance of a modern vertical kiln was described. Its advantages are low capital investment, economic fuel consumption, no separate cooler, unparalleled versatility, and uniform clinker quality.[22]

New developments in fine grinding equipment enable grinding a wide range of materials. Disintegration is achieved by impact pulverization.[23] Chemical additives are being used by Soviet chemists to change the surface of cement clinkers. This improves the strength and setting qualities and accelerates the grinding rate.[24]

The electrical design features of a cement plant were described, including power distribution, plant control, process control instrumentation, and control room.[25] A seven-story-high dust collector has shown many operating and economic advantages. Glass-bag dust collector systems have been perfected.[26]

A roundtable discussion on cement plant design was held at the cement industry technical conference in Allentown, Pa. Consensus was that computer usage will continue to grow in importance. A practical limit to kiln size may be reached by transportation problems. Vertical kilns are preferred in some foreign countries; however, the greater capacity of a rotary kiln is usually needed in the United States.[27]

CEMENT CHEMISTRY AND RESEARCH

The Stanton Walker lecture described the use of microscopical methods for diagnosing concrete failures and for examining air void and cement content in hardened concrete. Petrographic examination is most helpful in determining the proportions of cement and water used in batching concrete.[28] The Eighth Conference on the Silicate Industry, held at the House of Engineering, Budapest, Hungary, described the structure of hardened portland cement, and material transport and homogenization in the cement industry.[29]

A major research project into the measurement of concrete strength and curing has been conducted at the University of Maryland.[30]

Methods of evaluating the tensile strength of concrete were compared in another investigation.[31]

New compounds for studying the properties of portland cement constituents were prepared. These compounds control the setting rate of cement.[32] An X-ray spectrograph has been successfully applied to determining the cement content of hardened concrete. Cement content formulas were developed.[33]

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[19] Gieskieng, D. H. Literweight and Kiln Control. Miner. Processing, v. 6, No. 12, December 1965, pp. 26–30.
[20] McSpadden, M. Maintenance Aspects of Solid State Controllers and Related Instrumentation. Miner. Processing, v. 6, No. 10, October 1965, pp. 32–35.
[21] Gilbert, W. Cement Kiln Refractories. Cement, Lime and Gravel (London), v. 40, No. 5, May 1965, pp. 161–172.
[22] Gottlieb, S. How Good is the Modern Vertical Kiln? Rock Products, v. 68, No. 5, May 1965, pp. 89–91.
[23] Towne, F. T. Fine Grinding by Impaction. AIME, Soc. of Min. Eng., preprint No. 65 H 53, February 1965, 17 pp.
[24] Shaw, K. Use of Surface-Active Agents for Rapid Fine Grinding of Cement Clinkers. Cement, Lime and Gravel (London), v. 40, No. 10, October 1965, pp. 358–359.
[25] Herz, J. H., R. D. Miller, and D. B. Carson. Electrical Design Considerations for the Colton Cement Plant. Miner. Processing, v. 6, No. 5, May 1965, pp. 42–47.
[26] Rock Products. Giant Portland Cuts Costs, Ups Efficiency, With Glass-bag Dust Collector. V. 68, No. 2, February 1965, pp. 90, 92.
[27] Rock Products. What's Ahead for Cement Plant Design? V. 68, No. 11, November 1965, pp. 80–86, 112.
[28] Mielenz, R. C. Diagnosing Concrete Failures, Parts I and II. Cement, Lime and Gravel (London), v. 40, Nos. 4–5, April–May 1965, pp. 179–187.
[29] Hungarian Scientific Society of the Silicate Industry. Cement, Lime, and Gravel (London). Internat. Conf. on the Silicate Industry, v. 40, No. 10, October 1965, pp. 349–350.
[30] An Investigation into the Measurement of Concrete Strength. Cement, Lime, and Gravel (London), v. 40, No. 11, November 1965, p. 391.
[31] Pincus, G., and Hans Gesund. Evaluating the Tensile Strength of Concrete. Materials Research and Standards, v. 5, No. 9, September 1965, pp. 454–458.
[32] Lorant, M. Development of the First Calcium Aluminate Sulphates Free of Carbon Dioxide for Portland Cement Research Studies. Cement, Lime, and Gravel (London), v. 40, No. 2, February 1965, p. 67.
[33] Mander, J. E., and D. Y. MacIver. Determination of Cement Content in Hardened Concrete by X-Ray Spectrograph. Pit and Quarry, v. 58, No. 4, October 1965, pp. 127–133.

Advances in cement and concrete technology were summarized. Many new improvements, due to research and better knowledge of cement chemistry, have become possible.[34]

Portland cement chemistry was analyzed using X-ray diffraction. Soda contents were determined using a flame photometer.[35] Studies of hydration of cement constituents were conducted on calcium aluminoferrites. X-ray diffraction was used.[36]

Samples of calcium aluminate monosulfate were prepared and analyzed. This aided in studying the compounds present in dry and hydrated portland cement.[37] Differential thermal analysis was applied to qualitative studies of the hydration reactions in cement pastes. Materials analyzed included gypsum, ettringite, monosulfate, and different types of cement pastes.[38]

A hitherto unreported cement compound was detected, occurring in hydrothermally treated cements or blast furnace slags. Analysis showed it to be a gehlenite hydrate.[39] An apparatus for measuring the density of concretes by gamma-ray transmission was described.[40]

A new book describing recent research on and the physico-chemical and mechanical properties of cement and concrete materials was published.[41]

CEMENT PRODUCTS

A hydrophobic cement was developed by adding surface-active synthetic fatty acids to cement clinkers. These chemicals improve the plasticity and workability of cements, raise its strength and reduce its shrinkage, and increase frost resistance.[42] Scientists of the Department of Agriculture have formulated linseed oil compositions which emulsify and aid in curing concrete. Strength is improved.[43]

The science of comminution as applied to the cement industry was explained. An equation for the efficiency of cement grinding was evolved.[44] Techniques for the measurement of physical properties of portland cement powder, particle size and shape, surface area, density, dustability, and flow and shear strength are quantified.[45]

The Portland Cement Association described a project on the development of design criteria for reinforced concrete corbels. Complete specifications are given.[46] Prestressing to control shrinkage cracks in drying concrete became an important technical development. Careful engineering, good design of concrete mixes, and precasting or prestressing are effective.[47]

The British standard code of practice for the structural precast concrete industry was described. Sections include materials, standard mixes, design, and curing.[48] Progress in prestressed concrete includes new design criteria for reinforcing and large panel construction. Work is continued by the International Federation of Prestressed Concrete, meeting in Naples and London.[49]

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[34] Rockwood, N. C. Half Century of Cement and Concrete Research. Rock Products, v. 68, No. 10, October 1965, pp. 24, 110.

[35] Conwicke, J. E., and D. E. Day. Crystalline Solubility of Soda in Tricalcium Aluminate. J. Am. Ceram. Soc., v. 47, No. 12, December 1964, pp. 654–655.

[36] Lorant, M. The Chemistry of Hydration of Cement Constituents. Cement, Lime, and Gravel (London), v. 40 No. 1, January 1965, pp. 27–28.

[37] Berman, H. A. Preparation of Carbonate-Free Complex Calcium Aluminate. NBS J. Res. V. 69A (Phys. and Chem.), No. 1, January–February 1965, pp. 45–51.

[38] Kalousek, G. L. Analyzing SO_3-Bearing Phases in Hydrating Cements. Mat. Res. and Standards, v. 5, No. 6, June 1965, pp. 292–304.

[39] National Bureau of Standards. Cement Study Reveals New Compound. Tech. News Bull. V. 49 No. 7, July 1965, p. 116.

[40] Preiss, K. Measuring Concrete Density by Gamma Ray Transmission. Mat. Res. and Standards, v. 5, No. 6, June 1965, pp. 285–291.

[41] Neville, A. M. Properties of Concrete. John Wiley & Sons, Inc., New York, 1964, 534 pp.

[42] South African Mining and Engineering Journal (Johannesburg). Hydrophobic Cements. V. 76, No. 3783, Aug. 6, 1965, p. 1807.

[43] Lorant, M. New Linseed-Oil Preparations to Treat and Cure Concrete. Cement, Lime and Gravel (London), v. 40, No. 11, November 1965, p. 392.

[44] Pilpel, N. Powder Science in the Cement Industry. Part 1. Comminution. Cement, Lime, and Gravel (London), v. 40, No. 2, February 1965, pp. 57–62.

[45] Pilpel, N. Powder Science in the Cement Industry. Part II: Portland Cement Powder. Cement, Lime, and Gravel, (London), v. 40, No. 11, November 1965, pp. 379–384.

[46] Kriz, L. B., and C. H. Raths. Connections in Precast Concrete Structures—Strength of Corbels. Portland Cement Association (Skokie, Ill.), Bull. D85, February 1965, 61 pp.

[47] Engineering News-Record. Prestressing Limits Slab Cracks—California Attacks Drying Shrinkage. V. 174, No. 25, June 24, 1965, pp. 24–29.

[48] Kolek, J. The Structural Use of Precast Concrete. Cement, Lime, and Gravel (London), v. 40, No. 5, May 1965, pp. 189–190.

[49] Cement, Lime, and Gravel (London). Recommendations for Design and Construction of Prestressed Concrete Structures. V. 40, No. 11, November 1965, p. 393.

Chromium

By John L. Morning [1]

The year was marked by relatively stable prices both for chromite and for chromium alloys. High-quality U.S.S.R. chromite set the level of world prices. After a price adjustment at the beginning of the year, chromium ferroalloy prices were stable except for minor changes. When unilateral independence was declared in Southern Rhodesia at yearend, the uncertainty of the political situation brought indications of higher chromite prices for 1966.

Domestic consumption of chromite was the highest since 1957 with most being consumed in chromium ferroalloys.

Imports for consumption of low-carbon ferrochromium increased sharply and were the highest on record. In contrast, reduced imports of high-carbon ferrochromium continued the downward trend that started in 1960.

Table 1.—Salient chromite statistics
(Thousand short tons)

	1956–60 (average)	1961	1962	1963	1964	1965
United States:						
Exports	4	5	3	10	6	7
Imports for consumption	1,732	1,329	1,446	1,391	1,428	1,518
Consumption	1,477	1,200	1,131	1,187	1,451	1,582
Stocks Dec. 31: Consumer	1,578	1,633	1,700	1,583	1,287	1,094
World: Production	4,622	4,630	4,790	4,330	4,680	5,370

Legislation and Government Programs.—Barter contracts for high- and low-carbon ferrochromium were signed by the Department of Agriculture early in January; negotiations involving three countries were initiated in fiscal year 1964. The contracts call for delivery of ferrochromium produced from Turkish chromite with payment in surplus wheat exported to Israel. The contracts valued at $1,703,000 were to be concluded by October 1966.

The General Services Administration (GSA) secured congressional approval October 9 (Public Law 89–247) for a long-range program to dispose of 659,100 tons of chemical-grade chromite. Under provisions of the program, 20,000 tons were offered for sale on competitive bid November 5. All bids were below market price and were rejected by GSA. The material was to be reoffered at a later date.

A joint resolution passed by Congress October 9 (Public Law 89–252) authorized GSA to sell 33,552 pounds of low-grade exothermic chromium metal declared excess to stockpile needs. In response to its November 5 offering, GSA announced that no acceptable bids were received. The material was to be readvertised for sale in 1966.

The Department of the Treasury determined that ferrochromium containing less than 3 percent carbon, imported from Norway, was not being sold at less than fair value within the meaning of the Antidumping Act, 1921. This was in reply to a claim filed June 29, 1964.

[1] Commodity specialist, Division of Minerals.

Table 2.—U.S. defense materials inventories and objectives
(Thousand short tons)

Type of material	Objective	Inventory by program, Dec. 31, 1965: National stockpile	DPA	CCC and supplemental stockpile	Total
Chromite, chemical: Stockpile grade	591	559		684	1,243
Chromite, refractory:					
Stockpile grade	1,425	1,047		180	1,227
Nonstockpile grade		(1)			
Chromite, metallurgical:					
Stockpile grade	2,509	2,299	(1)	373	2,672
Nonstockpile grade		780	986		1,766
Ferrochromium, high-carbon:					
Stockpile grade	65	125		264	389
Nonstockpile grade		(1)			
Ferrochromium, low-carbon:					
Stockpile grade	80	107		189	296
Nonstockpile grade		21			21
Ferrochromium silicon: Stockpile grade	58	26		33	59
Chromium, metal electrolytic: Stockpile grade	3	1		2	3
Chromium metal, aluminothermic: Stockpile grade	3			4	4

[1] Less than ½ unit.

DOMESTIC PRODUCTION

The United States continued to depend solely on imported chromite. Ferrochromium and other chromium alloys were produced by eight companies, all in the eastern half of the United States. Chromium metal was produced by two companies. Basic refractory bricks or shapes containing chromite were manufactured by 11 companies. Sodium bichromate was produced by four firms for direct consumption or to produce other chromium chemicals such as chromic acid for chromium-plating solutions, colored pigments, and chromic oxide.

A major expansion to increase the production capacity of sodium bichromate, base material for chromium chemicals, was announced by Allied Chemical Corp. for its Baltimore, Md. plant.

CONSUMPTION AND USES

Domestic consumption of chromite was the highest since 1957. The metallurgical industry consumed 57 percent; the refractory industry consumed 29 percent; and the chemical industry consumed 14 percent.

The metallurgical industry consumed 891,000 tons of chromite containing 304,000 tons of chromium ferroalloys and chromium metal. An additional 17,000 tons of chromite was added directly to steel. Of the 891,000 tons consumed in making chromium ferroalloys and metal, 824,000 tons (averaging 50.1 percent Cr_2O_3) was classified by consumers as metallurgical-grade ore; 52,000 tons (averaging 48.3 percent Cr_2O_3) was classified as chemical-grade ore; and 19,000 tons (averaging 39.5 percent Cr_2O_3) was classified as refractory-grade ore. Eighty-eight percent of the metallurgical-grade ore had a chromium to iron ratio of 3:1 and above, and 8 percent had a ratio between 2:1 and 3:1, and 4 percent had ratio of less than 2:1.

Producers of chromite-bearing refractories consumed 452,000 tons of ore containing 109,000 tons of chromium. An additional 5,000 tons of ore containing 1,000 tons of chromium was used directly in furnace repairs.

The chemical industry consumed 217,000 tons of chromite containing 67,000 tons of chromium in producing 143,000 tons of chemical (sodium-bichromate equivalent).

The principal chromium ferroalloys were primarily used in stainless steel production. High-carbon ferrochromium was used in engineering steels with medium to-high-carbon and low-chromium contents and in stainless steel. Low-carbon ferrochromium was used in heat and corrosion-resistant stainless steels, especially those with low-carbon specifications. In stainless steel production, ferrochromium silicon was used as a slag treating agent to reduce the chromium content of the slag after the oxygen blowing of the steel bath had reduced the carbon content.

Gulf & Western Industries, Inc., and Amerace Corp. announced construction of plants for chromium plating of plastic parts.

Table 3.—Consumption of chromite and grade of ore used by primary consumer groups in the United States

(Thousand short tons)

Year	Metallurgical industry		Refractory industry		Chemical industry		Total	
	Gross weight	Average Cr_2O_3 (percent)	Gross weight	Average Cr_2O_3 (percent)	Gross weight	Average Cr_2O_3 (percent)	Gross weight	Average Cr_2O_3 (percent)
1956–60 (average)	926	46.8	398	34.8	153	45.3	1,477	43.4
1961	662	46.5	375	34.6	163	45.2	1,200	42.6
1962	590	46.6	365	35.0	176	45.3	1,131	42.7
1963	632	48.7	368	34.6	187	45.1	1,187	43.8
1964	832	49.0	430	33.8	r 189	45.1	r 1,451	44.0
1965	907	49.8	457	35.2	218	45.0	1,582	44.9

r Revised.

Table 4.—Production, shipments, and stocks of chromium ferroalloys and chromium metal in 1965

(Short tons)

Alloy	Production		Shipments	Producer stocks Dec. 31
	Gross weight	Chromium content		
Low-carbon ferrochromium	134,378	96,245	125,714	12,929
High-carbon ferrochromium	170,514	115,061	165,170	20,436
Ferrochromium silicon	77,640	31,186	75,792	8,246
Other [1]	6,693	4,748	7,409	943
Total	389,225	247,240	374,085	42,554

[1] Includes chromium briquets, chromium metal, exothermic chromium additives, and other miscellaneous chromium alloys.

Table 5.—Consumption of chromium ferroalloys and chromium metal in the United States, in 1965 by major end uses

(Short tons)

Use	Low-carbon ferro-chromium	High-carbon ferro-chromium	Ferro-chromium silicon	Exothermic ferro-chromium silicon	Chromium briquets	Other [1]	Total
Stainless steels	131,779	76,533	65,632		487	1,661	276,092
High-speed steels	769	996	72			18	1,855
Other tool steels	1,257	1,748	83			19	3,107
Other alloy steels [2]	19,810	47,534	8,307	5,957	603	9,683	91,894
Gray and malleable iron	650	4,876	115	8	491	711	6,851
High-temperature alloys	7,262	802	289		10	2,109	10,472
Nickel-base alloys	470	117				87	674
Other nonferrous alloys [3]	719	1,708			4	1,152	3,583
Total	162,716	134,314	74,498	5,965	1,595	15,440	394,528
Chromium content	112,586	87,719	30,496	2,541	872	8,912	243,126

[1] Includes exothermic high- and low-carbon ferrochromium, chromium metal, and other chromium alloys.
[2] Includes quantities that were believed used in producing high-speed and other tool steels and stainless steels because some firms failed to specify individual uses.
[3] Includes cutting and wear resistant alloys, hard-facing alloys welding rods, electrical-resistance alloys, and other nonferrous alloys.

STOCKS

Consumers reduced stocks of chromite ore thus continuing the trend that started in 1963; however, stocks remained substantial at yearend. Based on 1965 consumption, the industrial inventory of chromite represented 6 months consumption for metallurgical use, 13 months consumption for refractory use, and 8 months consumption for chemical use.

Producer stocks of ferrochromium products increased 56 percent over those of 1964 while stocks in consumers inventories increased slightly.

Stocks of chromium chemicals at producers' plants totaled 6,168 tons (sodium-bichromate equivalent) at yearend.

Table 6.—Consumers' stock of chromite, Dec. 31

(Thousand short tons)

Industry	1961	1962	1963	1964	1965
Metallurgical	773	771	686	509	443
Refractory	728	764	723	600	509
Chemical	132	165	174	178	142
Total	1,633	1,700	1,583	1,287	1,094

Table 7.—Consumers' stocks of chromium ferroalloys and chromium metal, Dec. 31

	1961	1962	1963	1964	1965
Low-carbon ferrochromium	10,006	5,531	7,293	12,219	13,630
High-carbon ferrochromium	10,086	5,684	6,049	13,862	14,707
Ferrochromium silicon	5,022	2,119	2,558	6,455	4,673
Exothermic ferrochromium silicon	822	729	610	775	987
Chromium briquets	513	409	276	328	378
Other (including chromium metal, exothermic high- and low-carbon ferrochromium, and other chromium alloys)	1,754	1,330	1,477	1,675	1,779
Total	28,203	15,802	18,263	35,314	36,154

PRICES

High-grade ore from U.S.S.R. set the pace for most world chromite prices. Published chromite prices remained relatively stable during the year with only minor adjustments for some grades. E&MJ Metal and Mineral Markets nominal quotations for chromite ores in January and December are shown in table 8. Turkish chromite was reportedly virtually sold out for 1965 delivery by early March. The price of the remainder fluctuated during the year, but very little was available for sale. The price increase for Transvaal ore was said to be due to higher inland and ocean freight rates. The unsettled political situation in Southern Rhodesia during the last quarter of the year tended to increase contract prices for 1966 delivery.

Most chromium ferroalloy prices were increased, effective January 1. Base prices for lump material in carload lots, f.o.b. shipping point, per pound of contained chromium were: High-carbon ferrochromium (67 to 71 percent chromium, all grades carbon) 19 cents nominal; low-carbon ferrochromium (0.025 percent carbon) 25.5 cents; low-carbon ferrochromium (0.05 percent carbon) 24.5 cents; charge chromium (63 to 71 percent chromium, 4.5 to 6 percent carbon, 3 percent maximum silicon) 15.5 cents; blocking chromium (10 to 14 percent silicon) 17.5 cents; and refined chromium (61 to 68 percent, chromium, 4.25 percent carbon), 22 cents. The same prices were quoted at yearend. Electrolytic chromium metal (98.5 percent chromium) and aluminothermic chromium metal (98.5 chromium, 0.5 percent carbon) were quoted at $1.15 to $1.19 per pound delivered, throughout the year.

In August, several ferroalloy producers announced simplified pricing schedules for chromium alloys which consolidated various size ranges into groups that sold at the same price, thereby, reducing the number of individual prices for a particular alloy.

The price of sodium bichromate, base material of the chromium chemical industry, remained unchanged throughout the year at 13 cents per pound for carload lots.

Table 8.—Price quotations for various grades of foreign chromite in 1965

Source	Cr_2O_3 (percent)	Cr/Fe ratio	Price per long ton [1] Jan. 1	Price per long ton [1] Dec. 31
Southern Rhodesia	48	3:1	$32.00–$35.00	$31.00–$35.00
South Africa, Republic of (Transvaal)	44	----------	18.00– 19.00	20.00– 21.50
Turkey	48	3:1	30.00– 32.00	29.50– 31.50
U.S.S.R.[2]	55	4:1	30.50– 33.00	30.50– 33.00

[1] Quotations are on a dry basis, subject to penalties if guarantees are not met, f.o.b. Atlantic ports.
[2] First quoted, July 19.

Source: E&MJ Metal and Mineral Markets.

FOREIGN TRADE

Exports.—Exports of chromite ore and concentrate amounted to 7,047 tons valued at $284,766 while reexports of chromite ores and concentrates totaled 94,963 tons valued at $3,719,364. Canada, Mexico, and Venezuela were the main recipients of these shipments. Chromium and chromium alloys, wrought or unwrought, and waste and scrap were exported to 17 countries and totaled 221 tons valued at $151,-042. West Germany received 77 percent of the total. Exports of sodium chromate and bichromate totaled 4,016 tons, valued at $862,285. Canada (71 percent), Mexico (9 percent), Colombia (6 percent) and Chile (6 percent) received 92 percent of the total.

Table 9.—U.S. exports of chromite ore and concentrate

Year	Exports		Reexports	
	Short tons	Value	Short tons	Value
1956–60 (average)	3,909	$210,294	23,337	$927,727
1961	5,201	344,907	35,890	1,373,083
1962	2,686	108,112	51,254	2,032,941
1963	9,726	352,181	63,764	2,505,000
1964	6,366	240,512	32,116	1,256,282
1965	7,047	284,766	94,963	3,719,364

Imports.—Chromite ore and concentrate imported into the United States increased 6 percent over that of 1964. Metallurgical-grade ore (over 46 percent Cr_2O_3) comprised 45 percent of the total imports, refractory-grade ore (under 40 percent Cr_2O_3) comprised 20 percent, and chemical-grade ore (40 to 46 percent Cr_2O_3) comprised 35 percent. The Republic of South Africa (32 percent), Southern Rhodesia (22 percent), Philippines (18 percent), and the U.S.S.R. (16 percent) supplied 88 percent of total imports. Imports for consumption of chromium, unwrought, and waste and scrap not alloyed, totaled 1,010 tons valued at $1,522,023; 449 tons came from the United Kingdom, 337 tons from Japan, 198 tons from France, and 27 tons from West Germany. Imports of sodium chromate and bichromate, totaled 18,000 tons valued at $3,204,860. Italy (4,960 tons), Japan (4,922 tons), West Germany (3,927), Republic of South Africa (1,996 tons), and U.S.S.R. (1,643 tons) accounted for 93 percent of the total. Imports of pigments containing chromium were chromium oxide green, 134 tons valued at $91,478; chrome yellow, 873 tons valued at $414,895; chromium zinc yellow, 408 tons valued at $162,143; and chrome green, 52 tons valued at $32,024. Chromium carbide imports were 43 tons valued at $72,944.

Table 10.—U.S. imports for consumption of chromite, by grades and countries, in 1965

Country	Not more than 40 percent chromic oxide (Cr_2O_3)			More than 40 percent but less than 46 percent chromic oxide (Cr_2O_3)			46 percent or more chromic oxide (Cr_2O_3)			Total		
	Short tons		Value	Short tons		Value	Short tons		Value	Short tons		Value
	Gross weight	Cr_2O_3		Gross weight	Cr_2O_3		Gross weight	Cr_2O_3		Gross weight	Cr_2O_3	
Europe: U.S.S.R.							241,533	133,617	$4,781,876	241,533	133,617	$4,781,876
Africa:												
South Africa, Republic of	27,610	9,299	$245,606	338,654	148,491	$3,396,732	114,789	55,258	1,886,877	481,053	213,048	5,529,215
Sudan							10,063	5,132	197,670	10,063	5,132	197,670
Zambia, Southern Rhodesia, and Malawi				84,690	37,605	1,664,138	244,106	124,313	4,473,172	328,796	161,918	6,137,310
Total	27,610	9,299	245,606	423,344	186,096	5,060,870	368,958	184,703	6,557,719	819,912	380,098	11,864,195
Asia:												
India							14,792	8,323	386,304	14,792	8,323	386,304
Philippines	269,585	85,732	4,978,414				8,960	5,197	168,000	278,545	90,929	5,146,414
Turkey	6,720	2,509	96,350	114,575	49,736	1,945,278	42,261	20,285	1,018,919	163,556	72,530	3,060,547
Total	276,305	88,241	5,074,764	114,575	49,736	1,945,278	66,013	33,805	1,573,223	456,893	171,782	8,593,265
Grand total	303,915	97,540	5,320,370	537,919	235,832	7,006,148	676,504	352,125	12,912,818	1,518,338	685,497	25,239,336

Table 11.—U.S. imports for consumption of ferrochromium, by countries

Year and country	Low-carbon ferrochromium (less than 3 percent carbon): Short tons, Gross weight	Short tons, Chromium content	Value	High-carbon ferrochromium (3 percent or more carbon): Short tons, Gross weight	Short tons, Chromium content	Value
1964:						
Europe:						
France	260	202	$72,311			
Germany, West	432	314	131,102			
Norway	10,453	7,334	2,534,659	219	155	$41,580
Sweden	4,965	3,587	1,228,013			
Switzerland	28	21	8,093			
United Kingdom	(1)	(1)	260			
Total	16,138	11,458	3,974,438	219	155	41,580
Africa:						
South Africa, Republic of	517	288	93,102	6,867	4,141	1,157,035
Zambia, Southern Rhodesia and Malawi	547	436	128,622			
Total	1,064	724	221,724	6,867	4,141	1,157,035
Asia: Japan	1,450	959	329,835	384	259	58,485
Grand total	18,652	13,141	4,525,997	7,470	4,555	1,257,100
1965:						
North America: Canada				79	50	8,155
Europe:						
France	155	113	41,985	55	38	10,694
Germany, West	1,372	1,000	392,663	585	408	114,200
Italy	661	434	173,954	1,653	1,086	276,901
Norway	4,731	3,281	1,189,300	255	186	49,269
Sweden	4,229	3,110	1,199,895			
Yugoslavia	329	240	86,460			
Total	11,477	8,178	3,084,257	2,548	1,718	451,064
Africa:						
Mozambique	1,199	673	248,588			
South Africa, Republic of	26,052	17,201	6,218,966	733	416	87,773
Total	27,251	17,874	6,467,554	733	416	87,773
Asia:						
Japan	9,093	6,040	2,319,382	1,990	1,337	307,804
Turkey	1,951	1,348	510,115			
Total	11,044	7,388	2,829,497	1,990	1,337	307,804
Grand total	49,772	33,440	12,381,308	5,350	3,521	854,796

[1] Less than ½ unit.

WORLD REVIEW

All major producing countries increased their output of chromite in 1965, raising the world estimated production to the highest on record. The Philippines, Republic of South Africa, Southern Rhodesia, Turkey and U.S.S.R. accounted for 83 percent of the world production.

NORTH AMERICA

Greenland.—Extensive deposits of chromite south of Godthaab were reported to be under investigation by Danish interests.

EUROPE

Finland.—The Government-owned Outokumpu Oy completed geological and metallurgical research on the utilization of its large low-grade chromite deposit at Kemi. Metallurgical tests indicated that recovered concentrate was about one-third of the ore mined. According to company plans, between 100,000 and 150,000 tons per year of chromite will be produced, beginning early in 1967. Plans also call for building a ferroalloy plant at Tornio, scheduled to

Table 12.—World production of chromite by countries [1]

(Short tons)

Country	1961	1962	1963	1964	1965 [p] [2]
North America:					
Cuba [e]	28,000	39,000	56,000	56,000	56,000
Guatemala	110	22	–	–	–
United States	[3] 82,000	–	–	–	–
South America:					
Brazil	17,037	27,380	48,546	[r] 28,430	[4] 26,411
Colombia	204	154	121	441	287
Europe:					
Albania	256,241	277,007	[r] 323,657	[e] 342,000	[e] 347,000
Greece (marketable)	34,324	26,633	18,347	[e] 18,000	[e] 18,000
U.S.S.R. [e] [5]	1,015,000	1,270,000	1,355,000	1,435,000	1,565,000
Yugoslavia	119,188	106,974	103,364	97,398	88,021
Africa:					
Malagasy Republic	11,600	20,342	12,346	12,974	2,628
Rhodesia, Southern	590,888	507,685	412,392	493,368	[e] 624,500
Sierra Leone	–	12,621	3,067	–	–
South Africa, Republic of	989,725	1,006,173	873,212	936,468	1,038,498
Sudan	–	8,800	[e] 18,700	18,700	[e] 33,000
United Arab Republic (Egypt)	1,532	–	–	–	–
Asia:					
Cyprus	[r] 19,822	[r] 7,207	[r] 5,411	3,341	5,501
India	[r] 53,732	73,467	71,419	36,844	65,777
Iran [6]	81,268	[e] 99,000	[e] 110,000	[e] 132,000	[e] 165,000
Japan	77,373	64,024	48,205	[r] 48,452	[e] 48,000
Pakistan	28,116	23,671	16,023	[r] 14,884	15,743
Philippines	705,811	585,643	506,094	515,969	611,288
Turkey	443,932	580,964	312,817	454,907	625,078
Viet-Nam, North [e]	32,000	36,000	33,000	33,000	33,000
Oceania:					
Australia	–	413	180	[r] 80	–
New Caledonia	40,413	17,036	–	–	–
World total [e]	[r] 4,630,000	[r] 4,790,000	[r] 4,330,000	[r] 4,680,000	5,370,000

[e] Estimate. [p] Preliminary. [r] Revised.

[1] In addition to countries listed, Bulgaria and Rumania, produce chromite, but data on output are not available; estimates by author of chapter included in total.

[2] Compiled mostly from data available June 1966.

[3] Produced in 1961 for Federal Government only; excludes quantity consumed by American Chrome Company.

[4] Bahia only.

[5] Output from U.S.S.R. in Asia included with U.S.S.R. in Europe.

[6] Year ended March 20 of year following that stated.

be in production by late 1967. The ore reserve of the Kemi deposit has been estimated at 37 million tons.

AFRICA

Rhodesia, Southern. — The unilateral declaration of independence of November 11 brought economic and financial sanction by the United Kingdom and other countries. As a result of these actions no mineral statistics were released after the first 9 months. Based on a 9-month output of 468,328 tons, production was at the rate of 624,500 tons per year. Rhodesia Chrome Mines Ltd., subsidiary of Union Carbide Corp. was reported to have increased its production from under 300,000 tons in 1964 to about 375,000 tons in 1965, with exports of 345,000 tons.

Winsor Ferroalloys (Pvt) Ltd. at Que Que was acquired by a newly formed company, Union Carbide Rhomet (Pvt.) Ltd. The facilities produced ferrochromium silicon from Selukwe ores and will be enlarged to triple its capacity to make other chromium alloys.

Rhodesian Alloys (Pvt) Ltd. announced plans to triple production of low-carbon ferrochromium from 17,000 tons per year to 50,000. Three additional 15,000 kilovolt-ampere furnaces will be installed at the plant at Gwelo.

Development continued on two ore bodies at the mine of the Inyala Chrome Company (Pvt) Ltd., an Associated Ore & Metal Corporation Ltd. subsidiary in the Belingwe district, southwest of Fort Victoria. Mining was started on the No. 1 ore body, producing hard, lumpy, high-grade ore. Fines will be accumulated for processing when the concentrator is completed in 1966.

South Africa, Republic of.—Production of chromite reached 1,038,498 tons, setting a record high. This was the second time that production exceeded 1 million tons, the other year being 1962. Exports totaled 772,960 tons and the United States received 62 percent of this total.

R.M.B. Alloys (Pty) Ltd. subsidiary of Rand Mines Ltd., increased production after an operating loss early in the year. Shipments were made against a record 3,700 ton order of ferrochromium for consignment to various European countries, the United States, and Canada.

ASIA

Iran.—Iran plans to increase chromite exports from 100,000 to 400,000 tons by 1967. By this time a new deep water port with modern materials-handling equipment will be completed at Bandar Abbas on the Persian Gulf. The port is close to the major producing areas around Kerman, Baft, Esfandagegh, and Faryeb. Deposits are estimated at 10 million tons with a proven reserve of 1.2 million tons.

Japan.—The Government's Fair Trade Commission gave permission to a group of 21 ferroalloy producers to form an antidepression cartel to regulate ferroalloy production. The association produces 100 percent of the countries high-carbon ferrochromium and 94 percent of its low-carbon ferrochromium.

Philippines.—Of the total production of chromite in the Philippines during 1965 about 83 percent was refractory grade. The main recipients of refractory-grade exports were the United States, 67 percent; Europe, 21 percent; Japan, 8 percent; and Canada, 3 percent. Japan received all the metallurgical-grade chromite exports. Increased world demand for refractory-grade fines (concentrate) resulted in Consolidated Mines, Inc. expanding its concentrator to 16,300 tons per day. Ore reserve of run-of-mine ore was increased to 3.9 million tons.

Turkey.—Chromite exports in the fourth quarter fell below the rate of the previous 9 months to bring the year's total to 467,678 tons. This represents a 21-percent increase over the exports of 1964, but below the goal of 500,000 tons. Average value of 1965 exports, f.o.b. Turkey, was $18.37 per ton as compared with $17.83 for 1964 exports. Yearend stocks at Turkish ports were reported to be 90,586 tons. The three largest producers, Etibank, Turk Maden A.S., and Koçman Co., probably accounted for 75 percent of the Turkish production.

TECHNOLOGY

The Organization for Economic Cooperation and Development, Paris, France, published papers presented at a seminar on "Modern Scientific Methods of Chromite Prospecting." The reports pointed out that geological conditions under which chromite occurs are complex and uncertain. Furthermore, the physical and chemical properties of chromite are such that indirect prospecting methods are difficult to utilize. Lack of thorough knowledge of ultrabasic rocks has hampered geologists in prospecting for chromite.

Chromite replaced zircon for sand molds and cores to eliminate metal penetration on large, heavy section steel castings.[2] Results of laboratory and foundry tests indicate that chromite has good dimensional stability with no chromium pickup in castings. Chromite also produced a greater chill depth in castings than zircon sand.

A new type of basic refractory made from fused magnesia-chrome grain was developed by the Harbison-Walker Refractories Co. The new refractory, produced from high-purity magnesia-chrome grain, is pressed to high density. Properties of high strength at elevated temperature, good strength at low temperature, resistance to slag attack, and high resistance to thermal shock are reported.

A comprehensive review of super 12-percent chromium steels listing properties, processing, and fabrication data, was published.[3] Some of the properties offered by the super 12-percent chromium steels are as follows: Ability to be heattreated in large sections to over 200,000 pounds per square inch tensile strength; outstanding thermal stability, including high hot ductility and resistance to embrittlement under stress; exceptional resistance to thermal shock and thermal fatigue; better resistance to stress-corrosion cracking than austenitic steels or regular 12-percent chromium steel; and better resistance to oxidation and scaling than lower chromium steels.

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[2] Richard, E. J. Chromite Sand Molds and Cores for Large Steel Castings. Foundry, v. 93, No. 6, June 1965, pp. 52, 55.

[3] Briggs, J. Z., and T. D. Parker. The Super 12% Cr Steels. Climax Molybdenum Co., New York, 1965, 220 pp.

American Society for Testing and Materials compiled and published all of the standards pertaining to alloys of iron-chromium, iron-chromium-nickel, and related alloys, including corrosion- and erosion-resisting and high-temperature-service types.

Cladding of steel products for abrasion or corrosion protection was the subject of several processes. Steel plate was cladded with 40-percent chromium carbide, forming an abrasion-resistant surface.[4] Cladding was applied with an electric arc under a molten welding flux blanket. Chromium-carbide content of the surface layer was controlled to produce random cracking of the cladding. This resulted in low stresses at the root of the crack, allowing the product to be processed through normal fabrication procedures for mild or low-alloy steels. Wear surfaces, such as ore chutes and parts of earthmoving equipment, are major applications.

Weld-overlay stainless steel cladding [5] for corrosion resistance has been demonstrated on processing equipment for resin manufacture, naval stores processing, and petroleum refining. Control of dilution of the welding alloy with the base metal in the molten pool of metal produced by the welding arc has been a major problem. Dilution can now be controlled by increasing the alloying content of the welding rod; making multiple passes with electrodes of intermediate compositions; using tubular welding rods filled with metal powders; or welding a strip of alloy metal to the base metal.

A corrosion-resistant-chromate-type coating for zinc castings subjected to temperatures up to 360° F, was chosen over 40 different types of finishes tested.

A process to coat wire at high speeds with chromate was announced.[6] The continuous process produces a chromate-surface finish with color and corrosion resistance in a single treatment. Wire is passed through a hot alkaline electrolytic bath, water rinsed, and chromate coated by passing the wire through a serrated carbide die. The process is completed by heating the wire to 425° F before water quenching to room temperature.

Decomposition of chromium iodide by Advanced Material Division of Materials Research Corp. produced ultra-high-purity chromium with no single metallic or gaseous impurity greater than 10 parts per million.

Studies [7] of the brittle fracture of high-purity chromium metal were continued.

Chromium can now be plated in a variety of colors. In a newly developed process [8] three variables, amperage, bath temperature, and catalyst, were controlled to produce black, blue, gray, or gold colors. Each color requires a different catalyst with some changes required in operating conditions. Other colors are being developed. The process operates at about room temperature in contrast to 125° F for conventional chrome plating.

Continued interest was shown in a copper-chromite catalyst for reduction of nitric oxide in automobile exhaust gases.[9]

U.S. Department of Agriculture scientists continued development of copper-chromium catalysts for stabilizing flavor of soybean oil. The catalysts are made by reducing metal-salt mixtures of copper and chromium with sodium borohydride.

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[4] Iron Age. Hard Cladding Goes on Steel. V. 196, No. 7, Aug. 12, 1965, p. 142.

[5] Chemical Week. Cladding With Welds. V. 97, No. 8, Aug. 21, 1965, pp. 31–32.

[6] Steel. Continuous Wire Coating Boosts Output Threefold. V. 157, No. 22, Nov. 29, 1965, p. 37.

[7] Garrod, R. I., and H. L. Wain. Dislocation Arrangements and Brittleness in Chromium. J. Less-Common Metals (Amsterdam, Netherlands), v. 9, No. 2, August 1965, pp. 81–94.

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[8] Merriam, J. C. Chrome Plate Deposits in Colors. Iron Age, v. 196, No. 22, Nov. 25, 1965, pp. 64, 65.

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Clays

By James D. Cooper [1]

CONTENTS

The quantity of clays produced in 1965 increased 4 percent, and the value was 6 percent greater than that reported in 1964. The individual types of clay all showed gains in both quantity and value, and with the exception of fire clay, reached record highs. Fuller's earth output showed the greatest percentage increase of 22 percent, mainly because of exceptional demand for absorbent clays for use as floor sweeping compounds and animal litter. Bentonite production increased 9 percent, with gains in all of the major use categories. As usual, the largest quantity increase was for miscellaneous clay, which increased 1 million tons over the 1964 output. The unit values for all types of clay except ball clay declined slightly.

Construction of new clay production plants and clay products plants as well as expansion of existing facilities continued during 1965, and tentative plans for construction of the first commercial-scale alumina-from-clay plant were announced. The initial facility, to be located in Georgia, will use about 1 million tons of clay per year.

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REVIEW OF DOMESTIC PRODUCTION, PRICES, AND FOREIGN TRADE BY TYPE OF CLAY

KAOLIN

Kaolin production, which has grown each year since 1957, continued to increase in both quantity and value in 1965. Paper manufacturers purchased 51 percent of the total output for coating and filling uses.

Table 1.—Salient clay and clay products statistics in the United States
(Thousand short tons and thousand dollars)

	1956–60 (average)	1961	1962	1963	1964	1965
Domestic clays sold or used by producers	47,720	47,389	47,797	50,135	52,947	55,089
Value	$156,882	$156,829	$163,012	$180,810	$192,631	$203,772
Exports	493	559	617	739	848	850
Value	$13,091	$14,285	$16,855	$21,374	$24,973	$25,595
Imports for consumption	167	156	132	126	137	110
Value	$3,040	$3,055	$2,540	$2,413	$2,638	$2,137
Clay refractories, shipments (value)	$187,321	$166,628	$166,095	$179,512	$205,267	$228,876
Clay construction products, shipments (value)	$482,260	$481,200	$512,900	$538,600	$569,200	$578,190

Table 2.—Value of clays produced in the United States, by States
(Thousand dollars)

State	1964	1965	Kinds of clay produced in 1965
Alabama	[1,2] $4,060	[1,2] $4,888	Kaolin, fire clay, bentonite, miscellaneous clay.
Arizona	[2,3] 213	[2] 164	Fire clay, bentonite, miscellaneous clay.
Arkansas	2,152	1,890	Kaolin, fire clay, miscellaneous clay.
California	r 8,433	7,226	Kaolin, ball clay, fire clay, bentonite, fuller's earth, miscellaneous clay.
Colorado	1,275	1,446	Fire clay, bentonite, miscellaneous clay.
Connecticut	262	322	Miscellaneous clay.
Delaware	11	11	Do.
District of Columbia	82	—	
Florida	8,405	9,752	Kaolin, fuller's earth, miscellaneous clay.
Georgia	58,899	63,158	Do.
Idaho	[1,2,3] 25	[1,2,3] 33	Kaolin, fire clay, bentonite, miscellaneous clay.
Illinois	[4] 4,358	[4] 4,601	Fire clay, fuller's earth, miscellaneous clay.
Indiana	2,264	2,160	Fire clay, miscellaneous clay.
Iowa	1,254	1,347	Do.
Kansas	935	953	Do.
Kentucky	[5] 1,801	[5] 2,580	Ball clay, fire clay, miscellaneous clay.
Louisiana	797	936	Miscellaneous clay.
Maine	58	63	Fire clay, miscellaneous clay.
Maryland	[5] 798	[5] 1,088	Ball clay, fire clay, miscellaneous clay.
Massachusetts	174	238	Miscellaneous clay.
Michigan	2,592	2,580	Do.
Minnesota	[3] 319	[3] 311	Fire clay, miscellaneous clay.
Mississippi	6,130	5,925	Ball clay, fire clay, bentonite, fuller's earth, miscellaneous clay.
Missouri	4,874	5,439	Fire clay, miscellaneous clay.
Montana	[2,3] 59	[2] 98	Bentonite, miscellaneous clay.
Nebraska	143	106	Miscellaneous clay.
New Hampshire	40	47	Do.
New Jersey	1,441	1,388	Fire clay, miscellaneous clay.
New Mexico	[3] 167	101	Do.
New York	1,993	1,717	Miscellaneous clay.
North Carolina	[1] 2,064	[1] 2,162	Kaolin, miscellaneous clay.
North Dakota	119	114	Fire clay, bentonite, miscellaneous clay.
Ohio	14,426	14,816	Fire clay, miscellaneous clay.
Oklahoma	[2] 854	[2] 806	Fire clay, bentonite, miscellaneous clay.
Oregon	r 356	359	Bentonite, miscellaneous clay.
Pennsylvania	[1] 15,814	[1] 17,697	Kaolin, fire clay, miscellaneous clay.
South Carolina	8,309	8,539	Kaolin, miscellaneous clay.
South Dakota	1,076	1,220	Bentonite, miscellaneous clay.
Tennessee	[4] 5,576	6,103	Ball clay, fuller's earth, miscellaneous clay.
Texas	[1,4] 6,695	6,865	Kaolin, ball clay, fire clay, bentonite, fuller's earth, miscellaneous clay.
Utah	[1,3] 330	[1,3] 332	Kaolin, fire clay, bentonite, fuller's earth, miscellaneous clay.
Virginia	1,614	1,657	Miscellaneous clay.
Washington	[3] 119	[2,3] 211	Fire clay, bentonite, miscellaneous clay.
West Virginia	[3] 309	[3] 328	Fire clay, miscellaneous clay.
Wisconsin	147	147	Miscellaneous clay.
Wyoming	12,816	13,633	Fire clay, bentonite, miscellaneous clay.
Other [6]	r 7,993	8,215	
Total	r 192,631	203,772	—
Puerto Rico	271	288	Miscellaneous clay.

r Revised.
1 Value of kaolin included with "Other" to avoid disclosing individual company confidential data.
2 Value of bentonite included with "Other" to avoid disclosing individual company confidential data.
3 Value of fire clay included with "Other" to avoid disclosing individual company confidential data.
4 Value of fuller's earth included with "Other" to avoid disclosing individual company confidential data.
5 Value of ball clay included with "Other" to avoid disclosing individual company confidential data.
6 Includes Hawaii, Nevada, and Vermont, and value indicated by footnotes 1 through 5.

Fillers for rubber, plastics, and other products accounted for 19 percent; refractories 12 percent; and various other uses 18 percent.

Imports totaled 91,756 tons, valued at $1,786,000, a decrease of 22 percent in quantity and 21 percent in value compared with 1964 figures. The United Kingdom was the principal supplier, with the other countries, Mexico, Canada, and West Germany accounting for 4 percent of the quantity and 6 percent of the value.

Exports were 192,875 tons worth $6.2 million, an increase of 27 percent in quantity and 34 percent in value compared with 1964 figures. Canada, Mexico, and Japan, the three largest buyers, received 71 percent of the exports compared with 84 percent in 1964.

Prices for kaolin, from Oil, Paint and Drug Reporter on December 27, 1965, were as follows: Domestic, dry-ground, calcined, air-floated, bags, carlots, works, $45 to $68 per ton; dry ground, uncalcined, air-floated, 99 percent through 325 mesh, Georgia, bags, carlots, works, $17.50 per ton; water-ground, washed, bags, carlots, works, $22.50 to $51 per ton. Imported white lump kaolin, bulk, carlots, ex-dock Philadelphia or Portland, Maine, was $23 to $45 per ton, and imported white kaolin, powdered, bags, carlots, ex-dock sold for $55 to $100 per ton.

United Clay Mines Corp., Trenton, N.J., which in 1964 purchased the Georgia Coating Clay Co., was in turn acquired in 1965 by Cyprus Mines Corp. as a part of its diversification into the nonmetallic minerals industries. The Anaconda Company completed pilot plant research on production of alumina from clay and announced tentative plans for a production facility in Georgia. If the facility is built the firm's Columbia Falls, Mont., plant will convert the alumina to aluminum metal. Kaolin deposits covering about 500 acres along the Continental Divide in Sierra County, N. Mex., were staked by Western Nuclear Inc.

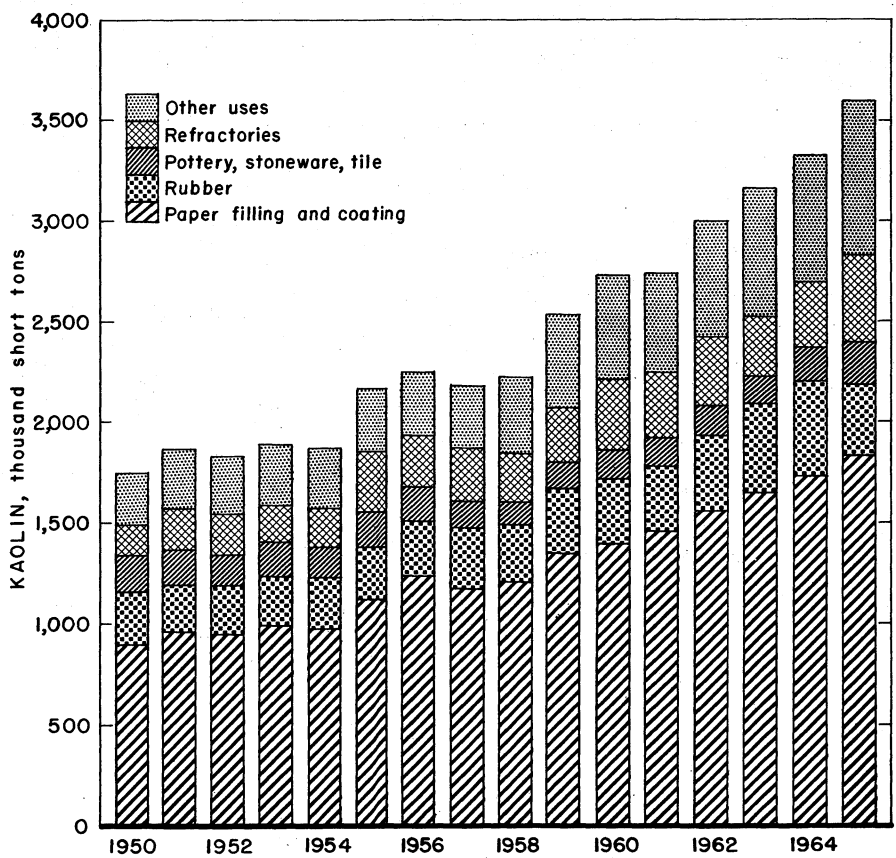

Figure 1.—Kaolin sold or used by domestic producers for specified uses.

Table 3.—Kaolin sold or used by producers in the United States, by States

Year and State	Sold by producers		Used by producers		Total	
	Short tons	Value	Short tons	Value	Short tons	Value
1956–60 (average)	2,137,293	$36,315,753	247,050	$2,460,596	2,384,343	$38,776,349
1961	2,471,518	44,877,971	268,298	2,054,899	2,739,816	46,932,870
1962	2,702,920	51,046,599	295,237	2,448,188	2,998,157	53,494,787
1963	2,911,926	57,239,980	251,647	2,530,294	3,163,573	59,770,274
1964:						
California	23,312	289,683	—	—	23,312	289,683
Florida and North Carolina	35,785	679,808	—	—	35,785	679,808
Georgia	2,488,447	53,945,807	95,708	574,072	2,584,155	54,519,879
South Carolina	W	W	W	W	521,101	7,166,929
Other States [1]	572,378	7,706,242	115,712	1,411,380	166,989	1,950,693
Total	3,119,922	62,621,540	211,420	1,985,452	3,331,342	64,606,992
1965:						
Florida and North Carolina	40,400	916,360	—	—	40,400	916,360
Georgia	2,576,095	56,709,816	145,147	700,994	2,721,242	57,410,810
South Carolina	W	W	W	W	518,893	7,317,568
Other States [1]	597,978	8,432,003	244,333	2,702,270	323,418	3,816,705
Total	3,214,473	66,058,179	389,480	3,403,264	3,603,953	69,461,443

W Withheld to avoid disclosing individual company confidential data; included with "Other States."

[1] Includes Alabama, Arkansas (1965), California (1965), Idaho, Pennsylvania, Texas, Utah, and Vermont, and States indicated by symbol W.

Table 4.—Georgia kaolin sold or used by producers, by uses

(Thousand short tons and thousand dollars)

Year	China clay, paper clay, etc.	Refractory uses	Total kaolin		
	Quantity	Quantity	Quantity	Value	
				Total	Average per ton
1956–60 (average)	1,598	218	1,816	$31,190	$17.18
1961	1,925	222	2,147	39,557	18.42
1962	2,094	184	2,278	44,655	19.60
1963	2,276	214	2,490	50,294	20.20
1964	2,389	195	2,584	54,520	21.10
1965	2,478	243	2,721	57,411	21.10

BALL CLAY

Ball clay production increased 4 percent in quantity and 5 percent in value over 1964 figures, and as usual, Tennessee was the leading producing State, with 66 percent of the volume and 63 percent of the value. Kentucky, Mississippi, California, Maryland, and Texas, in that order, were the other States reporting ball clay output.

The use pattern remained essentially unchanged, with whiteware, floor and wall tile, and refractories taking more than 85 percent of the total. Enamels, fillers, and building brick accounted for most of the balance.

The following prices were quoted for ball clay in Oil, Paint and Drug Reporter on December 27, 1965: Domestic, air-floated, bags, carlots, Tennessee, $18 to $22 per ton; crushed, moisture repellent, bulk, carlots, Tennessee, $8 to $11.25 per ton; imported, air-floated, bags, carlots, Atlantic ports, $46.50 to $48.25 per ton; lump, bulk, Atlantic ports, $31.50 to $37.50 per ton.

Ball clay imports totaled 14,898 tons in 1965, of which 10,800 tons was unbeneficiated material valued at $110,813, and 4,098 tons was beneficiated clay valued at $104,398. Comparable figures for 1964 were 13,036 tons of unbeneficiated clay valued at $132,291, and 3,016 tons of beneficiated clay worth $79,292. This is a decline of 7 percent in tonnage but an increase of 2 percent in value in 1965.

Table 5.—Ball clay sold or used by producers in the United States

Year	Short tons	Value
1956–60 (average)	436,729	$5,908,673
1961	444,593	6,090,091
1962	486,936	6,810,441
1963	547,668	7,541,471
1964	567,315	7,829,841
1965	590,717	8,197,474

FIRE CLAY

Fire clay output increased 6 percent in quantity and 5 percent in value in 1965, the third annual increase following several years of declining production. Refractories uses required 10 percent more fire clay than in 1964, and accounted for 51 percent of the total 1965 production compared with 49 percent in 1964. About 59 percent of the fire clay output came from the three leading States—Ohio, Pennsylvania, and Missouri—compared with 57 percent in 1964 and 55 percent in 1963.

Use of fire clay in nonrefractory applications has declined compared with refractories use in recent years, and this trend continued in 1965 when 44 percent of the output was used for heavy clay products. Only 2 years previous, 50 percent of the fire clay went into this use category. About 5 percent of the fire clay production went into such products as chemicals, cement, pottery, and stoneware.

Fire clay exports totaled 182,446 tons compared with 246,796 tons in 1964—a decline of 26 percent. The value decreased 35 percent, from $5,596,000 in 1964 to $3,667,000 in 1965. Canada, Mexico, and Japan, which took 80 percent of the fire clay exports in 1964, accounted for 88 percent in 1965.

H. K. Porter Co., Inc. acquired a site near Fulton, Mo., for construction of a new plant for production of fire clay and high alumina refractories. The firm's Laclede Works in St. Louis will be retired when the new plant is in full production. Harbison-Walker Refractories Co. spent $10 million on plant improvements and expansion of several facilities, including an addition to the research center at West Miffin, Pa. Kaiser Refractories Division of Kaiser Aluminum & Chemical Corp. was building a new shuttle kiln to increase production at the Mexico, Mo., plant.

Table 6.—Fire clay, including stoneware clay,[1] sold or used by producers in the United States, by States

Year and State	Sold by producers		Used by producers		Total	
	Short tons	Value	Short tons	Value	Short tons	Value
1956–60 (average)	2,705,896	$8,733,453	7,532,789	$38,447,064	10,238,685	$47,180,517
1961	2,067,833	7,084,999	6,621,884	31,716,800	8,689,717	38,801,799
1962	2,034,332	6,873,689	6,030,716	28,934,226	8,065,048	35,807,915
1963	2,454,714	9,392,863	5,935,460	30,165,007	8,390,174	39,557,870
1964:						
Alabama	W	W	W	W	387,207	2,580,924
Arkansas	—	—	242,360	1,515,893	242,360	1,515,893
California	73,156	257,289	472,880	1,776,396	546,036	2,033,685
Colorado	85,062	295,390	92,107	393,562	177,169	688,952
Illinois	147,552	1,343,216	143,224	550,316	290,776	1,893,532
Indiana	W	W	W	W	376,361	644,182
Iowa	17,146	19,280	—	—	17,146	19,280
Kansas	—	—	98,748	240,341	98,748	240,341
Kentucky	25,590	142,286	78,746	569,510	104,336	711,796
Maine	—	—	27	79	27	79
Maryland	W	W	W	W	29,204	102,667
Mississippi	300	1,500	207,335	428,835	207,635	430,335
Missouri	W	W	W	W	1,002,068	3,905,166
New Jersey	W	W	W	W	120,518	958,030
Ohio	912,617	2,449,473	1,383,571	8,479,262	2,296,188	10,928,735
Oklahoma	—	—	380	3,800	380	3,800
Pennsylvania	554,082	1,561,328	1,030,031	8,581,686	1,584,113	10,143,014
South Carolina	—	—	1,024	9,000	1,024	9,000
Texas	W	W	W	W	666,061	1,814,526
Other States [2]	799,597	3,636,082	2,183,155	8,738,282	401,333	2,368,869
Total	2,615,102	9,705,844	5,933,588	31,286,962	8,548,690	40,992,806

Table 6.—Fire clay, including stoneware clay,[1] sold or used by producers in the United States, by States—Continued

Year and State	Sold by producers		Used by producers		Total	
	Short tons	Value	Short tons	Value	Short tons	Value
1965:						
Alabama	W	W	W	W	460,450	$3,219,601
Arizona	20	$45	30	$68	50	113
California	W	W	W	W	485,118	1,665,456
Colorado	111,130	366,404	106,317	470,999	217,447	837,403
Illinois	134,379	1,265,069	160,267	568,422	294,646	1,833,491
Indiana	W	W	W	W	329,348	526,413
Iowa	5,723	6,295	—	—	5,723	6,295
Kansas	—	—	99,414	247,770	99,414	247,770
Kentucky	W	W	W	W	220,864	1,447,305
Maine	—	—	30	87	30	87
Maryland	W	W	W	W	25,126	113,943
Mississippi	110	550	204,853	436,061	204,963	436,611
Missouri	W	W	W	W	1,128,095	4,312,482
New Jersey	W	W	W	W	110,707	884,039
New Mexico	212	1,590	2,287	10,863	2,499	12,453
Ohio	990,122	2,663,799	1,488,101	8,747,363	2,478,223	11,411,162
Oklahoma	—	—	410	4,100	410	4,100
Pennsylvania	561,648	1,341,172	1,145,571	10,295,167	1,707,219	11,636,339
Texas	W	W	W	W	734,834	1,999,231
Other States[2]	1,020,493	4,936,523	2,984,532	11,751,488	510,483	2,519,541
Total	2,823,837	10,581,447	6,191,812	32,532,388	9,015,649	43,113,835

W Withheld to avoid disclosing individual company confidential data; included with "Other States."

[1] Includes stoneware clay as follows, in short tons: 1956–60 (average), 37,110; 1961, 24,554; 1962, 57,820; 1963, 44,798; 1964, 45,679; 1965, 49,517.

[2] Includes Arizona (1964), Arkansas (1965), Idaho, Minnesota, Montana (1964), Nevada (1965), New Mexico, North Dakota, Utah, Washington, West Virginia, and Wyoming, and States indicated by symbol W.

BENTONITE

Output of bentonite, spurred by increased demand in all major use categories, was 9 percent above that in 1964. The use of Wyoming bentonite in iron ore pelletizing, which has increased rapidly in the United States and Canada during the past 5 years, appeared to be levelling off. This use accounted for 406,022 tons in 1965 compared with 378,274 tons in 1964 and required 22 percent of the output for each year. There was a relative increase in bentonite used in foundries and steelworks, which remained the largest use category with 34 percent of the total compared with 31 percent in 1964. Drilling mud accounted for 24 percent of the output in 1965 compared with 25 percent in the previous year.

Bentonite exports were reported separately by the Bureau of the Census for the first time in 1965. A total of 227,536 tons, valued at $6,241,640, went to 60 countries. The three largest recipient countries accounted for 80 percent of the exports—Canada received 143,000 tons, United Kingdom 23,000 tons, and Australia 15,000 tons. Bentonite imports in 1965 were 389 tons valued at $17,892 compared with 179 tons valued at $5,903 in 1964. Italy and Mexico were the principal suppliers.

At the end of 1965 bentonite prices published in Oil, Paint and Drug Reporter were as follows: 200 mesh, bags, carlots, f.o.b. mines Wyoming, $14 per ton; imported, Italian, white, high-gel, bags, 5-ton lots, ex-warehouse, $91 per ton. The value of domestic bentonite sold or used by producers averaged $10.81 per ton, a decrease of 41 cents per ton from the 1964 figure.

The new 600-tons-per-day plant of The Black Hills Bentonite Co. near Casper, Wyo., was completed and in full operation at the end of January 1965. A new processing plant was under construction near Lovell, Wyo., by American Colloid Co. during the year, and a new firm was formed to process Montana bentonite at Duluth, Minn., for use by iron ore pelletizers in the Great Lakes Region. In the South, Magnet Cove Barium Corp. Ltd. completed a new 50,000-tons-per-year plant at Vaiden, Miss. Crude ore for the plant was produced from an open pit near West and trucked to the Vaiden plant.

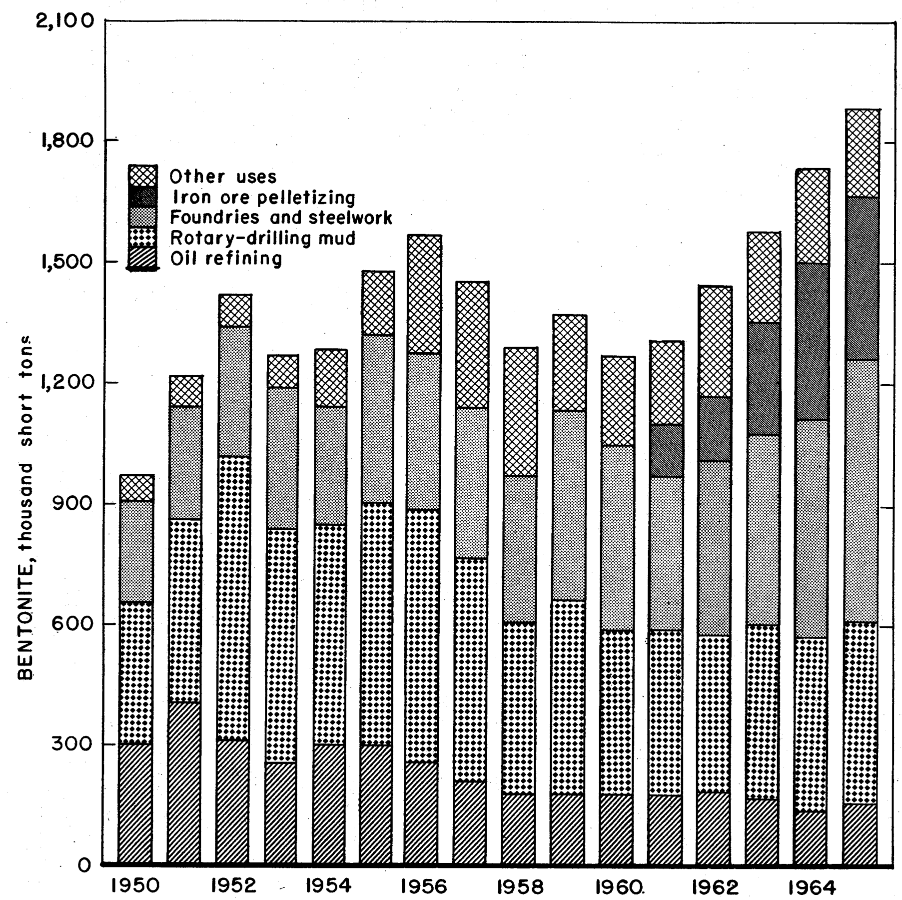

Figure 2.—Bentonite sold or used by domestic producers for specified uses.

Table 7.—Bentonite sold or used by producers in the United States, by States

Year and State	Short tons	Value	Year and State	Short tons	Value
1956–60 (average)	1,390,795	$16,476,963	1965:		
1961	1,307,191	15,224,347	California	27,560	W
1962	1,444,135	16,254,215	Colorado	1,196	$10,817
1963	1,584,516	18,536,229	Mississippi	279,535	3,476,558
1964:			Oregon	758	9,096
California	20,817	366,120	Texas	114,477	829,105
Colorado	1,270	12,956	Utah	2,889	40,220
Mississippi	269,783	3,352,472	Wyoming	1,290,961	13,495,935
Oregon	718	8,613	Other States [1]	170,571	2,545,237
Texas	111,016	1,294,516	Total	1,887,947	20,406,968
Utah	6,059	81,867			
Wyoming	1,172,103	12,648,835			
Other States [1]	147,737	1,648,017			
Total	1,729,503	19,413,396			

W Withheld to avoid disclosing individual company confidential data; included with "Other States."

[1] Alabama, Arizona, Idaho, Montana, Nevada, North Dakota, Oklahoma, South Dakota, and Washington (1965).

FULLER'S EARTH

Absorbent uses, which increased 30 percent in 1965, continued to pace the fuller's earth industry, and demand for fuller's earth for insecticide-fungicide carriers also continued strong, increasing 19 percent. All other important uses increased except for drilling mud which declined slightly. The total quantity sold or used by producers for all uses was 22 percent above the 1964 figure.

Price quotations for fuller's earth have not been published in the trade journals for many years. The average value of the material sold or used in 1965 was $21.83 per ton compared with $23.09 in 1964.

Only 27 tons of fuller's earth valued at $1,503 was imported in 1965, all from the United Kingdom. Exports totaled 18,575 tons worth $905,623, or $48.75 per ton. Exports of fuller's earth were reported for the first time as a separate category in 1965.

A new attapulgite mining and processing plant was completed in Marion County, Fla., by the Mid-Florida Mining Co., and commercial shipments were scheduled for early in 1966.

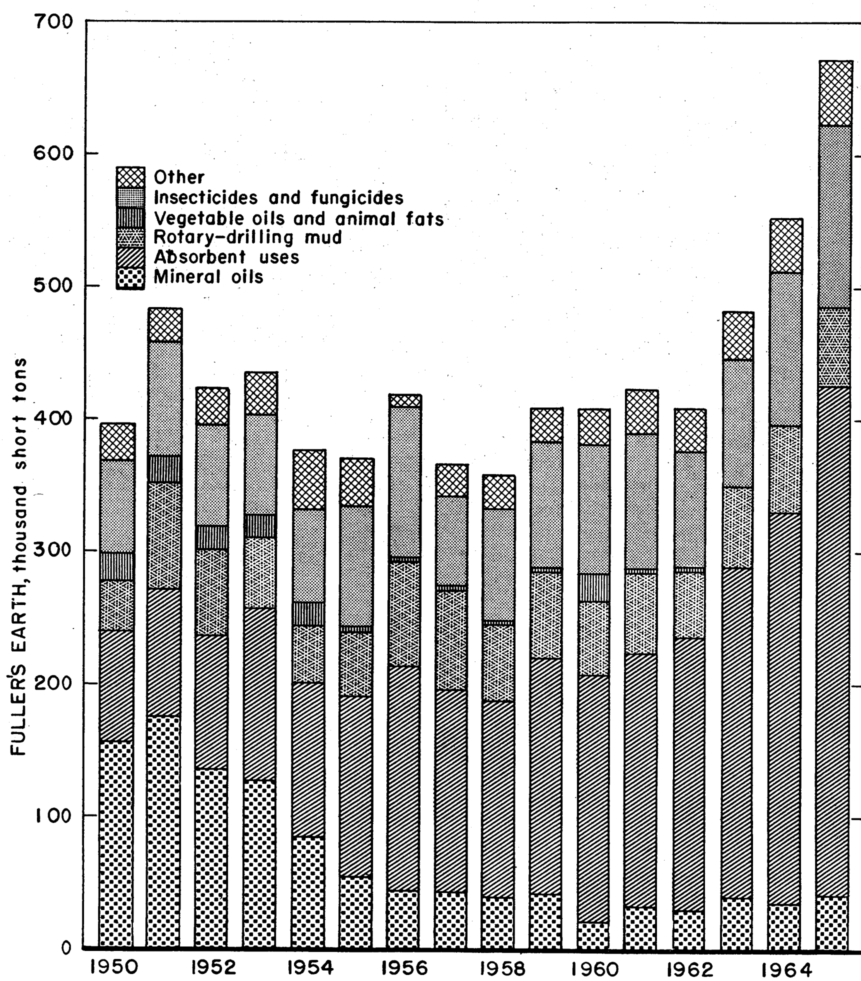

Figure 3.—Fuller's earth sold or used by producers for specified uses.

Table 8.—Fuller's earth sold or used by producers in the United States, by States

Year and State	Short tons	Value
1956–60 (average)	391,929	$8,546,786
1961	422,181	9,518,238
1962	409,989	9,377,355
1963	481,817	11,210,618
1964:		
Florida and Georgia	455,701	11,111,072
Utah	3,172	44,919
Other States [1]	93,013	1,586,906
Total	551,886	12,742,897
1965:		
Florida and Georgia	554,635	$13,618,806
Tennessee	26,676	389,520
Utah	3,584	52,382
Other States [1]	89,527	662,394
Total	674,422	14,723,102

[1] Includes California, Illinois, Mississippi, Nevada, Tennessee (1964), and Texas.

MISCELLANEOUS CLAY AND SHALE

Clays and shales of many types are used in production of clay construction products such as brick and tile as well as in cement and lightweight aggregates. These materials, often consisting of mixtures of several types of clay minerals, are included in the category "Miscellaneous Clay and Shale." Products such as pottery, refractories and fillers also may contain miscellaneous clay and shale.

The 1965 output of miscellaneous clay and shale increased 3 percent in quantity and 2 percent in value compared with 1964 figures. The unit value dropped about 1 cent per ton, to $1.22. The largest increases, by uses, were for clay construction products, which increased 3 percent, and for lightweight aggregates, which increased 10 percent.

Most of the miscellaneous clay and shale output was used by the producers, with the clay products plant typically adjacent to or very near the mine pit. In 1965 about 97 percent of the production came from captive mines as opposed to 96 percent in 1964.

Exports of clays not classified by individual types are included in this section, but these clays are for the most part of much higher quality than the common clays used for brick, cement, and similar products. The 1965 data for the clays "Not Individually Classified" are not comparable with those for prior years, as bentonite and fuller's earth have now been broken out for individual reporting. Exports of clays not individually classified in 1965 totaled 228,105 tons valued at $8,536,954, or $28.66 per ton. The principal recipient countries were Canada, with 25 percent; Mexico, 9 percent; West Germany and Japan, each 7 percent; and Australia, 6 percent. The balance went to about 70 countries in quantities ranging from 1 to 11,000 tons.

Table 9.—Miscellaneous clay, including shale and slip clay sold or used by producers in the United States, by States

Year and State	Sold by producers		Used by producers		Total	
	Short tons	Value	Short tons	Value	Short tons	Value
1956–60 (average)	1,174,560	$1,796,926	31,702,794	$38,196,733	32,877,354	$39,993,659
1961	916,772	1,035,824	32,871,157	39,227,174	33,787,929	40,262,998
1962	957,201	1,003,061	33,434,860	40,262,516	34,392,061	41,265,577
1963	1,041,823	1,190,063	34,926,431	43,004,301	35,968,254	44,194,364
1964:						
Alabama	W	W	W	W	1,603,854	1,478,862
Arizona	—	—	167,365	212,708	167,365	212,708
Arkansas	—	—	649,266	636,241	649,266	636,241
California	105,061	199,828	2,955,736	5,306,534	3,060,797	5,506,362
Colorado	W	W	W	W	379,470	573,108
Connecticut	W	W	W	W	211,621	262,400
Delaware	—	—	11,300	11,300	11,300	11,300
District of Columbia	—	—	82,150	82,150	82,150	82,150
Georgia	—	—	1,621,263	973,821	1,621,263	973,821
Idaho	W	W	W	W	29,077	24,784
Illinois	209,449	217,449	1,506,600	2,247,238	1,716,049	2,464,687
Indiana	178,699	190,245	990,266	1,429,841	1,168,965	1,620,086
Iowa	W	W	W	W	990,863	1,234,888
Kansas	—	—	685,900	694,768	685,900	694,768
Kentucky	—	—	815,846	1,089,557	815,846	1,089,557
Louisiana	W	W	W	W	779,679	796,832
Maine	—	—	44,620	57,740	44,620	57,740

Table 9.—Miscellaneous clay, including shale and slip clay sold or used by producers in the United States, by States—Continued

Year and State	Sold by producers		Used by producers		Total	
	Short tons	Value	Short tons	Value	Short tons	Value
Maryland	W	W	W	W	605,375	$694,933
Massachusetts	—	—	138,214	$174,214	138,214	174,214
Michigan	—	—	2,385,365	2,592,279	2,385,365	2,592,279
Minnesota	—	—	212,616	318,962	212,616	318,962
Mississippi	7,000	$7,000	767,796	767,796	774,796	774,796
Missouri	W	W	W	W	963,842	969,281
Montana	—	—	48,962	58,588	48,962	58,588
Nebraska	—	—	142,891	142,891	142,891	142,891
New Hampshire	—	—	45,620	39,820	45,620	39,820
New Jersey	—	—	378,997	482,709	378,997	482,709
New Mexico	W	W	W	W	104,145	167,128
New York	W	W	W	W	1,499,268	1,993,463
North Carolina	—	—	3,199,177	2,064,087	3,199,177	2,064,087
Ohio	216,526	214,340	2,492,185	3,282,529	2,708,711	3,496,869
Oklahoma	W	W	W	W	834,807	850,307
Oregon	W	W	W	W	r 288,803	r 347,610
Pennsylvania	105,895	78,428	1,497,092	5,592,501	1,602,987	5,670,929
South Carolina	—	—	1,220,678	1,133,401	1,220,678	1,133,401
Tennessee	—	—	939,468	643,241	939,468	643,241
Texas	W	W	W	W	3,378,918	3,585,917
Utah	4,436	6,676	113,512	196,542	117,948	203,218
Virginia	—	—	1,440,385	1,613,523	1,440,385	1,613,523
Washington	990	495	126,892	118,911	127,882	119,406
West Virginia	—	—	261,498	308,522	261,498	308,522
Wisconsin	—	—	119,156	146,670	119,156	146,670
Undistributed [1]	537,814	696,129	r 11,791,959	r 13,016,787	660,051	733,403
Total	1,365,870	1,610,590	r 36,852,775	r 45,435,871	r 38,218,645	r 47,046,461
1965:						
Alabama	60,000	55,000	1,699,176	1,612,775	1,759,176	1,667,775
Arizona	—	—	129,209	163,584	129,209	163,584
Arkansas	—	—	662,761	661,825	662,761	661,825
California	82,829	137,435	2,549,739	4,355,777	2,632,568	4,493,212
Colorado	W	W	W	W	411,939	598,168
Connecticut	W	W	W	W	237,251	322,455
Delaware	—	—	11,400	11,400	11,400	11,400
Florida	W	W	W	W	278,363	270,700
Georgia	—	—	1,679,318	1,043,957	1,679,318	1,043,957
Idaho	W	W	W	W	46,766	32,690
Illinois	W	W	W	W	1,874,399	2,767,785
Indiana	148,641	157,642	980,998	1,476,229	1,129,639	1,633,871
Iowa	54	81	1,078,847	1,340,254	1,078,901	1,340,335
Kansas	—	—	689,904	705,325	689,904	705,325
Kentucky	—	—	837,670	1,132,160	837,670	1,132,160
Louisiana	W	W	W	W	908,702	935,696
Maine	—	—	48,793	62,805	48,793	62,805
Maryland	W	W	W	W	888,920	973,993
Massachusetts	—	—	181,100	237,700	181,100	237,700
Michigan	—	—	2,401,922	2,580,034	2,401,922	2,580,034
Minnesota	—	—	207,495	311,243	207,495	311,243
Mississippi	—	—	922,972	949,526	922,972	949,526
Missouri	W	W	W	W	1,098,320	1,126,267
Montana	W	W	W	W	76,310	98,457
Nebraska	—	—	106,319	106,319	106,319	106,319
New Hampshire	—	—	53,200	46,900	53,200	46,900
New Jersey	—	—	395,153	504,151	395,153	504,151
New Mexico	1,985	18,494	55,536	69,869	57,521	88,363
New York	W	W	W	W	1,353,800	1,717,142
North Carolina	—	—	3,383,226	2,161,882	3,383,226	2,161,882
Ohio	214,496	213,908	2,377,118	3,191,321	2,591,614	3,405,229
Oklahoma	W	W	W	W	793,120	802,171
Oregon	5,250	44,100	285,480	305,698	290,730	349,798
Pennsylvania	138,080	75,136	1,548,923	5,985,418	1,687,003	6,060,554
South Carolina	—	—	1,318,343	1,221,480	1,318,343	1,221,480
Tennessee	W	W	W	W	1,079,952	521,042
Texas	W	W	W	W	3,604,738	3,832,420
Utah	5,980	14,940	136,492	224,250	142,472	239,190
Virginia	—	—	1,415,397	1,657,229	1,415,397	1,657,229
Washington	W	W	W	W	162,311	210,682
West Virginia	—	—	289,395	327,576	289,395	327,576
Wisconsin	—	—	118,624	146,607	118,624	146,607
Undistributed [1]	653,045	745,967	12,444,004	13,816,578	282,158	352,877
Total	1,310,360	1,462,703	38,008,514	46,409,872	39,318,874	47,872,575

r Revised. W withheld to avoid disclosing individual company confidential data; included with "Undistributed."

[1] Includes States indicated by symbol W and Florida (1964), Hawaii, Nevada (1965), North Dakota, South Dakota, Vermont, West Virginia (1964), and Wyoming.

Table 10.—Clays sold or used by producers in the United States in 1965, by kinds

(Short tons)

Uses	Kaolin	Ball clay	Fire clay and stoneware clay	Bentonite	Fuller's earth	Miscellaneous clay including slip clay	Total
Pottery and stoneware:							
Whiteware, etc.	[1] 185,579	[1] 299,671	—	—	—	—	[1] 485,250
Stoneware, art pottery, flower pots, and glaze slip	(1)	(1)	49,517	—	—	78,360	[1] 127,877
Total	185,579	299,671	49,517			78,360	613,127
Floor and wall tile	(2)	128,226	239,933	—	—	137,730	[3] 505,889
Refractories:							
Firebrick and block	372,057	(4)	3,380,151	—	—	(4)	3,786,068
Bauxite, high-alumina brick	(4)	—	94,577	—	—	(4)	118,931
Fire-clay mortar	(4)	(4)	108,313	(5)	—	(4)	125,832
Clay crucibles	—	—	(4)	—	—	—	(4)
Glass refractories	(4)	(4)	—	—	—	—	(4)
Zinc retorts and condensers	—	—	(4)	—	—	—	(4)
Foundries and steelworks	(4)	(4)	682,952	[5] 648,721	—	(4)	1,354,335
Saggers, pins, stilts, and wads	10,955	(4)	(4)	—	—	—	52,097
Other refractories	47,522	92,120	314,647	(5)	—	29,566	344,318
Total	430,534	92,120	4,580,640	648,721	—	29,566	5,781,581
Heavy clay products: Building brick, paving brick, drain tile, sewer pipe, and kindred products	—	(2)	3,949,397	—	—	20,417,567	[3] 24,366,964
Architectural terra cotta	(2)	—	(2)	—	—	—	13,957
Lightweight aggregates	—	—	—	—	—	7,429,545	7,429,545
Filler:							
Paper filling	651,427	—	—	(2)	—	—	[6] 651,427
Paper coating	1,185,526	—	—	—	(2)	—	[6] 1,185,526
Rubber	348,443	—	—	—	—	—	348,443
Paint	83,418	—	—	—	—	—	83,418
Fertilizers	51,294	—	(4)	—	—	6,542	[6] 57,836
Insecticides and fungicides	13,014	—	6,565	6,490	138,435	(2)	[6] 164,504
Other fillers	195,489	(2)	10,607	—	(2)	(2)	223,052
Total	2,528,611	(2)	17,172	6,490	138,435	6,542	2,714,206
Portland and other hydraulic cements	97,178	—	50,546	(2)	—	11,063,201	[3] 11,210,925
Miscellaneous:							
Filtering, decolorizing, and clarifying	—	—	—	163,460	42,802	—	206,262
Rotary-drilling mud	—	—	6,169	453,343	60,159	5,292	524,963
Chemicals	(2)	—	(2)	(2)	(2)	—	97,846
Animal feed	—	—	—	21,091	—	—	21,091
Absorbent uses	—	—	(2)	(2)	384,785	(2)	[3] 384,785
Enameling	(2)	(2)	—	(2)	—	—	(2)
Catalysts (oil refining)	(2)	—	—	—	—	—	(2)
Pelletizing:							
Iron ore	—	—	—	406,022	—	—	406,022
Other	—	—	—	13,126	(2)	—	[3] 13,126
Reservoir, pond and ditch lining	—	—	—	18,169	—	—	18,169
Other uses	362,051	70,700	122,275	157,525	48,241	151,071	783,104
Total	362,051	70,700	128,444	1,232,736	535,987	156,363	2,455,368
Grand total:							
1965	3,603,953	590,717	9,015,649	1,887,947	674,422	39,318,874	55,091,562
1964	3,331,342	567,315	8,548,690	1,729,503	551,886	[r] 38,218,645	[r] 52,947,381

[r] Revised.
[1] Some stoneware, art pottery, etc., included with whiteware.
[2] Included with miscellaneous "Other Uses."
[3] Incomplete figure; remainder included with miscellaneous "Other uses."
[4] Included with "Other."
[5] Some "Fire clay mortar" and "Other refractories" included with foundries.
[6] Incomplete figure; remainder included with "Other."

CONSUMPTION AND USES

The predominant use for clays in 1965 was in heavy clay construction products, which accounted for 44 percent of the total clay output. Cement production claimed 20 percent, lightweight aggregates 13 percent, and refractories 11 percent. The quantities consumed for all major uses increased.

Refractories.—Clay refractories appeared to be more than holding their own in 1965 with respect to nonclay refractory materials following a number of years of actual or relative declines. Shipments of superduty and high-alumina fire clay refractory brick and shapes increased about 19 percent but the lower heat-duty products increased only 6 percent. Value of all clay refractories including plastics, mortars and castables, increased 12 percent.

In total quantity, shipments of nonclay refractories in 1965 were about equal to the 1964 figure, while the value increased 5 percent. Silica refractories shipments declined 10 percent in value while shipments of mullite brick and some basic refractory products increased sufficiently to result in a net increase for the year.

Table 11.—Shipments of refractories in the United States, by kinds

Product	Unit of quantity	Shipments 1964 Quantity	Shipments 1964 Value (thousands)	Shipments 1965 Quantity	Shipments 1965 Value (thousands)
Clay refractories:					
Fire-clay (including semisilica) brick and shapes, except superduty.	1,000 9-inch equivalent	289,955	$45,863	307,502	$49,301
Superduty fire-clay brick and shapes.	-----do-----	72,307	21,160	85,888	25,936
High-alumina brick and shapes (50 percent Al_2O_3 and over) made substantially of calcined diaspore or bauxite.[1]	-----do-----	38,443	19,150	45,955	23,894
Insulating firebrick and shapes	-----do-----	r 53,722	13,443	62,203	16,249
Ladle brick	-----do-----	224,035	25,827	220,285	26,509
Sleeves, nozzles, runner brick and tuyeres.	-----do-----	48,800	11,590	49,768	12,490
Glasshouse pots, tank blocks, feeder parts and upper structure shapes used only for glass tanks.[1]	Short ton	12,667	4,291	15,518	5,273
Hot-top refractories	-----do-----	73,345	5,219	68,695	5,035
Clay-kiln furniture, radiant-heater elements, potters' supplies, and other miscellaneous shaped refractory items.	------------	NA	8,544	NA	8,240
Refractory bonding mortars, air-setting (wet and dry types).[2]	Short ton	59,485	7,051	62,950	7,539
Refractory bonding mortars, except air-setting types.[2]	-----do-----	11,948	1,189	12,949	1,303
Ground crude fire clay, high-alumina clay and silica fire clay.	-----do-----	351,050	3,458	453,950	4,617
Plastic refractories and ramming mixes.[1]	-----do-----	180,659	15,718	192,199	17,422
Castable refractories (hydraulic-setting).	-----do-----	137,846	14,067	154,226	15,760
Insulating castable refractories (hydraulic-setting).	-----do-----	26,394	3,370	30,142	3,986
Other clay refractory materials sold in lump or ground form.[3,4]	-----do-----	206,608	5,327	195,763	5,322
Total clay refractories	------------	XX	205,267	XX	228,876

Table 11.—Shipments of refractories in the United States, by kinds—Continued

Product	Unit of quantity	Shipments 1964 Quantity	1964 Value (thousands)	1965 Quantity	1965 Value (thousands)
Nonclay refractories:					
Silica brick and shapes	1,000 9-inch equivalent	127,781	$23,981	109,586	$21,109
Magnesite and magnesite-chrome brick and shapes (magnesite predominating) (excluding molten cast and fused magnesia).	do	104,504	94,085	107,145	98,259
Chrome and chrome-magnesite brick and shapes (chrome predominating) (excluding molten cast).	do	39,490	30,550	32,491	26,009
Graphite crucibles, retorts, stopper heads, and other shaped refractories, containing natural graphite.	Short ton	15,073	11,572	17,728	14,474
Mullite brick and shapes made predominantly of kyanite, sillimanite, and alusite or synthetic mullite (excluding molten-cast).	1,000 9-inch equivalent	5,589	7,148	6,429	8,414
Extra-high alumina brick and shapes made predominantly of fused bauxite, fused or densesintered alumina (excluding molten-cast).	do	3,881	7,779	3,551	8,481
Silicon carbide brick and shapes made predominantly of silicon carbide.	do	3,298	11,178	3,517	11,630
Zircon and zirconia brick and shapes made predominantly of either of these materials.	do	947	3,814	1,239	4,654
Forsterite, pyrophyllite, molten-cast, dolomite, dolomite-magnesite, and other nonclay brick and shapes.		NA	30,394	NA	37,615
Mortars:					
Basic bonding mortars (magnesite or chrome ore predominating).	Short ton	r 219,576	r 19,210	231,334	19,978
Other nonclay refractory mortars	do	r 27,296	r 3,558	42,977	5,516
Nonclay refractory castables (hydraulic-setting).	do	20,825	3,194	24,690	4,329
Plastic refractories and ramming mixes(wet and dry types):					
Basic (magnesite, dolomite, or chrome ore predominating).	do	153,172	16,292	156,144	17,328
Other nonclay plastic refractories and ramming mixes.	do	32,514	7,651	37,907	9,212
Dead-burned magnesia or magnesite.	do	250,049	15,175	195,456	12,828
Carbon refarctories; brick, blocks and shapes, excluding those containing natural graphite.	do				
Nonclay gunning mixes	do	277,125	24,090	255,148	25,014
Other nonclay refractory materials sold in lump or ground form.[3]	do				
Total nonclay refractories		XX	r 309,671	XX	324,850
Grand total refractories		XX	r 514,938	XX	553,726

r Revised.

NA Not available, XX Not applicable.

[1] Excludes data for mullite and extra-high alumina refractories. These products are included with mullite and extra-high alumina brick and shapes in the nonclay refractories section.

[2] Includes data for bonding mortars which contain up to 60 percent Al_2O_3, dry basis. Bonding mortars which contain more than 60 percent Al_2O_3 dry basis are included in the nonclay refractories section.

[3] Represents only shipments by establishments classified in "manufacturing" industries, and excludes shipments to refractory producers for the manufacture of brick and other refractories.

[4] Includes data for calcined clay, ground brick, and siliceous and other gunning mixes.

Kaiser Refractories Division was expanding the Moss Landing, Calif., plant to increase production of high-strength basic brick and was building a new tar bonded refractories plant at Columbus, Ohio. A second high temperature kiln was included in A. P. Green Refractories Co. expansion of the Tarentum, Pa., basic refractories plant. General Refractories Co. announced plans for construction of a new plant at Warren, Ohio, to produce a complete line of refractories to serve basic oxygen steel producers. Facilities of The Babcock and Wilcox Co. Augusta, Ga., works were being expanded for production of ceramic fibers.

Heavy Clay Products.—Production of building brick and quarry tile increased 4 and 9 percent, respectively, in 1965 while all other heavy clay construction products registered declines ranging from 4 to 15 percent. Building brick production requires far more clay than all of the other clay construction products combined, and the quantity of clay used for this category increased by more than 2 percent in 1965.

The Structural Clay Products Institute (SCPI) opened a new field office in St. Louis, Mo., to provide improved service to clay building products manufacturers and builders in the St. Louis area. Brickmakers throughout the United States continued to advance the cause of load-bearing brick walls through the program developed by SCPI.

A number of clay products plants changed hands in 1965. U.S. Concrete Pipe Co. increased its diversification into clay products by purchasing the Robinson Clay Products Co. plant at Mogadore, Ohio. The 15-million-brick-per-year plant of Carpenter Brick Co. at South Windsor, Conn., was bought by a Canadian firm—Diamond Clay Products Ltd. Also in Connecticut, the Kelsey-Ferguson Brick Co. at East Windsor Hill was acquired by American Gypsum Co. for stock worth about $2.2 million. Boren Clay Products Co. acquired Sampson Brick Co. at Roseboro, N.C., and announced plans for a new tunnel kiln plant to produce 30 million brick per year. A 10-year modernization program was announced for the Ross Clay Products Co. which was acquired by Clay City Pipe Co., Urichsville, Ohio. Pee Dee Ceramics, Inc., purchased the J. D. Murchison Brick Mill in Marion County, S.C., and announced plans for modernizing and eventual doubling of production capacity.

Millikin Brick Co., Pittsburgh, Pa., announced plans for a new plant with annual capacity of 25 million brick. The Waccamaw Clay Products Co. obtained a loan from Economic Development Administration for a plant at Myrtle Beach, S.C., to produce decorative face brick. Mosaic Tile Co. planned to build two new plants, one in the South to produce quarry tile and one in the West to make floor and wall tile.

Production capacity of the Washington Brick Division, Thomas Somerville Co. at Muirkirk, Md., was doubled by addition of new kilns, dryers, and other equipment and 100,000 square feet of new buildings. Port Costa Clay Products Co., Port Costa, Calif., continued expansion of the clay products and lightweight aggregates production facilities. A 25-million-brick-per-year addition was made to the Denton, Tex., plant of Acme Brick Co. In York, Pa., the capacity of Glen-Gery Brick Co. was increased by installation of a new tunnel kiln and three new dryers. Edgar Brick Co., Edgar, Fla., was expanding production capacity from 4 million to 10 million brick annually.

Lightweight Clay and Shale Aggregates.—Production of lightweight aggregates in 1965 required 7,430,000 tons of clay and shale, an increase of 10 percent over the 6,753,000 tons used for this purpose in 1964. Output in 1965 came from 54 firms with 67 plants in 34 States. Data on expanded slate aggregates are not included with those for clay and shale although the final products are in many ways similar. Expanded slate aggregate production in 1965 was 679,000 tons, a decrease of about 3 percent from the 1964 production of 703,000 tons. There were five producers.

The new automated expanded shale aggregate plant of Lehigh Portland Cement Company at Woodsboro, Maryland, started commercial production early in 1965. Capacity of the rotary kiln plant is 1,000 tons per day. Birmingham Slag Division, Vulcan Materials Co. completed a new lightweight shale aggregate plant at Bessemer, Alabama with annual production capacity of 400,000 tons.

The Expanded Clay and Shale Association (ESCA), with headquarters at Allentown, Pa., adopted a new name in 1965 designed to more closely represent all of its members and potential members, including firms producing lightweight aggregates from fly ash and other materials. The new name of the organization is Lightweight Aggregate Producers Association (LAPA).

Table 12.—Shipments of principal structural clay products in the United States

Product	1956–60 (average)	1961	1962	1963	1964	1965
Unglazed brick (building)						
1,000 standard brick	6,740,540	6,427,600	6,913,100	7,405,000	7,743,800	8,089,131
Value ____thousands	$223,280	$225,300	$246,500	$267,100	$284,600	$301,038
Unglazed structural tile						
short tons	589,800	476,000	422,900	342,800	311,400	313,260
Value ____thousands	$8,660	$7,400	$6,600	$5,600	$5,400	$5,128
Vitrified clay sewer pipe and fittings						
short tons	1,843,720	1,763,800	1,743,600	1,771,900	1,837,200	1,732,159
Value ____thousands	$89,520	$90,500	$91,000	$97,700	$104,000	103,420
Facing tile, ceramic glazed, including glazed brick						
1,000-brick equivalent	391,620	388,000	370,300	352,900	332,700	307,944
Value ____thousands	$30,740	$31,600	$31,100	$28,600	$27,500	25,430
Facing tile, unglazed and salt glazed 1,000-tile, 8- by 5- by 12-inch,						
equivalent	18,920	11,200	10,800	8,500	6,900	6,327
Value ____thousands	$3,120	$2,100	$2,200	$1,700	$1,500	$1,435
Clay floor and wall tile and accessories, including quarry tile						
1,000 square feet	228,100	228,400	253,100	267,100	288,800	283,385
Value ____thousands	$126,940	$124,300	$135,500	$137,900	$146,200	$141,739
Total value___thousands	$482,260	$481,200	$512,900	$538,600	$569,200	$578,190

Source: Bureau of the Census.

WORLD REVIEW

Australia.—Great interest was shown in Australian bentonite occurrences, probably due in large part to the rapidly expanding iron ore pelletizing industry which presently uses Wyoming bentonite as binder. Several firms moved into the Springsure, Queensland area, following a bentonite discovery by the Bureau of Mineral Resources.

Austria.—Bentonite production was 4,450 tons, an increase of 29 percent from the 3,440 tons reported in 1964.

Ceylon.—A Government-sponsored survey resulted in discovery of a large kaolin deposit near Colombo.

India.—Fire clay output increased 18 percent, to 468,000 tons, compared with 397,000 tons in 1964. Other clay production reported in addition to kaolin consisted of 8,947 tons of ball clay. A deposit containing perhaps 100 million tons of ceramic clay was explored in the Birbhum district of West Bengal.

Israel.—The fire clay industry in the Maktesh Ramon in Israel increased rapidly, and production was expected to more than double in 1965, to about 80,000 tons. A processing plant was under construction for upgrading and calcining the products, most of which will be exported.

Table 13.—World production of china clay by countries [1]

(Short tons)

Country [1]	1961	1962	1963	1964	1965 [p,2]
North America:					
Mexico	66,910	NA	51,325	70,796	89,436
United States	2,739,816	2,998,157	3,163,573	3,331,342	3,603,953
South America:					
Argentina	40,141	r 42,667	r 39,572	r 46,715	NA
Chile	15,599	33,581	40,674	r 50,665	33,180
Colombia	r 55,000	r 77,000	r 83,000	r 89,000	91,000
Ecuador	601	416	388	228	NA
Peru	514	386	324	364	430
Europe:					
Austria	379,076	370,809	385,088	405,781	361,203
Belgium	NA	56,994	55,910	NA	NA
Bulgaria	r 60,000	r 67,000	r 85,000	r 91,000	e 99,000
Czechoslovakia	r 330,000	r 350,000	r 350,000	r 345,000	365,000
Denmark:					
Crude	8,567	e 8,800	e 8,300	8,818	12,125
Washed and pressed	4,669	3,644	NA	NA	2,756
France [3]	283,322	264,619	299,599	316,887	NA
Germany, West (marketable)	411,689	422,262	r 499,030	503,692	466,102
Greece	27,778	38,535	e 38,500	e 33,000	e 60,600
Hungary	46,697	44,994	48,760	r 55,488	e 60,600
Italy:					
Crude	r 96,329	r 96,652	r 109,000	70,273	80,997
Kaolinic earth	r 85,187	r 133,597	111,978	104,374	NA
Portugal:					
Crude	21,951	14,082	41,871 (crude and washed)	13,472	42,839 (crude and washed)
Washed	32,810	33,857		28,738	
Spain (crude)	139,875	184,960	228,849	155,345	NA
Sweden	29,873	28,911	r 34,969	48,502	NA
U.S.S.R.e	1,400,000	1,500,000	1,650,000	1,650,000	1,650,000
United Kingdom	1,924,633	r 1,900,000	2,130,000	2,280,000	e 2,470,000
Yugoslavia	e 7,800	5,000	4,500	5,000	5,500
Africa:					
Eritrea	3,858	661	NA	NA	e 230
Kenya	817	1,294	7,345	r 1,420	1,889
Morocco	—	—	—	—	1,084
Mozambique	132	198	6	11	165
Nigeria	—	6	17	3	29
Rhodesia, Southern	20,386	—	12,240	21,000	NA
South Africa, Republic of	26,474	31,366	37,413	43,495	45,629
Swaziland	58	2,743	r 2,211	344	830
Tanzania	r 173	175	201	122	—
United Arab Republic (Egypt)	29,961	16,095	26,503	69,221	52,663
Asia:					
Hong Kong	9,441	7,139	5,621	5,648	5,277
India	409,280	r 429,586	r 550,000	r 570,000	647,313
Iran [4]	3,307	NA	NA	7,683	NA
Japan	29,695	79,212	109,381	r 118,333	102,916
Korea, South	r 56,413	42,101	57,609	66,729	79,635
Malaya	1,759	3,875	1,317	1,591	1,749
Pakistan	790	—	—	1,084	1,421
Viet-Nam, South	NA	4,365	4,928	2,283	NA
Oceania: Australia [5]	57,219	40,399	r 49,889	50,532	NA

e Estimate. p Preliminary. r Revised. NA Not available.

[1] China clay is also produced in Brazil, China, East Germany, Israel, Taiwan and Thailand, but data on production are not available; a negligible quantity is produced in Malagasy, and Paraguay.

[2] Compiled mostly from data available August 1966.

[3] Includes kaolinic clay.

[4] Year ended March 20 of year following that stated.

[5] Includes ball clay.

Italy.—Bentonite output was 173,888 tons, an increase of 12 percent from 1964 figures when 155,672 tons was reported.

Mexico.—18,700 tons of bentonite was produced in 1965. None was reported in 1964. Kaolin production increased 26 percent.

Morocco.—Output of montmorillonitic clay classified as smectite was 41,450 tons in 1965, an increase of 16 percent over that reported in 1964. In addition, 15,600 tons of bentonite was produced in 1965.

Pakistan.—Fuller's earth production increased 70 percent, from 7,600 tons in 1964 to 13,000 tons in 1965. Fire clay production dropped from 18,800 tons in 1964 to 15,000 tons in 1965.

Peru.—Production of bentonite was 5,534 tons in 1965 compared with 665 tons in 1964. Fire clay output decreased from 9,700 tons in 1964 to 7,960 tons in 1965. Miscellaneous clay production was 509,000 tons, a decrease of 13 percent.

Rumania.—Kaolin production has reportedly grown from 2,000 to 35,000 tons and bentonite output from 3,000 to 90,000 tons since 1950. Plans call for more than doubling kaolin output and greatly increasing bentonite output by 1970 as well as for improving the quality of the products. A major effort was under way in 1965 to increase reserves of the two types of clay.

South Africa, Republic of.—Production of fire clay was 288,000 tons in 1965, a slight decrease from the 294,000 tons reported in 1964. Bentonite output rose 18 percent, from 10,267 tons in 1964 to 12,077 tons in 1965.

Swaziland.—Several high-grade kaolin deposits were discovered about 60 miles from the capital, Mbabane, and a processing plant was planned. The Japanese have indicated interest in the high-quality products including paper coating clay that may be produced.

Taiwan.—A bentonite deposit estimated to contain about 2 million tons was discovered in the county of Ping Tung in southern Taiwan.

Tunisia.—New plants were planned or were under construction for the manufacture of structural clay products and chinaware to increase production for local use and provide a surplus for export.

Yugoslavia.—Fire clay production was 290,000 tons, a 12-percent increase compared with 1964 output. Bentonite output remained at the 1964 level of 22,000 tons.

TECHNOLOGY

The results of a symposium on the theory, equipment, and techniques, most applicable to clay mineral analysis were published. Principal analytical methods discussed were X-ray diffraction, electron microscopy, infrared, differential thermal, and chemical analysis.[2]

The danger of obtaining erroneous results in clay mineral analysis by X-ray diffraction if segregation of clay minerals occurs during the mounting of specimens was discussed. Mounting of samples by settling in aqueous solutions was found to be especially prone to error. Three acceptable and four unacceptable mounting techniques were listed.[3]

X-Ray analysis was suggested as a possible method of determining clay particle sizes by interpretation of small-angle scattering. Evidence obtained from study of 19 clay samples was presented.[4]

Statistical methods were used to study the kaolins of the coastal plain of Georgia and South Carolina. Analysis of variance was used successfully to distinguish between the hard and soft kaolins on the basis of Al_2O_3 and Fe_2O_3 present as well as on the degree of crystallinity. Other variables were strongly characteristic of the clay types but were not shown to be statistically different. Evidence was presented which indicated that the hard type may have been deposited in saline waters, and the soft type in fresh water.[5]

The results of research recently completed with the Bureau of Mines 10-inch attrition grinder demonstrated that filler-grade kaolin could be reduced to minus 2-micron material to meet paper coating requirements more economically by closed circuit grinding than by open-circuit continuous grinding or batch grinding. Best results were obtained grinding 20 pounds per hour at 45 percent solids and with 100 percent circulating load. The resulting kaolin product was 82.7 percent minus 2-micron material, and the power consumption was 341 kilowatt-hours per ton of clay feed and 487 kilowatt-hours per ton of minus 2-micron material.[6]

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[2] Rich, C. I., and G. W. Kunze (eds.). Soil Clay Minerology—A Symposium. The University of North Carolina Press, Chapel Hill, N.C., 1964, 330 pp.

[3] Gibbs, Ronald J. Error Due to Segregation in Quantitative Clay Mineral X-Ray Diffraction Mounting Techniques. Am. Mineral, v. 50, Nos. 5 and 6, May–June 1965, pp. 741–751.

[4] Arnott, Ronald J. Particle Sizes of Clay Minerals of Small-Angle X-Ray Scattering. Am. Mineral., v. 50, No. 10, October 1965, pp. 1563–1575.

[5] Hinckley, David N. Mineralogical and Chemical Variations in the Kaolin Deposits of the Coastal Plain of Georgia and South Carolina. Am. Mineral., v. 50, Nos. 11 and 12, November-December 1965, pp. 1865–1883.

The latest methods of in-plant handling and bulk transportation of high quality kaolin and other clays were described.[7]

Two ammonium alum processes were evaluated by the Bureau of Mines as possible methods of producing alumina from clay. Detailed data on the processes were presented, including estimated costs for plants capable of producing 1,000 tons of alumina per day. Neither process was determined to be competitive with the Bayer process of production from bauxite.[8]

Specially prepared kaolin was used as a color-reactable coating pigment in a patented process for making sensitized sheet material.[9]

Several processes for production of synthetic zeolites from kaolin were described. Although relatively impure, the clay based zeolites should be relatively inexpensive, and suitable for petroleum cracking.[10] A number of new patents for production of zeolites and cracking catalysts from clays were issued in 1965.[11]

Experimental evidence was presented to demonstrate the effect of humidity on the lattice dimensions of K-saturated expanding clay minerals. X-ray diffraction measurements obtained on 19 samples of bentonitic material and one sample of vermiculite from various locations showed a consistently larger basal spacing at 55 percent relative humidity than at 1 percent.[12]

Bentonite modified by cation exchange with hydrochloride octadecylamine or by effect of dimethyldichlorosilane increased the strength of polycaprolactam fiber by 10 to 12 percent when added in small amounts. Maximum strength was achieved when about 1 percent bentonite was added.[13]

Potential uses for material from Maryland-Virginia diatomite-clay deposits were studied, with emphasis on possible use of the unseparated diatomite-montmorillonitic material as absorbents and adsorbents. The geology and mineralogy of the deposits were described.[14]

Comparative data recently obtained demonstrated the differences between several western bentonites and resulted in improved methods of testing of the clays and for determining optimum conditions for formulation of foundry sands.[15]

Lignite was evaluated by the Bureau of Mines as a binder material for use in production of iron ore pellets. Successful results were obtained in three of the four concentrates tested.[16]

Results of waterproofing below ground line with bentonite filled panels were reported. The bentonite panels were applied to outside walls by staples, tape, or other means, and the area carefully backfilled to

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[6] Stanczyk, Martin H., and I. L. Feld. Continuous Attrition Grinding of Coarse Kaolin (In Two Parts) 2. Closed-Circuit Tests. BuMines Rept. of Inv. 6694, 1965, 13 pp.

[7] Browning, Ralph R., Jr. Bulk Handling. Ceramic Age, v. 81, No. 10, October 1965, pp. 22–24.

Ceramic Industry. Bell Clays Transported With Wharton Dry Bulk Trailers. V. 84, No. 1, January 1965, pp. 47–50.

Minerals Processing. Handling Kaolin. V. 6, No. 4, April 1965, pp. 32–33.

[8] Peters, Frank A., Paul W. Johnson, and Ralph C. Kirby. Methods for Producing Alumina From Clay. An Evaluation of Two Ammonium Alum Processes. BuMines Rept. of Inv. 6573, 47 pp.

[9] Hemstock, Glen A. (assigned to Minerals & Chemicals Philipp Corp., Menlo Park, N.J.). Color-Reactable Inorganic Absorbent Pigment and Sensitized Sheet Material Coated Therewith. U.S. Pat. 3,226,252, Dec. 28, 1965.

[10] Chemical Week. Clay Comes on Strong. V. 96, No. 16, Apr. 17, 1965, pp. 73–74.

[11] Chomitz, N. (assigned to American Cyanamid Co., Stanford, Conn.). Hydrocarbon Cracking Catalyst Obtained by Acid Treating Kaolin and Adding Magnesia. U.S. Pat. 3,213,038, Oct. 19, 1965.

Maher, Philip K. (Assigned to W. R. Grace & Co., New York). Preparation of Crystalline Zeolites of Uniform and Controlled Particle Size. U.S. Pat. 3,185,544, May 25, 1965.

Maher, Philip K., and Eugene J. Nealon (assigned to W. R. Grace & Co., Clarksville, Md.). Process for the Preparation of a Crystalline Zeolite. U.S. Pat. 3,205,037, Sept. 7, 1965.

Malden, W. Michael, and Robert M. DeBaum (assigned to American Cyanamid Co., Stamford, Conn.). Process for Preparing Silica Alumina Catalyst and Catalyst Prepared Thereby. U.S. Pat. 3,210,266, Oct. 5, 1965.

Mason, R. B. (assigned to Esso Research and Engineering Co.). British Pat. 979,274, Jan. 1, 1965.

Mumptow, F. A. (assigned to Union Carbide Corp.). British Pat. 1,007,853, Oct. 22, 1965.

[12] Sayegh, Antione H., Moyle E. Harward, and Ellis G. Knox. Humidity and Temperature Interaction With Respect to K-Saturated Expanding Clay Minerals. Am. Mineral., v. 50, Nos. 3 and 4, March–April 1965, pp. 490–495.

[13] Osukov, I. O., V. P. Solomko, and others. Reinforcing Capron Fibre With the Aid of Modified Bentonite Akad. Nauk. Ukr.S.S.R. Dopovidi (Ukrainian), No. 6, 1963, pp. 798–801, 4 pp. Foreign Technol. Div., Air Force Systems Command, transl. FTD–TT–64–1184, Apr. 20, 1965.

[14] Knechtel, Maxwell M., and John W. Hosterman. Outlook for Resumption of Diatomite Mining in Southern Maryland and Eastern Virginia. U.S. Geol. Survey Res. 1965, Prof. Paper 525–D, pp. D151–D155.

[15] Yearley, B. C., and J. D. Hedberg. Differences in Western Bentonite Affect Sand Mix Properties. Foundry v. 93, No. 6, June 1965, pp. 44–47.

[16] Fine, M. M., and C. W. Wahl. Iron Ore Pellet Binders From Lignite Deposits. BuMines Rept. of Inv. 6564, 1964, 18 pp.

prevent tearing or dislodging the panels. Water seepage which could not be controlled by other methods was stopped by the bentonite panels.[17]

Patents were obtained on rejuvenating and maintaining activity of montmorillonite catalysts [18] and for use of bentonite in improved drilling muds,[19] greases [20] and coatings for magnetic sheet material.[21]

Patents were issued on the preparation of extremely fine-grained, lightweight attapulgite for use as sorbents and filter aids,[22] for producing organic-modified bentonite which reacts with dye-forming components to produce colored clay,[23] and for producing inorganic color-reactable absorbent pigment for use in transfer printing with benzoyl leuco methylene blue and violet lactone.[24]

A new, highly automated coal-burning rotary kiln expanded shale aggregate plant with 1,000 tons per day capacity was described. A single control can put the entire plant into operation, with each section of the plant starting in proper sequence. Automatic devices also shut down the plant in proper sequence on command or in case of electric or equipment failure. Separate controls are available for the various sections of the plant for operating individually or out of normal sequence.[25]

Two other rotary kiln expanded shale aggregate plants in the United States were described. Data on mining methods and shale reserves were included.[26]

A fully automatic lightweight aggregate plant in the Republic of South Africa utilizing the travelling grate sintering furnace was described. Two employees are required, one to operate a front-end loader feeding raw material to the plant hoppers and the other to attend the control console.[27]

Oil shale residue from high temperature retorting (2,500° F) was tested and found to be suitable for use as lightweight aggregate in concrete. Residue from lower temperature retorting was not suitable for concrete aggregate.[28]

Reports were published by the Bureau of Mines on the testing and evaluation of selected samples of clays and shales in Illinois and Indiana for potential use in production of lightweight aggregates.[29]

The results of sampling and evaluating clays in Pennsylvania for various uses were published. Field work, chemical analyses, and X-ray studies were conducted by the Pennsylvania Bureau of Topographic and Geologic Survey, and the testing and evaluation of clay samples for potential uses were done by the Federal Bureau of Mines. A total of 151 samples from 41 counties were tested for about 20 possible uses. Additional large samples were taken where warranted and tested by rotary kiln or sintering hearth for lightweight aggregate potential.[30]

A similar report was released on sampling and testing of clays and shales in cooperation with the Virginia Division of Mineral Resources in 13 southwestern Virginia counties. The principal potential uses

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[17] Lazarr, Thaddeus R. Waterproofing Below the Ground Line. Civil Engineering–ASCE, v. 35, No. 6, June 1965, p. 73.

[18] Kaplin, Harry, John A. Hodgkiss, and Titus Z. Trzaskowski (assigned to General Aniline & Film Corp., New York). Process of Maintaining the Activity and of Regenerating the Activity of Used or Spent Acid Activated Montmorillonite Catalyst. U. S. Pat. 3,211,670, Oct. 2, 1965.

[19] Turner, Finis (assigned to Magnet Cove Barium Corp., Houston, Tex.). Beneficiated Clay Composition for Use in Drilling Fluids. U.S. Pat. 3,220,946, Nov. 30, 1965.

[20] Loeffer, Donald E. (assigned to Shell Oil Co., New York). Lubricant Compositions. U.S. Pat. 3,222,279, Dec. 7, 1965; U.S. Pat. 3,223,628–9, Dec. 14, 1965.

[21] Trigg, Warren M., and Byron V. McBride (assigned to Westinghouse Electric Corp., East Pittsburgh, Pa.). Coatings for Magnetic Sheet Material. U.S. Pat. 3,189,483, June 15, 1965.

[22] Allegrini, A. P., and T. A. Cecil (assigned to Minerals & Chemicals Philipp Corp., Menlo Park, N.J.), Method of Treating Attapulgite Clay to Produce a Low Bulk Density Product. U.S. Pat. 3,174,826, Mar. 23, 1965.

[23] Elkins, I. D. (assigned to Kerr-McGee Oil Industries, Inc., Oklahoma City, Okla.). Method of Preparing Colored Modified Clay. U.S. Pat. 3,190,870, June 22, 1965.

[24] Hemstock, Glen A. (assigned to Minerals & Chemicals Philipp Corp., Menlo Park, N.J.). Color-Reactable Inorganic Absorbent Pigment and Coating Composition Containing Same. U.S. Pat. 3,223,546, Dec. 14, 1965.

[25] Levine, Sidney. Lehigh Designs to Reduce Fines. Rock Products, v. 68, No. 10, October 1965, pp. 58–63.

[26] Levine, Sidney. Non-Profit Foundation Produces Lightweight Aggregates. Rock Products, v. 68, No. 2, February 1965, pp. 66–68.

Taeler, David H. Custom Built Plant. Minerals Processing, v. 6, No. 1, January 1965, pp. 12–14.

[27] Holz, Peter. Unique Lightweight Aggregate Plant for South Africa. Minerals Processing, v. 6, No. 12, December 1965, pp. 32–33.

[28] Pray, Ralph. Oil Shale Waste as a Concrete Aggregate. Mines Mag., v. 55, No. 8, August 1965, pp. 25–26.

[29] Sweeney, John W., and Howard P. Hamlin. Lightweight Aggregates. Expansion Properties of Selected Indiana Shales. BuMines Rept. of Inv. 6574, 1965, 28 pp.

———. Lightweight Aggregates. Expansion Properties of Selected Illinois Shales and Clays. BuMines Rept. of Inv. 6614, 1965, 34 pp.

[30] O'Neill, Bernard J., Jr., and others. Properties and Uses of Pennsylvania Shales and Clays. Pennsylvania Geol. Survey Bull. M51, 1965, 448 pp.

found for clays in the area were lightweight aggregate, brick, tile, and pottery. Of a total of 120 samples tested, nearly 100 were suitable for use in clay products.[31]

Gassing and viscosity changes in porcelain enamel slips due to microbial action were studied and 10 effective microbial growth inhibitors were found in a total of 33 tested in the laboratory. Two of these inhibitors, formaldehyde and a nitroparaffin were used for in-plant testing, and the nitroparaffin, tris (hydroxymethyl) nitromethane was determined to be the most promising.[32]

A patented device for production of cups and other thin-walled ceramic ware utilizes pressure and low frequency vibration to force a small mass of clay slip between nonrotating formers which define the inside and outside shape of the ceramic objects.[33]

A U.S. patent was issued on a machine and method for treating new brick to produce simulated used brick. The automatic device dips the brick in asphaltic material, applies mortar, and tumbles the brick to give them a used appearance.[34]

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[31] Johnson, Stanley S., Marion V. Denny, and D. C. Le Van. Analyses of Clay, Shale and Related Materials—Southwestern Counties. Commonwealth of Va., Dept. of Conservation and Econ. Dev., Div. of Miner. Res., Min. Res. Rept. 6, 1965, 210 pp.

[32] Kemp, Homer T., Jr., Thomas L. Stalter, and Edward E. Mueller. Improve Slip Properties —Inhibit Microbial Growth. Ceramic Age, v. 81, No. 3, March 1965, pp. 42–47.

[33] Staffordshire Potteries (Holding) Ltd. British Pat. 983,184, Feb. 10, 1965.

[34] Harrison, Lee, and William R. O'Leary, Jr. Method of and Machine for Making Used Bricks, U.S. Pat. 3,168,413, Feb. 2, 1965.

Cobalt

By Harold W. Lynde, Jr.[1]

Domestic consumption of cobalt reached a record high of 13.6 million pounds, 28 percent more than in 1964. The large increase was attributed to continuing economic growth, military requirements, and advances in research and technology. The largest increment in usage was in high-temperature, high-strength alloys, used in severe environments including turbine or jet engines.

Cobalt production increased in each of the four major free world producing countries—Congo (Léopoldville), Morocco, Canada, and Zambia.

Legislation and Government Programs.—General Services Administration reported no sales of cobalt from government stockpiles during the year. At yearend the national stockpile contained 70,707,896 pounds of specification-grade cobalt, the supplemental stockpile, 1,065,398 pounds, and the Defense Production Act (DPA) inventory, 18,855,916 pounds, for a total of 90,629,210 pounds. The stockpile quota remained at 42,000,000 pounds. An additional 11,570,378 pounds of cobalt not meeting specifications was in the national and DPA stockpiles.

No cobalt exploration projects were active under the program administered by the Office of Minerals Exploration, Geological Survey.

DOMESTIC PRODUCTION

Bethlehem Cornwall Corp. increased production 12 percent. A cobaltous pyrite concentrate recovered from magnetite ores at Cornwall and Morgantown, Pa., was calcined and leached at Sparrows Point, Md., and the leach solution was shipped to The Pyrites Co., Inc., Wilmington, Del., for recovery of cobalt.

The Bunker Hill Co. recovered 147 tons of residue containing 6,703 pounds of cobalt at its Kellogg, Idaho, zinc plant; shipments were 33 tons containing 1,881 pounds of cobalt.

CONSUMPTION AND USES

Domestic cobalt consumption was at an alltime high, 13.6 million pounds, 28 percent higher than in 1964. Particularly large increases were reported for use in permanent magnet alloys, high-temperature, high-strength alloys, other metallics (principally metal-to-glass seal materials for radio and X-ray tubes and other electronic devices), and salts and driers. Other large-use categories included alloy hard-facing rods and materials, alloy steels other than high-speed and tool steels, and other nonmetallics (principally catalysts).

[1] Commodity specialist, Division of Minerals.

Table 1.—Salient cobalt statistics

(Thousand pounds of contained cobalt)

	1956–60 (average)	1961	1962	1963	1964	1965
United States:						
Consumption	9,018	9,596	11,268	10,529	10,650	13,595
Imports for consumption	16,304	10,495	12,433	10,522	12,443	15,408
Stocks Dec. 31: Consumer	1,271	1,807	1,479	1,099	1,420	1,590
Price: Metal____per pound	$2.60–$1.50	$1.50	$1.50	$1.50	$1.50	$1.50–$1.65
World: Production	31,000	31,800	34,200	28,400	31,000	34,200

Table 2.—Cobalt materials consumed by refiners or processors in the United States

(Thousand pounds of contained cobalt)

Form [1]	1956–60 (average)	1961	1962	1963	1964	1965
Alloy and concentrate	4,448	1,121	721	1,075	1,174	1,188
Metal	964	1,101	1,255	1,339	1,392	1,669
Hydrate	54	16	17	15	21	32
Other	148	33	52	6	9	3

[1] Total consumption is not shown because some metal, hydrate, and carbonate originated from alloy and concentrate.

Table 3.—Cobalt products[1] produced and shipped by refiners and processors in the United States

(Thousand pounds)

Product	1964				1965			
	Production		Shipments		Production		Shipments	
	Gross weight	Cobalt content	Gross weight	Cobalt content	Gross weight	Cobalt content	Gross weight	Cobalt content
Oxide	430	302	434	305	458	320	438	306
Hydrate	705	271	654	256	785	341	811	341
Salts:								
Acetate	410	97	370	88	407	99	421	102
Carbonate	523	231	458	201	570	250	537	235
Sulfate	548	120	464	102	697	131	842	162
Other	257	58	211	48	372	85	370	83
Driers	10,193	650	9,529	594	11,842	746	11,792	747
Total	13,066	1,729	12,120	1,594	15,131	1,972	15,211	1,976

[1] Figure on metal withheld to avoid disclosing individual company confidential data.

Table 4.—Cobalt consumed in the United States, by uses

(Thousand pounds of contained cobalt)

Use	1956–60 (average)	1961	1962	1963	1964	1965
Metallic:						
High-speed steel	191	220	343	404	305	304
Other tool steel	315	44	64	138	154	113
Other alloy steel		540	546	697	563	807
Permanent magnet alloys	2,684	2,457	2,867	2,352	2,210	2,736
Cutting and wear-resisting materials	219	257	316	275	337	414
High-temperature high-strength alloys	2,483	2,354	3,015	2,453	2,461	3,261
Alloy hard-facing rods and materials	468	550	650	607	801	1,055
Cemented carbides	262	298	610	409	431	530
Nonferrous alloys	422	145	128	158	326	330
Other		659	582	426	427	892
Total	7,044	7,524	9,121	7,919	8,015	10,442
Nonmetallic (exclusive of salts and driers):						
Ground-coat frit	493	526	533	580	599	535
Pigments	216	192	168	222	209	259
Other	199	314	474	606	548	684
Total	908	1,032	1,175	1,408	1,356	1,478
Salts and driers: Lacquers, varnishes, paints, inks, pigments, enamels, glazes, feed, electroplating, etc. (estimate)	1,067	1,040	972	1,202	1,279	1,675
Grand total	9,018	9,596	11,268	10,529	10,650	13,595

Table 5.—Cobalt consumed in the United States, by forms
(Thousand pounds of contained cobalt)

Form	1956–60 (average)	1961	1962	1963	1964	1965
Metal	6,829	7,478	9,091	8,146	8,265	10,872
Oxide	800	900	998	935	958	961
Purchased scrap	323	178	207	246	148	87
Salts and driers	1,067	1,040	972	1,202	1,279	1,675
Total	[1] 9,018	9,596	11,268	10,529	10,650	13,595

[1] Includes a small quantity of ore and alloy.

PRICES

Prices, which had remained stable at $1.50 per pound for metal since March 1, 1960, were raised by Union Minière du Haut Katanga effective March 1, 1965.

After that date, metal granules (99 percent cobalt) in 500-pound kegs were $1.65 per pound, f.o.b. carrier, New York or Chicago. Regular metal fines (95 to 96 percent cobalt) in 500-pound kegs were $1.65 per pound contained cobalt, f.o.b. carrier, New York. Metallurgical grade cobalt oxide (75 to 76 percent cobalt) in 250-pound kegs, was $1.85 per pound of contained cobalt, f.o.b. carrier, New York.

Black cobalt oxide in 250-pound kegs was $1.28 per pound for the 70- to 71-percent grade and $1.32 per pound for the 72.5- to 73.5-percent grade, f.o.b. shipping point, with freight allowed and prepaid to destination. West of the Mississippi, black oxide prices were 3 cents per pound higher.

S-grade cobalt metal powder and briquets (99.9 percent cobalt plus nickel) were $1.68 and $1.83 per pound, respectively, in minimum 20,000-pound lots, f.o.b. Fort Saskatchewan, Alberta, or Niagara Falls, Ontario, Canada.

FOREIGN TRADE

Exports of unwrought cobalt and cobalt alloys and of waste and scrap totaled 1,242,146 pounds, gross weight, of which 21 percent went to Japan, 19 percent to Canada, and 17 percent to United Kingdom.

Exports of wrought cobalt and cobalt alloys were 199,041 pounds, gross weight, of which 46 percent went to Australia, 13 percent to Canada, and 11 percent to United Kingdom.

Because of changes in export classifications effective January 1, these export categories are not strictly comparable with those of previous years.

Imports for consumption increased 24 percent, with largest increases in the importation of cobalt metal of Congo (Léopoldville) origin, both directly and by way of Belgium. In addition to metal and oxide imports, cobalt sulfate came from the United Kingdom and West Germany, cobalt compounds (not specified) from West Germany, United Kingdom, and Canada, and cobalt salts from Canada.

Table 6.—U.S. imports for consumption of cobalt metal and oxide, by countries
(Thousand pounds)

Country	Metal		Oxide (gross weight)	
	1964	1965	1964	1965
Belgium-Luxembourg	1,744	4,099	1,449	897
Canada	660	558	54	50
Congo (Léopoldville)	5,246	5,770	----	----
France	971	1,129	----	----
Germany, West	1,401	1,051	----	----
Ireland	----	(1)	----	----
Japan	36	36	----	----
Netherlands	28	117	----	----
Norway	1,222	1,939	----	----
United Kingdom	25	147	11	----
Total	11,333	14,846	1,514	947

[1] Less than ½ unit.

Table 7.—U.S. imports for consumption of cobalt, by classes
(Thousand pounds and thousand dollars)

Year	Metal		Oxide		Salts and compounds		Total [1]	
	Gross weight	Value	Gross weight	Value	Gross weight	Value	Gross weight	Cobalt content (estimated)
1956–60 (average)	[2] 14,915	[2] $29,405	1,066	$1,351	301	$162	19,089	16,304
1961	10,036	14,867	681	663	159	59	10,876	10,495
1962	11,809	17,119	978	943	120	47	12,907	12,433
1963	10,322	14,677	468	451	94	45	10,913	10,522
1964	11,333	16,526	1,514	1,422	94	43	12,941	12,443
1965	14,846	23,132	947	1,011	108	149	15,901	15,408

[1] Includes imports of white alloy (1956–60) and ores and concentrates (1956–60, 1962 and 1963).
[2] Includes scrap.

WORLD REVIEW

Free world cobalt production increased 11 percent to about 15,700 tons. Each of the four major producers—Congo (Léopoldville), Morocco, Canada, and Zambia—increased output during the year.

Canada.—Cobalt was recovered in Canada principally as a byproduct of nickel-copper production, but also from silver-cobalt ores of the Cobalt-Gowganda area, and from scrap. Production increased 19 percent to 1,899 tons.

The International Nickel Co. of Canada Ltd., produced electrolytic cobalt and cobalt oxide at its Port Colborne, Ontario, refinery, and cobalt oxide at its Thompson, Manitoba, refinery. Company deliveries of cobalt were 1,010 tons.

Sherritt Gordon Mines Ltd. produced cobalt metal powder, briquets, and strip at its Fort Saskatchewan, Alberta, refinery from calcines, alloy grindings scrap, and the company's Lynn Lake, Manitoba, nickel-copper ore concentrates. Production was 530,137 pounds, down 11 percent from 1964, and sales were 487,440 pounds, down 22 percent. An interval of several months elapsed between the conclusion of metal production from a supply of cobalt-bearing calcines and the beginning of production from a new supply of high-temperature alloy grindings.

Violamac Mines Ltd. operated its subsidiary, Cobalt Refinery Ltd., at Cobalt, Ontario, recovering 156,998 pounds of cobalt as cobalt and nickel oxide. This was a 15-percent increase over the 1964 total of 136,342 pounds.

Eldorado Mining & Refining Ltd., which had developed a process to recover cobalt from speiss produced by Cobalt Refinery, dropped plans to begin commercial production. This left Cobalt Refinery with

Table 8.—World production of cobalt by countries[1]
(Short tons of contained cobalt)

Country	1961	1962	1963	1964	1965 p[2]
Australia (cobalt in cobalt oxide)	r 19	r 17	19	19	20
Canada [3]	1,591	1,741	1,512	r 1,592	1,899
Congo, Republic of the (Léopoldville) (recoverable cobalt)	9,178	10,674	8,131	r 8,461	9,204
Cuba (recoverable cobalt from sulfide) e	----	181	192	(4)	(4)
Morocco (content of concentrate)	1,422	1,583	1,511	1,850	2,019
U.S.S.R. (metal) e	1,100	1,200	1,300	1,300	1,400
Zambia (formerly Northern Rhodesia) (content of white alloy, cathode metal and other products)	1,701	951	778	1,552	1,702
World total e	r 15,900	r 17,100	r 14,200	r 15,500	17,100

e Estimate. p Preliminary. r Revised.
[1] Cobalt is also recovered, principally in West Germany, from pyrites produced in Finland, and estimates are included in the world total. Production data for Bulgaria, East Germany, and Poland are not available, and no estimates for these countries are included in the world total. Cobalt concentrates are being stockpiled in Uganda, but exact figures are not available. U.S. figure withheld to avoid disclosing individual company confidential data included in the world total.
[2] Compiled mostly from data available June 1966.
[3] Cobalt in all forms. Excludes the cobalt content of nickel-oxide sinter shipped to the United Kingdom by International Nickel, but includes the cobalt content of Falconbridge shipments of nickel-copper matte to Norway.
[4] Data not available, no estimate included in total.

excess speiss. During 1965 the company sold speiss in Europe, as well as to Eldorado.

Falconbridge Nickel Mines Ltd. recovered electrolytic cobalt at Kristiansand S., Norway, from nickel-copper matte produced at Falconbridge, Ontario.

Congo, Republic of the (Léopoldville).—Union Minière du Haut-Katanga increased output 9 percent.

Production of copper-cobalt ores continued from the Kambove, Sesa, Kakanda, Kamoto, and Musonoi open-pit mines and the Kambove and Kamoto underground mines. Ores were treated at the Kolwezi, Kakanda, and Kambove concentrators to produce copper-cobalt oxide, dolomitic oxide, and sulfide concentrates.

Extraction was accomplished at the Shituru plant at Jadotville and the Luilu plant at Kolwezi. The Shituru plant produced electrolytic cobalt, about 95-percent pure, part of which was exported and part further refined to about 99.6-percent cobalt in an electric furnace, granulated, and shipped to the Luilu plant, Kolwezi, for degassing. The Luilu plant, in addition to producing electrolytic cobalt for refining at Shituru, also produced increasing amounts of commercial-grade cobalt cathodes, 99.9-percent pure, for degassing and export.[2]

Cobalt production in recent years has been as follows:

Product	1963	1964	1965
Electrolytic cobalt cathodes	2,200	2,239	1,450
Electrolytic cobalt granules	5,321	5,664	3,829
Electrolytic cobalt commercial-grade cathodes	----	558	3,940
Cobalt in cobalt-copper alloy	610	----	----
Cobalt in various products	----	----	27
Total	8,131	8,461	9,246

Finland.—Outokumpu Oy, the State-owned nonferrous metals producer, negotiated an agreement with Sherritt Gordon Mines Ltd., to use that company's process in a new cobalt recovery plant at Kokkola. The plant will have annual capacity of about 1,300 tons of cobalt per year, and will utilize cobaltous pyrite sinter presently shipped to West Germany for recovery of cobalt.

Zambia.—Rhokana Corp. Ltd., produced 5.45 million tons of ore containing 2.29 percent copper and 0.14 percent cobalt from the Nkana North, Nkana South, and Mindola mines in the year ending June 30, 1965. About 19.4 percent of the cobalt was recovered in 36,915 tons of cobalt concentrate averaging 3.98 percent cobalt and 9.25 percent copper. Electrolytic cobalt production was 1,106 tons, and sales were 1,711 tons.[3]

During May the company placed in commission a cyanide regrind circuit which enabled the recovery of considerably larger tonnages of cobalt concentrate; recovery of cobalt was estimated to have improved from 16 to 34 percent.

Chibuluma Mines Ltd. produced 15,989 tons of cobalt-copper concentrate in the year ending June 30, 1965. Sales were about 2,000 tons, and the rest was stockpiled.

TECHNOLOGY

Geologic publications described cobalt occurrences in Maryland,[4] Nevada,[5] and Flin Flon, Saskatchewan, Canada.[6]

Four new cobalt minerals were reported: Wairauite, CoFe, in New Zealand serpentine;[7] moorhouseite, essentially (Co, Ni, Mn) $SO_4 \cdot 6H_2O$; apolwite, essentially (Co, Mn, Ni) $SO_4 \cdot 4H_2O$, efflorescences on sulfides, Nova Scotia, Canada;[8] and a very fine-grained unnamed cobalt analog of

[2] Union Minière du Haut-Katanga. Annual Report. Brussels, Belgium, 1965, 40 pp.

[3] Rhokana Corp. Ltd. Annual Report. Lusaka, Zambia, 1965, 24 pp.

[4] Heyl, Allen V., and Nancy G. Pearre. Copper, Zinc, Lead, Iron, Cobalt, and Barite Deposits in the Piedmont Upland of Maryland. Maryland Geol. Survey, Bull. 28, 1965, 72 pp.

[5] Beal, Laurence H. Geology and Mineral Deposits of the Bunkerville Mining District, Clark County, Nevada. Nevada Bureau of Mines, Bull. 63, 1965, 96 pp.

[6] Falkner, Edward Leslie. The Distribution of Cobalt and Nickel in Some Sulphide Deposits of the Flin Flon Area, Saskatchewan. Canadian Min. J. (Quebec), v. 86, No. 3, March 1965, p. 79.

[7] Challis, G. A., and J. V. P. Long. Wairauite—A New Cobalt-Iron Mineral. Miner. Mag and J. Miner. Soc. (London), v. 33, September 1964, pp. 942–948.

[8] Jambor, J. L., and R. W. Boyle. Moorhouseite and Aplowite, New Cobalt Minerals From Walton, Nova Scotia. Canadian Miner., v. 8, pt. 2, 1965, pp. 166–171.

pentlandite, Co_9S_8, from near Noranda, Quebec, Canada.[9] Some problems of the crystal structure of cobaltite were resolved.[10]

Union Minière du Haut Katanga published a finely illustrated monograph describing its development and current operations. Included were brief summaries of the mining and concentration of ores and production of cobalt granules and cathodes.[11]

Sherritt Gordon Mines Ltd. recovered cobalt, nickel, and copper from an oxidized cobalt-nickel-iron sulfide concentrate.[12]

A versatile chemical process for recovery of nickel and cobalt from nickeliferous laterites was described,[13] and the economics discussed.[14] The end product, nickel and cobalt sulfide, would be further processed in existing nickel refineries. The process involves pugging the ore with sulfuric acid, drying, roasting, leaching, and precipitation.

A Bureau of Mines publication described a sulfatizing process for laterites using a sulfur dioxide-air reaction gas;[15] a recovery process for cobalt in an aqueous solution of copper, zinc, and cobalt sulfate salts was patented.[16]

An announcement was made of commercial production of an ultra-high-purity electron beam float-zone refined cobalt rod with nominal impurity analysis of 100 parts per million interstitial content (O_2, N_2, H_2, C) and 25 parts per million substitutional content.[17]

Areas of activity in fundamental and applied research were indicated by papers presented in the volume, Journées Internationales des Applications du Cobalt;[18] six papers reported on fundamental research, four on magnetic materials, eight on heat-resisting alloys, five on high-strength steels and alloys, and two on wrought cobalt.

Substantial progress made in documenting the properties of cobalt since 1958, when a previous description was written, was summarized by publication of best available data on its crystal structure, allotropic transformation, thermal, thermodynamic, electrical, and magnetic properties.[19] Magnetic properties of cobalt and some of its alloys and ionic compounds[20] and the role of cobalt in high-strength alloys[21] were reviewed.

A large number of articles were published on various cobalt alloy systems. These and other technical reports dealing with cobalt, its alloys, and metallic and nonmetallic applications, were abstracted in a section of the quarterly journal Cobalt.[22]

Research on the superalloys and heat-resisting alloys was concerned with the improvement of strength and of creep and corrosion resistance. Summaries of developments and trends in these materials,[23] and also on materials for gas turbine engines were published.[24] Coatings also were being developed to protect alloys from various forms of corrosion.

Properties of several cobalt base alloys were reported: Cobalt-tungsten superal-

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[9] Stumpfl, E. F., and A. M. Clark. A Natural Occurrence of Co_9S_8, Identified by X-Ray Microanalysis. Neues Jahrb. Mineral. Monatsh, v. 8, 1964, pp. 240–245.

[10] Giese, R. F., Jr., and P. F. Kerr. The Crystal Structures of Ordered and Disordered Cobaltite. Am. Mineral., v. 50, No. 7–8, July-August 1965, pp. 1002–1014.

[11] Union Minière du Haut Katanga. Monograph. 1964, 83 pp.

[12] Maschmeyer, D., and B. Benson. Hydrometallurgical Treatment of Oxidized Nickel-Cobalt Concentrate. Canadian Min. and Met. Bull. (Montreal), v. 58, No. 641, September 1965, pp. 931–938.

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[14] Young, K. A., N. Zubryckyj, D. J. I. Evans, and V. N. Mackiw. A Sulphation Leach Process For Recovering Nickel and Cobalt From Laterite Ores. Sherritt Gordon Mines Ltd., Res. and Devel. Div., Fort Saskatchewan, Alberta, Canada, March 1965, 27 pp.

[15] Joyce, F. E., Jr. Sulfatization of Nickeliferous Laterites. BuMines Rept. of Inv. 6644, 1965, 16 pp.

[16] Barut, Cihat M., and Raymond O. Lehr (assigned to Dorr-Oliver Inc., Stamford, Conn.). Process For The Treatment of An Aqueous Solution Containing Various Metal Sulphate Salts For The Recovery of Metal Values, Particularly of Cobalt, Therefrom. U.S. Pat. 3,168,375, Feb. 2, 1965.

[17] Materials Research Corp. Advanced Materials Division, Ultra-High Purity Cobalt. Orangeburg, N. Y. February 1965, 1 p.

[18] Journées Internationales des Applications du Cobalt. Centre d'Information du Cobalt, Brussels. Belgium, 1965, 407 pp.

[19] Winterhager, H., and J. Krüger. Pure Cobalt and Its Properties. Cobalt, No. 29, December 1965, pp. 185–195.

[20] Pauthenet, R. Magnetic Properties of Cobalt and of Some Cobalt Alloys and Ionic Compounds. Cobalt, No. 26, March 1965, pp. 3–9; No. 27, June 1965, pp. 76–84.

[21] Habraken, L., and D. Coutsouradis. Tentative Synthesis on the Role of Cobalt in High-Strength Alloys. Cobalt, No. 26, March 1965, pp. 10–24.

[22] Cobalt. Cobalt Information Center, Battelle Memorial Institute, Columbus, Ohio, Nos. 26–29, 1965.

[23] Decker, R. F., and R. R. DeWitt. Trends in High-Temperature Alloys. J. Metals, v. 17, No. 2, February 1965, pp. 139–145.

loys;[25] high-temperature alloy MAR-M 509;[26] and embrittlement of L-605.[27] Vapor deposition of cobalt-tungsten alloys was accomplished by hydrogen reduction of anhydrous mixed vapors of cobaltous chloride and tungsten hexachloride.[28]

Cobalt-bearing magnets continued to receive substantial attention. Among those studied were the Alnico magnets, including Alnico 8[29] and also cobalt-platinum magnetic alloys.[30] The cobalt-platinum alloys are malleable and ductile. A process for producing ductile cobalt-iron-vanadium magnetic alloy was patented.[31] IBM produced a ferromagnetic amorphous gold-cobalt alloy by vapor-deposition.[32]

The cobalt-bearing maraging steels were increasingly utilized because of their great strength, good machineability, and simple heat treatment. Among extensive publications were ones on properties[33] and utilization.[34]

A Bureau of Mines publication reported that substitution of cobalt in types 302 and 309 stainless steel had an irregular effect on corrosion resistance; at some levels of cobalt content, corrosion resistance was improved by the presence of cobalt.[35]

Coating by metalizing, flame spraying, and plasma flame spraying continued to receive close study, with attention to materials and fabrication of new parts, as well as hardfacing of worn parts.[36]

Conditions of deposition and properties of electrolytic-deposited and electroless cobalt and cobalt-bearing alloys were intensively studied, particularly for use in computer applications. A bibliography on cobalt coatings and a survey and bibliography of electrodeposition of cobalt alloys were published.[37]

The production of cobalt and cobalt alloys by powder metallurgy was summarized.[38]

Heat of formation, low-temperature heat capacity, and entropy at 298.15° K were determined for $CoSO_4$.[39] Oxidation of iron-cobalt-nickel glass sealing alloy was studied.[40]

A report discussed the possible use of large quantities of radioactive cobalt with high specific activity (curies of cobalt-60 per gram of product) as a heat source for generation of electricity, useful heat, or propulsion force.[41]

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[25] Freche, John C., Richard L. Ashbrook, and Gary D. Sandrock. The Potential For Cobalt-Tungsten Superalloys. Metal Prog., v. 87, No. 5, May 1965, pp. 74–79.

[26] Wheaton, H. L. MAR-M 509, A New Cast Cobalt-Base Alloy For High-Temperature Service. Cobalt, No. 29, December 1965, pp. 163–170.

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[28] Donaldson, J. G. Vapor Deposition of Cobalt-Tungsten Alloys. BuMines Rept. of Inv. 6713, 1965, 15 pp.

[29] Julien, C. A., and F. G. Jones. The Magnetic Property Effects of $\alpha\gamma$ Phase in Alnico 8 Alloys. Cobalt, No. 27, June 1965, pp. 73–75.

[30] Walmer, Marlin S. (assigned to Hamilton Watch Co., Lancaster, Pa.). Cobalt-Platinum Alloy and Magnets Made Therefrom. U.S. Pat. 3,206,337, Sept. 14, 1965.

[31] Chen, Charles W. (assigned to Westinghouse Electric Corp., East Pittsburgh, Pa.). Processes For Producing Ductile Cobalt-Iron-Vanadium Magnetic Alloys. U.S. Pat. 3,189,493, June 15, 1965.

[32] Mader, S., and A. S. Nowick. Metastable Co-Au Alloys: Example of an Amorphous Ferromagnet. Appl. Phys. Letters, v. 7, No. 3, Aug. 1, 1965, pp. 57–59.

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[35] Tilman, M. M. Effects of Substituting Cobalt For Nickel on the Corrosion Resistance of Two Types of Stainless Steel. BuMines Rept. of Inv. 6591, 1965, 17 pp.

[36] Hall, Frank E. Flame-Sprayed Coatings. Prod. Eng., v. 36, No. 25, Dec. 6, 1965, pp. 59–64.

[37] Morral, F. R. Bibliography on Cobalt Coatings. Cobalt Information Center, Battelle Memorial Inst., January 1965, 15 pp.

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Cobalt Information Center, Battelle Memorial Institute. Bibliography of Cobalt Alloy Coatings. January 1965, 34 pp.

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Columbium and Tantalum

By Richard F. Stevens, Jr. [1]

Although interest in the high-temperature uses of columbium and tantalum in nuclear and aerospace applications continued during 1965, these, like most other refractory metals, became in such short supply that releases from Government stockpiles were required early in 1966. The primary use of columbium, in the form of ferrocolumbium, increased almost 50 percent as steel production reached a new high. The use of tantalum, primarily in capacitors and other electronic applications, increased significantly in response to the military needs developed by the Viet-Nam conflict.

Legislation and Government Programs.—During the year the General Services Administration (GSA) awarded two contracts for the upgrading of columbium and tantalum materials from the national (strategic) stockpile. On June 14, Molybdenum Corporation of America was awarded a contract for the conversion of columbite concentrates to 360,000 pounds, columbium content, of ferrocolumbium. The fee for this upgrading will be reimbursed by payment-in-kind of tungsten concentrates from the Defense Production Act (DPA) inventory. On December 15, Fansteel Metallurgical Corp. was awarded a contract for the conversion of tantalum and columbium bearing tin slags to 84,500 pounds of tantalum metal powder of four different grades, 15,500 pounds of tantalum metal slabs, 15,000 pounds of columbium metal powder, and 90,000 pounds of columbium oxide powder (approximately 63,000 pounds Cb content). Payment for this upgrading will be made in pig tin from the DPA inventory.

Of the approximately 25,740 pounds of tantalum metal which was approved for disposal from the national (strategic) stockpile by the Congress in December 1964, GSA offered and sold 20,300 pounds in mid 1965 at an average price of $9.39 per pound, and 5,364 pounds in the form of tantalum stick filaments were transferred to the Atomic Energy Commission (AEC) for governmental use at the Oak Ridge National Laboratory, Oak Ridge, Tenn.

Although no columbium disposals were made in 1965, GSA announced plans early in 1966, for a long-term columbium disposal program covering the orderly disposal of 5 million pounds of surplus columbium from the DPA inventory. Under this program GSA announced their intention to release 1 million pounds of columbium in concentrates in the first half of 1966 to help relieve the demand for this material which became in short supply during 1965.

Throughout 1965 columbium and tantalum continued to be eligible for governmental financial assistance under the regulations of the Office of Minerals Exploration, Geological Survey, which permits government loans of not more than 50 percent of the total allowable costs of specified exploration.

As a result of successful research conducted on the high-temperature properties of Hf–Ta alloys (see Technology section), the National Aeronautics and Space Administration (NASA) awarded a 1 year, $125,000 contract to Fansteel Metallurgical Corp. for the development of industrial processing technology and manufacturing capability for the commercial production of the Hf–20Ta alloy.

[1] Commodity specialist, Division of Minerals.

Table 1.—Salient columbium-tantalum statistics

(Pounds)

	1956–60 (average)	1961	1962	1963	1964	1965
United States:						
Production: [1]						
Columbium metal (Cb content)	W	252,000	128,000	104,000	r 94,609	W
Tantalum metal (Ta content)	[2] 248,000	484,000	514,000	418,000	r 448,302	712,137
Ferrocolumbium and ferrotantalum-columbium (Cb+Ta content)	[3] 668,992	1,156,051	1,573,915	1,575,943	820,000	1,960,920
Consumption:						
Columbium metal contained in all raw materials consumed (Cb content) [4] [5]	[3] 1,184,000	1,738,000	2,844,000	2,054,000	2,758,000	2,749,152
Tantalum metal contained in all raw materials consumed (Ta content) [6]	[3] 517,000	828,000	946,000	502,000	510,000	774,785
Ferrocolumbium and ferrotantalum-columbium (Cb-Ta content)	533,375	1,052,181	1,397,638	1,345,789	1,478,770	2,198,744
Imports for consumption:						
Columbium mineral concentrate (gross weight)	4,010,363	2,777,700	5,050,888	5,909,512	4,600,800	4,891,786
Tantalum mineral concentrate (gross weight)	907,899	1,004,151	1,211,757	944,459	980,702	1,196,487
Columbium metal and columbium-bearing alloys (Cb content)	[7] 5,786	2,139	2,875	1,414	3,792	9,749
Tantalum metal and tantalum-bearing alloys (Ta content)		--------	--------	2,025	3,491	7,122
Exports:						
Columbium ore and concentrate (gross weight)	58,961	56,487	21,330	46,887	343,433	NA [8]
Tantalum ore and concentrate (gross weight)	10,254	--------	36,322	56,010	199,793	283,629
Columbium metal, compounds, and alloys (gross weight)	[7] 9,629	13,376	16,827	14,276	4,674	4,217
Tantalum metal, compounds, and alloys (gross weight)		15,554	17,934	44,390	32,489	20,780
Tantalum and tantalum alloy powder (Ta content)	4,202	5,585	7,445	14,146	32,217	24,662
World: Production of columbium-tantalum concentrates (gross weight)	6,744,000	10,975,000	9,665,000	9,530,000	11,745,000	14,880,000

r Revised.
W Withheld to avoid disclosing individual company confidential data.
[1] Domestic mine production of columbite-tantalite concentrate plus columbium-tantalum content of euxenite concentrate averaged 301,175 pounds per year during 1956–59; no domestic mine production since 1959.
[2] Average of 1958–60 only.
[3] Average of 1957–60 only.
[4] Includes columbium consumed in the production of ferrocolumbium.
[5] Includes some Cb in Ta ores which was not recovered.
[6] Includes some Ta in Cb ores which was not recovered.
[7] Columbium and tantalum metals and alloys; separate statistics not available.
[8] NA Not available; effective Jan. 1, 1965, columbite exports were placed in a basket category and are no longer separately classified.

Table 2.—Columbium materials in Government inventories as of December 31, 1965
(Thousand pounds, columbium content)

Material	Objective	National (Strategic) stockpile	Defense Production Act (DPA) inventory	Supplemental stockpile	Total
Columbium concentrate:					
Stockpile grade	----------	5,313	7,956	340	13,608
Nonstockpile grade	----------	1,364	80	36	1,480
Columbium carbide powder:					
Stockpile grade	20	21	----------	----------	21
Ferrocolumbium:					
Stockpile grade	930	296	----------	----------	296
On order-upgrading [1]	----------	360	----------	----------	360
Nonstockpile grade	----------	152	----------	----------	152
Ferrotantalum-columbium: [2]					
Stockpile grade	----------	104	----------	----------	104
Columbium metal:					
Stockpile grade	45	30	----------	----------	30
On order-upgrading [1]	----------	15	----------	----------	15
Columbium oxide powder:					
Stockpile grade	----------	23	----------	----------	23
On order-upgrading [1]	----------	63	----------	----------	63

[1] Material on order to be acquired through upgrading contracts.
[2] Credited to ferrocolumbium objective.

Table 3.—Tantalum materials in Government inventories as of December 31, 1965
(Thousand pounds, tantalum content)

Material	Objective	National (Strategic) stockpile	Defense Production Act (DPA) inventory	Supplemental stockpile	Total
Tantalum minerals:					
Stockpile grade	2,947	1,562	1,439	----------	3,001
Nonstockpile grade	----------	1,459	65	2	1,526
Tantalum carbide powder:					
Stockpile grade	27	29	----------	----------	29
Tantalum metal:					
Stockpile grade	360	101	----------	----------	101
On order-upgrading [1]	----------	100	----------	----------	[1] 100

[1] Material on order to be acquired through upgrading contracts.

DOMESTIC PRODUCTION

As has been the situation since 1960, there was no domestic mine production during 1965.

During the year production of columbium metal powder, withheld to avoid disclosing individual company confidential data, dropped significantly while production of columbium metal ingots increased slightly to 48 tons. The following companies produced columbium in 1965: E. I. du Pont de Nemours & Co., Inc., Baltimore, Md.; Fansteel Metallurgical Corp., Muskogee, Okla.; Kawecki Chemical Co., Boyertown, Pa.; Kennametal, Inc., Latrobe, Pa.; Stellite Division of Union Carbide Corp. (UCC), Kokomo, Ind.; and Wah Chang Corp., Albany, Oreg.

Production of tantalum metal powder (including capacitor grade powder) increased in 1965 and totaled 356 tons while production of tantalum metal ingots decreased to 139 tons. Fansteel Metallurgical Corp.; Kawecki Chemical Co.; Kennametal, Inc.; Linde Division of Union Carbide Corp., Indianapolis, Ind.; National Research Corp., Newton, Mass.; Stellite Division of Union Carbide Corp.; and Wah Chang Corp. were the principal tantalum metal producers in 1965.

During the year tantalum carbide was produced by Kawecki Chemical Co.; Kennametal, Inc.; Stellite Division of Union Carbide Corp.; and Wah Chang Corp. In addition, columbium carbide was produced by Kennametal and Wah Chang.

Producers of ferrocolumbium, ferrotantalum-columbium, and columbium-base master alloys during 1965 were: Kawecki Chemical Co.; Molybdenum Corporation of America, Washington, Pa.; Reading Alloys Co., Inc., Robesonia, Pa.; Shieldalloy Corp., Newfield, N.J.; Mining and Metals Division of Union Carbide Corp., Niagara Falls, N.Y.; and Vanadium Corporation of America at its plants in Cambridge, and Vancoram, Ohio, and Graham, West Va. These ferroalloys were produced in electric furnaces by Molybdenum Corporation of America, Union Carbide Corp., and Vanadium Coporation of America. Kawecki, Reading Alloys, and Shieldalloy produced these ferroalloys by the thermite process. Union Carbide produced high-purity ferrocolumbium and nickel-columbium at Niagara Falls, N.Y. from the Cb_2O_5 recovered by a solvent-extraction process at its plant in Marietta, Ohio.

The Kemet Department of the Linde Division of Union Carbide Corp. announced plans to double the production of solid-tantalum capacitors and to expand storage facilities at its plant in Greenville, S.C.

CONSUMPTION AND USES

Consumption of columbium metal in 1965 continued to be primarily in ferroalloys for addition to steels to control grain size and was believed to account for approximately 85 percent of the metal consumed. Consumption of tantalum metal was mainly in the form of powder and ingots for use in the manufacture of capacitors, other electronic equipment, and corrosion-resistant chemical equipment.

Total consumption of columbium plus tantalum in ferroalloys increased almost 50 percent to the highest level on record as steel production continued to increase. The consumption of ferrocolumbium (FeCb) and ferrotantalum-columbium (FeTa-Cb) in high-temperature alloys, welding rods, and malleable iron castings, which decreased in 1964, increased in 1965. The greatest single volume increase in the usage of these ferroalloys was reported as other alloy steels. Domestic consumption of ferrocolumbium during 1965, by major use categories, was: Other alloys steels (45 percent), stainless steels (27 percent), high-temperature alloys (14 percent), carbon steels (12 percent), and nickel-base alloys, welding rods, and permanent magnet alloys (1 percent). The consumption of ferrotantalum-columbium continued to decrease during the year and amounted to less than 2 percent of the total reported FeCb plus FeTa–Cb consumption (table 4). The major uses of ferrotantalum-columbium were in the production of stainless steels (43 percent), capacitors (33 percent), high-temperature alloys (10 percent), nickel-base alloys (9 percent), and cemented carbides (4 percent).

Additional data on ferrocolumbium and ferrotantalum-columbium are contained in the "Ferroalloy" chapter of this Yearbook.

Union Carbide Corp. announced development of a commercial process for electrocladding and electroforming tantalum and columbium metals from a molten alkali-metal fluoride bath. The process is being marketed through the Stellite Division.

Ductile arc-cast tantalum wire became commercially available in diameters ranging from ½ to 0.002 inch from the General Electric Co., Cleveland, Ohio.

Kawecki Chemical Co. was licensed by Imperial Metal Industries Ltd., a subsidiary of Imperial Chemical Industries Ltd., England, as the exclusive United States agent for the domestic manufacture and marketing of a new columbium-base alloy designated SU 16. This alloy, with a nominal composition Cb–11W–3Mo–2Hf—0.08 C, retains most of its strength at elevated temperatures and is expected to find wide application in the aerospace industry. The alloy can be readily fabricated to thin sheet and wire and recrystallized after cold working without loss of ductility.

Fansteel Metallurgical Corp., added acid-proof tantalum chemical equipment produced at its Muskogee, Okla., plant and aerospace fabrications formed at its California plant to its line of refractory metals marketed through Joseph T. Ryerson & Son, Inc.

Fansteel announced that an expansion of capacity had been completed during the year in the VR/Wesson Division and that plans were underway for expanding production capacity of the electro-metals group.

The Arnold Engineering Co., Marengo, Ill., a subsidiary of the Allegheny Ludlum

Steel Corp., announced that it will expand its rolling mill production of ultra-thin columbium, tantalum, titanium, zirconium, and hafnium foil and strip in gauge sizes ranging from 1 mil (0.001 inch) to 0.00067 inch and under.

High strength rings of Haynes alloys Cb–752 (Cb–10W–2.5 Zr) which have a yield stress in excess of 18,000 pounds per square inch (psi) at 2,400° F were produced commercially by the Stellite Division of Union Carbide Corp.

Ciba Corp., Summit, N.J., established a rare-metals department to market the high-purity columbium and tantalum powders, nitrides, and carbides produced by its Swiss parent company, Ciba Ltd.

High-purity (99.9 + percent) tantalum sheets having uniform grain size were produced commercially in standard thicknesses from 0.005 to 0.1875 inch and widths from ¼ to 24 inches by the General Electric Co. This tantalum sheet, designated GE–43, is available in lengths from 5 to 25 feet depending upon thickness and metal condition (cold-worked or recrystallized).

The major refractory metals facilities of the Fansteel Metallurgical Corp., including the electron-beam and arc-melting equipment, have been moved from the Richmond, Calif., and North Chicago, Ill., locations to the Muskogee, Okla., plant where most metal production operations are now centralized. The fabrication equipment of the Airtek Division of Fansteel Astro Nuclear Group, Compton, Calif., acquired in 1964, allows Fansteel to process material from raw ore at Muskogee to finished product at Compton.

The Refractomet Division of Universal-Cyclops Steel Corp. announced that it would produce tantalum mill and fabricated products from electron-beam- and arc-melted ingots. To supply the larger size sheets and massive shapes required by industry, Cyclops can arc-cast 10-inch diameter tantalum ingots weighing 1,000 pounds.

Sylvania Electric Products, Inc., Sylcor Division, Hicksville, N.Y., commercially developed a modified silicide base slurry coating containing silver for the protection of columbium metal, a hafnium-tantalum base slurry coating, designated Coating R515, for the protection of columbium and tantalum substrates in the temperature range from 3,000° to 4,000° F, and a tin-aluminum base coating to protect all four major refractory metals (W,Mo,Cb and Ta) in the temperature range between 1,800° and 3,450° F.

The National Research Corp. developed a high-temperature tantalum alloy by the addition of minor amounts of yttrium which inhibits grain growth at elevated temperatures resulting in longer life and better high-temperature performance.

Sprague Electric Co., North Adams, Mass., announced that it had licensed the General Electric Co. (GE) to produce solid-electrolyte tantalum capacitors. Under the agreement, GE paid Sprague for its past production of this type of capacitor and received a nonexclusive license "with royalties" for the future production of tantalum capacitors covered by Sprague patents. This action was similar to the arrangements Sprague previously made with Union Carbide Corp. and Cornell-Dubilier Electric Co., as reported in the 1964 Yearbook.

Though interest in columbium superconducting alloys continued during the year and these alloys continued to be offered commercially, the amount of columbium consumed in this application was small.

United Metallurgical Corp., Berkeley, Calif., founded in 1963 as a jointly owned refractory metal production facility by Temescal Metallurgical Corp. and Phelps Dodge Corp. operated intermittently during the latter part of 1964 and 1965. The company was disbanded early in 1966 following an out-of-court settlement between the two forming companies which had filed law suits to determine control of the joint company.

Table 4.—Consumption by end uses of ferrocolumbium and ferrotantalum-columbium in the United States

(Pounds of contained columbium plus tantalum)

Product	1964	1965
Stainless steels	526,265	601,247
Other alloy steels	563,591	974,999
Carbon steels	178,370	265,545
Tool steels [1]	1,136	1,268
Welding rods [2]	10,847	11,492
Gray and malleable castings	90	158
High-temperature alloys	180,464	313,043
Permanent-magnet alloys	3,141	5,222
Nickel-base alloys	8,246	11,468
Miscellaneous [3]	6,620	14,302
Total	1,478,770	2,198,744

[1] Includes high-speed steels.
[2] Includes hard facing alloys.
[3] Includes electrical resistance alloys, premixed powders, cemented carbides, and capacitors.

STOCKS

With the exception of stocks of tin slags which increased almost 15 percent, consumer and dealer stocks were drawn down substantially at yearend and were (in short tons): Columbite, 550; tantalite, 868; and pyrochlore, 210.

In addition there were the following columbium inventories at yearend: Primary metal, 48,627 pounds; ingot, 31,703 pounds; scrap, 54,537 pounds; oxide, 229,420 pounds; and other columbium compounds, 17,938 pounds. Tantalum inventories included: Primary metal, 76,672 pounds; capacitor grade tantalum powder, 97,733 pounds; ingot, 20,561 pounds; scrap, 93,379 pounds; oxide, 57,941 pounds; potassium tantalum fluoride, 69,002 pounds; and other tantalum compounds, 21,506 pounds.

Consumer inventories of ferrocolumbium and ferrotantalum-columbium as of December 31, 1965, were: Ferrocolumbium, 525,042 pounds (contained columbium plus tantalum); and ferrotantalum-columbium, 10,667 pounds (contained columbium plus tantalum). Producer stocks of ferrocolumbium at yearend were 548,000 pounds (contained columbium plus tantalum); producer stocks of ferrotantalum-columbium, withheld to avoid disclosing individual company confidential data, continued to decrease.

PRICES

Long term prices for columbite ore, c.i.f., U.S. ports were quoted by E&MJ throughout the year at $0.80 to $0.90 per pound of contained pentoxides for material having a Cb_2O_5 to Ta_2O_5 ratio of 10:1 and at $0.75 to $0.80 per pound for material having a ratio of 8.5:1. In March and throughout the remainder of the year spot prices for both grades were quoted at $1.10 to $1.15 and $1.00 to $1.05 per pound of contained pentoxides. During the last half of the year, spot prices for Canadian pyrochlore were quoted at $1.15 to $1.18 per pound of Cb_2O_5, f.o.b. mine or mill, while discounts were allowed for long-term contracts. Brazilian pyrochlore reportedly sold for approximately $0.93 to $0.95 per pound of Cb_2O_5. During 1965 the price for tantalite ores, 60 percent basis, c.i.f. U.S. ports, more than doubled to approximately $7.50 to $8 per pound of contained pentoxides having a Ta_2O_5 to Cb_2O_5 ratio of 3:1.

Ferrocolumbium containing 50 to 60 percent columbium, 0.40 percent carbon (maximum), and 8 percent silicon (maximum) was quoted by E&MJ Metal and Minerals Market through February 8 at $3 per pound of contained columbium, ton lots, 2-inch lump, packed and delivered. From mid February through March the quoted price was $2.85, and from April through June the quoted price ranged from $2.80 to $3 per pound of Cb. In July the price increased to $3.17 and for the last quarter of the year the price ranged from $3.02 to $3.17 per pound. Although several metal producers announced that they planned to increase their prices for columbium and tantalum metal, the 1965 quotations by E&MJ for these materials remained unchanged from 1964. Columbium metal, 99.5 percent purity, continued to be quoted at $36 per pound for roundels and at $50 per pound for rough ingots. Tantalum metal continued to be quoted at $30 to $49 per pound for powder, $47 to $60 per pound for sheet, and $52 to $65 per pound for rod.

Table 5.—Average grade of concentrate received by U.S. consumers and dealers in 1965, by country of origin

(Percent of contained pentoxides)

Country	Columbite			Tantalite	
	Cb_2O_5	Ta_2O_5	Ratio	Ta_2O_5	Cb_2O_5
Australia	---------	---------	---------	47	26
Brazil [1]	55	0.29	---------	45	13
Canada [2]	52.4	.32	---------	---------	---------
Congo (Leopoldville)	---------	---------	---------	38	4
French Guiana	---------	---------	---------	44	37
Malaysia	44	15	2.9: 1	41	26
Mozambique	46	19	2.4: 1	56	17
Nigeria	67	7	9.6: 1	42	5
Portugal	37	27	1.4: 1	37	9
South Africa, Republic of	---------	---------	---------	56	18
Uganda	33	10	3.3: 1	---------	---------

[1] Material reported from Brazil as columbite actually represents pyrochlore.
[2] Pyrochlore concentrate.

FOREIGN TRADE

Exports.—During the year 1,244 pounds of unwrought columbium and columbium alloys were exported primarily to the United Kingdom and West Germany. A total of 2,973 pounds of wrought columbium and columbium alloys were exported primarily to the United Kingdom, France, the Netherlands, and Japan. Reexports of tantalum ore were shipped to West Germany, Japan, Austria, the United Kingdom, Canada, and France. Tantalum metal was exported to Japan, the Netherlands, France, West Germany, Switzerland, and the United Kingdom.

Imports.—Imports for consumption of unwrought columbium metal increased from 3,792 pounds valued at $15,954 in 1964 to 9,749 pounds valued at $82,042 in 1965. All of these 1965 imports of columbium came from West Germany. In 1965 imports for consumption of unwrought tantalum metal increased to 7,122 pounds valued at $63,457 from 3,491 pounds valued at $52,283 in 1964. In 1965 these imports came from the United Kingdom (34 percent), Japan (19 percent), France (18 percent), Switzerland (13 percent), Canada (11 percent), and West Germany (5 percent). During the year 19,040 pounds of tantalum waste and scrap were also reported imported from Canada. In addition, 56 pounds of wrought tantalum alloys and 63 pounds of wrought columbium alloys were imported from West Germany during 1965.

Receipts of microlite and tin slags reported in table 7, originated from Mozambique and from the Congo (Léopoldville), Malaysia, Nigeria, and Spain.

Table 6.—U.S. exports of columbium and tantalum, by classes

Class	1964		1965	
	Pounds	Value	Pounds	Value
Columbium ores and concentrates	343,433	$188,563	(1)	(1)
Columbium and columbium alloys unwrought and waste and scrap	603	4,669	1,244	$20,087
Columbium and columbium alloys, wrought	4,071	417,091	2,973	156,892
Tantalum ores and concentrates	199,793	401,695	283,629	698,194
Tantalum and tantalum alloys, wrought	12,027	582,961	9,621	843,027
Tantalum metals and alloys in crude form and scrap	20,462	226,420	11,159	114,583
Tantalum and tantalum alloy powder	32,217	573,733	24,662	756,857

[1] No longer separately classified, beginning Jan. 1, 1965.

Table 7.—Receipts of microlite and tin-slags reported by consumers and dealers [1]
(Pounds)

Material	1963			1964 [2]			1965		
	Gross weight	Cb_2O_5 content	Ta_2O_5 content	Gross weight	Cb_2O_5 content	Ta_2O_5 content	Gross weight	Cb_2O_5 content	Ta_2O_5 content
Microlite	80,695	3,478	54,207	182,591	3,186	128,182	131,056	2,533	91,350
Tin slags	30,968,743	1,627,641	1,410,778	2,516,153	280,459	154,538	8,822,136	563,886	428,911

[1] May incorporate some duplication.
[2] Data known to be incomplete.

Table 8.—U.S. imports for consumption of columbium-mineral concentrates by countries
(Pounds)

Country	1956-60 (average)	1961	1962	1963	1964	1965
North America:						
Canada	2,800	35,575	1,509,928	1,881,704	1,940,133	1,860,631
Mexico	---	---	---	---	---	25,288
Total	2,800	35,575	1,509,928	1,881,704	1,940,133	1,885,919
South America:						
Argentina	1,171	---	---	---	---	---
Bolivia	758	---	---	---	---	---
Brazil	116,195	73,363	95,767	1,784,558	35,478	675,168
Total	118,124	73,363	95,767	1,784,558	35,478	675,168
Europe:						
Belgium—Luxembourg [1]	---	---	32,549	33,732	5,922	---
Denmark [1]	---	---	---	---	56,217	---
Finland	---	---	---	2,207	3,307	---
Germany, West	13,228	---	2,204	2,205	---	---
Netherlands	9,711	---	28,926	20,432	---	7,545
Norway	337,406	---	662,498	346,688	---	---
Portugal	48,581	22,457	42,565	4,465	21,527	---
Spain	195	---	---	---	14,610	---
United Kingdom	12,644	---	56,002	---	33,600	---
Total	421,765	22,457	824,744	409,729	135,183	7,545
Africa:						
British East Africa	7,685	29,971	---	22,488	---	---
Uganda					8,717	18,199
Congo (Léopoldville)	584,014	113,085	55,846	163,437	---	44,125
Burundi and Rwanda					7,716	34,412
Malagasy Republic	10,594	6,524	7,536	---	21,885	---
Mozambique	91,362	60,613	25,453	73,498	13,228	32,187
Nigeria	2,389,816	2,181,318	2,388,377	1,301,314	2,311,783	2,111,711
Rhodesia and Malawi	1,727	20,700	7,137	853	---	---
South Africa, Republic of	26,953	2,240	4,974	10,142	56,000	---
Western Equatorial Africa	---	---	11,244	---	---	---
Total	3,112,151	2,414,451	2,500,567	1,571,732	2,419,329	2,240,634
Asia:						
Aden	270	---	---	---	---	---
Malaysia	352,034	228,459	119,882	261,789	70,677	82,520
Thailand	2,709	---	---	---	---	---
Total	355,013	228,459	119,882	261,789	70,677	82,520
Oceania: Australia	510	3,395	---	---	---	---
Grand total:						
Pounds	4,010,363	2,777,700	5,050,888	5,909,512	4,600,800	4,891,786
Value	$4,021,717	$2,305,941	$3,419,361	$3,143,789	$2,276,536	$2,711,677

[1] Presumably country of transshipment rather than original source.

Table 9.—U.S. imports for consumption of tantalum-mineral concentrates by countries

(Pounds)

Country	1956–60 (average)	1961	1962	1963	1964	1965
South America:						
Argentina	3,531	4,444	3,637	4,519	---------	---------
Brazil	177,255	159,925	194,955	241,148	142,047	281,308
British Guiana	---------	---------	---------	---------	1,103	---------
French Guiana	3,521	---------	---------	5,031	4,240	896
Surinam	---------	---------	---------	---------	---------	15,300
Total	184,307	164,369	198,592	250,698	147,390	297,504
Europe:						
Belgium—Luxembourg [1]	8,274	47,993	31,896	2,137	---------	55,266
France	---------	---------	---------	---------	---------	12,287
Germany, West	27,086	---------	11,276	---------	---------	---------
Netherlands	1,602	26,495	---------	4,779	119,715	81,932
Portugal	21,365	29,793	95,692	72,711	32,281	47,772
Spain	632	11,148	2,645	---------	---------	13,484
Sweden	198	---------	---------	---------	---------	---------
Total	59,157	115,429	141,509	79,627	151,996	210,741
Africa:						
British East Africa					---------	---------
Kenya	945	36,182	9,911	8,287	5,362	---------
Uganda					---------	4,505
Congo (Léopoldville)	462,615	164,277	228,185	147,257	101,160	159,627
Burundi and Rwanda					2,208	15,432
Malagasy Republic	14,966	11,953	12,126	52,246	16,101	8,157
Mozambique	66,875	219,847	351,087	156,528	277,144	276,391
Nigeria	28,225	121,110	48,551	64,831	83,710	35,980
Rhodesia and Malawi	36,706	53,098	98,716	93,990	16,149	7,908
South Africa, Republic of	13,567	31,677	8,733	31,597	4,059	12,192
Western Equatorial Africa					---------	---------
Central African Republic	---------	---------	26,455	---------	472	---------
Western Portuguese Africa	---------	---------	3,490	6,746	110,494	6,615
Total	623,899	638,144	787,254	561,482	616,859	526,807
Asia:						
Indonesia	---------	---------	---------	---------	---------	20,000
Japan	---------	---------	4,401	---------	1,311	5,999
Malaysia	4,143	82,807	57,437	11,113	---------	96,666
Thailand	903	---------	5,941	13,795	46,343	26,777
Total	5,046	82,807	67,779	24,908	47,654	149,442
Oceania: Australia	35,490	3,402	16,623	27,744	16,803	11,993
Grand total:						
Pounds	907,899	1,004,151	1,211,757	944,459	980,702	1,196,487
Value	$1,253,900	$2,001,944	$3,526,948	$2,410,814	$1,606,095	$2,149,727

[1] Presumably country of transshipment rather than original source.

WORLD REVIEW

NORTH AMERICA

Canada.—Open pit production of pyrochlore concentrate by St. Lawrence Columbium Metals Corp., Oka, Quebec, the sole Canadian producer, continued to increase during 1965 as the company further expanded its mill capacity from 1,000 to 1,300 tons of ore per day.[2] To meet the high demand for columbium, St. Lawrence planned to further expand the mill capacity to 1,500 tons per day in 1966. Shipments of pyrochlore concentrate to consumers in the United States increased during 1965 and represented approximately half of the company's total deliveries, the remainder going primarily to European consumers. Another indication of the tight columbium situation was the fact that most of the company's output was committed through mid 1966. During the year, St. Lawrence initiated a $2 million underground mining program to produce 4,000

[2] Carbonneau, C., and J. C. Caron. The Production of Pyrochlore Concentrates at St. Lawrence Columbium and Metals Corp. Canadian Min. and Met. Bull. (London), v. 58, No. 635, March 1965, pp. 281–289.

Table 10.—Free world production of columbium and tantalum concentrates (gross weight) [1] by countries
(Pounds)

Country	1961 Columbium	1961 Tantalum	1962 Columbium	1962 Tantalum	1963 Columbium	1963 Tantalum	1964 Columbium	1964 Tantalum	1965 p [2] Columbium	1965 p [2] Tantalum
North America: Canada (shipments)	119,261	---------	1,909,433	---------	2,692,935	---------	4,222,424	---------	4,510,182	---------
South America:										
Argentina (U. S. imports)	---------	4,444	---------	3,637	---------	4,519	---------		---------	
Brazil:										
Columbium-tantalum	[3] 38,477	[3] 264,519	[3] 38,164	[3] 322,804	[3] 42,767	[3] 231,000	[3] 24,643	[3] 180,777	[4] 675,168	[4] 281,308
Pyrochlore concentrates	3,368,629	---------	224,869	---------	---------	---------	712,086	---------	2,636,702	---------
French Guiana	---------		---------		5,031		r 2,205		1,874	
Europe:										
Norway	708,118	---------	r 769,405	---------	782,633	---------	410,056	---------	187,391	---------
Portugal (U. S. imports)	22,457	29,793	42,565	95,692	4,465	72,711	21,527	32,281	---------	47,772
Spain (U. S. imports)	---------	11,148	---------	2,645	---------		14,610	---------	---------	13,484
Africa:										
Burundi-Rwanda (U. S. imports)	([5])		([5])		([5])		r 7,716	2,208	34,412	15,432
Congo, Republic of the (Léopoldville) (U. S. imports) [5] [6]	113,085	164,277	55,846	228,185	163,437	147,257	([7])	101,160	45,125	159,627
Malagasy Republic	46,750		20,720		37,920		7,940		8,820	
Mozambique [8]	r 371,946		r 346,517		r 337,927		r 416,670		[4] 32,187	[4] 276,391
Nigeria	5,257,280	26,230	5,066,880	38,013	4,506,880	33,600	5,239,360	r 22,400	5,707,520	29,030
Rhodesia, Southern	---------	138,380	---------	159,820	---------	151,000	---------	141,320	---------	e 62,960
South Africa, Republic of	---------	20,000	---------	8,000	---------	64,000	---------	14,000	---------	6,000
South-West Africa	670	5,790	1,116	10,444	418	4,143	r 447	r 1,027	1,080	1,135
Uganda	16,240		28,851		19,841		12,858		17,920	
Asia: Malaysia	212,800	---------	246,400	---------	197,120	---------	125,440	---------	103,040	---------
Oceania: Australia	31,808		43,097		r 30,089		32,636		21,660	
Free world total e	r 10,975,000		r 9,665,000		r 9,530,000		r 11,745,000		14,880,000	

e Estimate. p Preliminary. r Revised.
[1] Frequently the composition (Cb_2O_5–Ta_2O_5) of this concentrate lies in an intermediate position, neither Cb_2O_5 nor Ta_2O_5 being strongly predominant. In such cases the production figure has been centered.
[2] Compiled mostly from data available June 1966.
[3] Exports.
[4] U.S. imports.
[5] Burundi-Rwanda included in Republic of the Congo through 1963.
[6] In addition, tin-columbium-tantalum concentrate was produced as follows: 1961, e 1,400,000 pounds; 1962–65 not available; columbium-tantalum content averaging about 10 percent.
[7] Revised to none.
[8] Includes microlite as follows: 1961, 68,780 pounds; 1962, 115,080; 1963, 160,060; 1964, 131,050; 1965, not available.

tons per day from a depth of 2,000 feet. Development will be completed late in 1966 and mining was scheduled to begin in early 1967.

Ferrocolumbium was produced in Canada by the Metals and Carbon Division, Union Carbide Canada Ltd.; Masterloy Products Ltd.; and Metallurg (Canada) Ltd. The major Canadian ferrocolumbium consumers were Atlas Steels Division of Rio Algom Mines Ltd., Welland; the Algoma Steel Corp. Ltd., Sault Ste. Marie; Black Clawson-Kennedy Ltd., Owen Sound; Dominion Foundries & Steel Ltd., Hamilton; Canadian Westinghouse Co. Ltd., Hamilton, all in Ontario; and Crucible Steel of Canada Ltd., Sorel, Quebec.

The Macro Division of Kennametal, Inc., Port Coquitlam, British Columbia, manufactured high-purity tantalum carbide, tantalum-columbium carbide, tantalum-columbium-titanium carbide, and tantalum-columbium-tungsten carbide. Masterloy Products Ltd. Ottawa, continued to produce a self-reducing columbium additive, which was a mixture of pyrochlore and an aluminum or ferrosilicon reductant, for use in steelmaking.

SOUTH AMERICA

Brazil.—The pyrochlore operations of Distribuidora e Exportadora de minerios e Adubos, S.A. (DEMA), at Araxa, Minas Gerais, progressed smoothly during the year and the company reportedly planned to expand operations in 1966.[3] During 1965 a modification in the flotation technique resulted in the production of a higher grade concentrate containing 57 to 58 percent Cb_2O_5. Prior to this change, which lowered the silica (SiO_2) content, the Cb_2O_5 content had been about 54 percent. Production of pyrochlore concentrate during the year exceeded the estimates reported in the 1964 chapter and increased from approximately 712,000 pounds in 1964 to 2.6 million pounds in 1965. The 1965 exports of pyrochlore concentrate to Japan, the Netherlands, the United Kingdom, and the United States increased substantially to over 2.9 million pounds from some 150,000 pounds in 1964. Production of ferrocolumbium by the thermite batch process increased from almost 40,000 pounds in 1964 to over 600,000 pounds in 1965. During 1965 465,000 pounds of FeCb were exported and 22,000 pounds were sold domestically, compared with the total of 11,000 pounds exported in 1964.

DEMA plans to significantly increase the production capacity of its mill to about 992,000 pounds of pyrochlore concentrate per month early in 1966. The increasing of mining operations to match the mill expansion will present no problems since mining is conducted by simple surface stripping and subsequent open pit techniques applied to the extremely rich (4+ percent Cb_2O_5) ore. Although the Comisso Nacional de Energia Nuclear (CNEN) has only granted permits to export approximately 5 million pounds of concentrate, DEMA has expressed hope that their production in 1966 will exceed 11 million pounds to allow the filling of sales orders already contracted. This large demand for columbium is a further indication of the tight supply situation which developed in 1965.

Although the DEMA pyrochlore concentrate contained a higher Cb_2O_5 content than those from Canada, the DEMA material, which was reportedly slightly inferior because of its fine mesh size and radioactive content, was sold at a lower price than the Canadian concentrate.

The ownership of DEMA changed during 1965 when Molybdenum Corporation of America (Molycorp), which had owned 25 percent of the company, and Pato Consolidated Gold Dredging Ltd., of British Columbia, Canada, purchased the 25 percent interest held by Wah Chang Corp. DEMA is currently owned by Brazilian interests (50 percent), Molybdenum Corp. (33 1/3 percent), and Pato (16 2/3 percent). However, since Pato is a subsidiary of the International Mining Corp., the company which recently purchased Kennecott Copper Corp. interest in Molybdenum Corp., Molybdenum Corp. effectively has a 50 percent interest in DEMA.[4] Management of the joint venture between Pato and Molycorp. will be through the newly formed Niobium Corp., a New York holding company owned by Molycorp. (66 2/3 percent) and Pato (33 1/3 percent) and represented by D. M. Kentro, general manager for rare earth and columbium mining operations of Molycorp.

British Guiana.—A columbite and tantalite mining operation employing about

[3] Bureau of Mines. Mineral Trade Notes. V. 62, No. 6, June 1966, pp. 11–12.
[4] Metal Bulletin (London). Molycorp.'s Pyrochlore Interest. No. 4992, Apr. 27, 1965, p. 24.

100 miners was reported at Oranapai, Mazaruni. Because of the area's remote location, ore transportation is the mine's major problem.

EUROPE

Belgium.—At its factory at Hoboken, a new rolling mill was installed by Fansteel-Hoboken, S.A. to fabricate tantalum sheet for corrosion-resistant use in the chemical and oil industries. This growing demand for tantalum sheet prompted Fansteel-Hoboken to acquire a major shareholding interest in Toleries Gantoises, Drongen, a producer of specialized equipment for the chemical industry.[5]

France.—Estimated production of ferrocolumbium during the year was approximately 600,000 pounds, columbium content, of which one-third to one-half was exported to West Germany.

Germany, Federal Republic of.—Production of ferrocolumbium during the year was estimated to be 600,000 pounds, columbium content. Since approximately 340,000 pounds were imported from France and Austria, apparent consumption and shipments of ferrocolumbium were estimated to be 940,000 pounds.

Norway.—The Norwegian pyrochlore producer, Norske Bergverk A/S, a government-owned corporation, suspended mining operations of the low-grade pyrochlore deposits at Sove, near Ulefoss in the Telemark district, on September 1. Although the concentrate was quite rich, with 55 to 60 percent Cb_2O_5 and low tin and tantalum contents, the operation became increasingly uneconomical as lower grade ores were worked.[6] This pyrochlore was converted to ferrocolumbium by ferroalloy producers in the United Kingdom, West Germany and Sweden.

Portugal.—Metallium Corp. continued to be the major Portuguese tantalum producer, recovering tantalite as a coproduct of tin mining operations. While most tantalite producers in 1965 recovered only the higher grade concentrates containing 60 percent Ta_2O_5 and up, Metallium continued to produce some medium grade concentrates containing 35 to 40 percent Ta_2O_5 for regular customers who required the lower grade. The tantalum production of Portugal was stimulated by a booming tin market and by the addition of Metallium's two new tantalite processing units in the Lima Valley.

Sweden.—Swedish production of ferrocolumbium in 1965 was estimated at 400,000 pounds, columbium content, all of which was believed consumed by the domestic steel industry.

Switzerland.—The new refractory metals refining plant recently constructed by Ciba Ltd. near Basle became operational in 1965 and has a capacity of 100 tons per year. The plant reportedly uses a special chlorination type process to extract high-purity columbium and tantalum metals.

United Kingdom.—Ferrocolumbium production in the United Kingdom during the year has been estimated at 1.5 million pounds, columbium content, of which approximately one-third was exported to Western Europe, Republic of South Africa, Japan, and the United States, while the remaining 1 million pounds was consumed domestically by such companies as Murex Ltd., Rainham (Essex). Murex installed two up-to-date induction furnaces designed for the production of a wide variety of metals and alloys to meet the increasing demand for Murex "master" alloys. More than 200 different metals and alloys are produced by Murex annually by thermit reduction and by electric and high vacuum furnace techniques.[7]

AFRICA

Congo (Léopoldville).—To obtain a reliable source of supply of columbium, Union Carbide Corp. continued to develop an open pit pyrochlore mine near Beni, North Kivu. It is anticipated that a pilot plant with a capacity of 40 tons of ore per day will be constructed and operated as a joint venture between United Carbide and Belgium interests.

Mozambique.—The principal columbite-tantalite producers in Mozambique, Sociedade Mineria de Morropino and Empresa Mineria do Alto Logonha, which both recovered columbite-tantalite ores from the pegmatite deposits southwest of Nampula, were troubled by technical, transportation, and management difficulties which resulted in significantly decreased production.

Nigeria.—The production of columbium, which was recovered as a coproduct of tin

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[5] Chemical Trade Journal and Chemical Engineer (London). Tantalum Sheet Plant. V. 156, No. 4066, May 13, 1965, p. 584.

[6] Metal Bulletin. Norsk Bergverk to Close. No. 5020, Aug. 6, 1965, p. 25.

[7] Steel Times (London). Murex Steps Up Production of "Master" Alloys. V. 191, No. 5077, Nov. 5, 1965, p. 586.

mining operations, increased 9 percent to 5.7 million pounds during the year as a result of the increased demand and almost all of the future columbite production was committed under forward long-term contracts. Juntar Nigeria Co. recovered tin and columbium from its Kuru III deposit where the ratio of tin to columbium is about one to five. Although Amalgamated Tin Mines of Nigeria Ltd., increased columbium production substantially, most of the increase came from the treatment of the company's columbium-rich tin slag stocks. The Bisichi Tin Co. (Nigeria) Ltd. will use hydraulic mining techniques to recover additional tin and columbium from its Bukuru mine in Northern Nigeria.

Rhodesia, Southern.—The Benson mine north of Mtoko continued to be the country's chief independent tantalum producer during the year, obtaining tantalum concentrates from microlite ore. Other columbium and tantalum production was obtained as a byproduct of tin mining at Kamativi.

South-West Africa.—Much of the 14 percent increase in production of tantalite-columbite concentrates during the year was obtained as a byproduct of beryl mining operations by S.W.A. Lithium Mines (Pty.) Ltd. Other companies producing tantalite from the country's extensive tantalum-rich pegmatite deposits included Atlantic Explorations Co. (Pty.) Ltd., and Tantalite Valley Minerals (Pty.) Ltd.

Uganda.—Tororo Industrial Chemicals & Fertilizers Ltd., recovered and exported almost 26,000 pounds of Cb_2O_5 in pyrochlore concentrate from apatite tailings.

ASIA

Japan.—The position of producers of high-grade tantalum, who have been unable to meet the demand in capacitors and chemical equipment, has been aggravated by the freezing of imports of tantalum foil and tube to such an extent that production of the metal is uneconomic in competition with low-price imports.[8] Production of tantalum metal during 1965 totaled 20,700 pounds.

Malaysia.—Preliminary reports indicated that production of columbite-tantalite concentrate which was recovered as a byproduct of tin mining operations continued to decrease steadily and fell approximately 18 percent during the year. During 1964 Malaysia imported almost 27,000 pounds of tantalum concentrate, also recovered from tin slags, from Thailand and reexported 13,000 pounds to the United States.

Thailand.—Union Carbide Corp. (UCC) announced that the new tin smelter constructed by Thai Smelting & Refining Co., a joint venture of UCC and Eastern Mining Development Co. Ltd. (Thailand), which began operation during the year will produce high-grade tantalum bearing tin slag byproduct which will be used to help alleviate the short supply of this metal. This slag reportedly will contain an insufficient quantity of columbium to justify its recovery.

OCEANIA

Australia.—Greenbushes Tin N. L. began recovering tin and tantalum by dredging and open pit methods at Greenbushes, Western Australia, during the year.[9] Although initial production was expected to be between 50,000 and 100,000 pounds of tantalum concentrate annually averaging approximately 53 percent Ta_2O_5 and 19 to 20 percent Cb_2O_5, Greenbushes produced only slightly more than 3,800 pounds of tantalite during 1965 owing to a breakdown of the dredging system. The company announced plans to expand production to about 450,000 pounds of tantalite concentrate annually in 1968.

Additional 1965 tantalite production was reported from the Pilbara District (about 900 pounds) and the Yalgoo District (about 7,661 pounds) of Western Australia.

TECHNOLOGY

Extractive and physical metallurgical investigations of columbium and tantalum were continued during 1965 by the Bureau of Mines. One report was issued by Bureau metallurgists which studied the extraction of columbium and tantalum from their ores and concentrates by direct chlorination of high-grade minerals in the presence of carbon at temperatures between 500° and 800° C.[10] Using this extraction

[8] Metal Bulletin (London). Japanese Tantalum Worries. No. 5005, June 15, 1965, p. 27.
[9] Metal Bulletin (London). Tantalite Dearer. No. 5045, Nov. 5, 1965.
[10] May, S. L., and G. T. Engel. Extraction of

technique, recoveries of 99 percent of the columbium and tantalum were obtained. Metallurgical beneficiation of low-grade source materials by carbothermic reduction produced a ferroalloy amenable to chlorination at a temperature of 500° C and subsequent columbium and tantalum recoveries of 90 percent.

A second report issued by Bureau scientists discussed a study of the chlorination kinetics of tantalum and columbium made to determine the effects of temperature, chlorine concentration, geometric surface area, and gamma irradiation.[11] Because the reaction products were volatile at the temperature used, the reaction rate was followed by measuring the weight loss of the solid.

A detailed review of coatings for refractory metals subjected to extremely high temperatures indicated that although satisfactory coatings have been developed to protect columbium and molybdenum, coatings for tantalum are still in an early stage of development.[12]

A method was developed for the electrodeposition of thick, coherent, and dense deposits of columbium and tantalum by electrolysis of molten refractory metal fluoride in mixtures of alkali metal fluorides.[13] Using this process, Cb and Ta could be electroformed into parts which required no machining or additional forming.

The influence of up to 50 percent molybdenum on the oxidation of Cb–Mo alloys was determined in air at 1,000° to 1,200° C.[14] At 1,000° C minimum oxidation was observed in the Cb–10Mo alloy.

Emphasis was continued on additional research to develop coatings and alloying additions which would protect columbium and tantalum and increase their high-temperature oxidation resistance.[15]

Using a glass lubricant, "H" shaped sections were successfully extruded from Ta–10W and Ta–30Cb–7.5V alloys at temperatures ranging from 300° to 3,250° F.[16] Ta–10W sections were successfully extruded when clad with a seamless molybdenum sleeve which served as the lubricant.

The Cb–1Zr alloy showed negligible weight changes and no noticeable deposits during two 3,000 hour natural convection loop tests in potassium at 1.070° C.[17] The mechanical strength of the PWC–533 alloy (Cb–5 Mo,–3Zr–3Ti–0.1C) and a modified Cb–Zr alloy was not affected by boiling potassium when exposed for 3,000 hours at 1,095° C.

Tantalum and columbium metals and alloys were evaluated as structural materials for use in space-power liquid metals

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Tantalum and Columbium From Ores and Concentrates by Chlorination. BuMines Rept. of Inv. 6635, 8 pp.

[11] Landsberg, Arne, and Frank E. Block. A Study of the Chlorination Kinetics of Germanium, Silicon, Iron, Tungsten, Molybdenum, Columbium, and Tantalum. BuMines Rept. of Inv. 6649, 1965, 26 pp.

[12] National Research Council. Coated Refractory Metal Technology—1965. Materials Advisory Board, National Academy of Sciences, Rept. MAB–210–M, November 1965, 123 pp.

[13] Mellors, G. W., and S. Senderoff. Electrodeposition of Coherent Deposits of Refractory Metals. J. Electrochem. Soc., v. 112, No. 3, March 1965, pp. 266–272.
West, Philip. Refractory Metals Can be Plated and Electroformed. Mat. in Design Eng., v. 62, No. 1, July 1965, pp. 93–94.

[14] U.S. Atomic Energy Commission. Reactor Materials. V. 8, Nos. 1–4, (published quarterly), 1965, 249 pp.

[15] Air Force Systems Command, Research and Technology Division. Air Force Materials Symposium. Wright Patterson Air Force Base, Ohio, Tech. Rept. AFML-TR-65-29. June 9–11, 1965, 895 pp., Defense Documentation Center, 463572.
Aves, Jr., W. L., and G. W. Bourland. Investigation and Development of Techniques To Extend the Utility of Pack Process and Compositions for Coating Molybdenum and Columbium Alloys. LTV Aerospace Corp., Dallas, Texas. AFML–TR–65–272 (U.S. Air Force Contract No. AF 33(615)–1678), August 1965, 170 pp.
Gadd, J. D. Advancement of Protective Coating Systems for Columbium and Tantalum Alloys. Thompson Ramo Woldridge Inc., Cleveland, Ohio, AFML–TR–65–203 (U.S. Air Force Contract No. 33 (615)–1525), April 1965, 191 pp.
Hill, V. L., and J. J. Rausch. Protective Coatings for Tantalum-Base Alloys. IIT Research Institute, Chicago, Ill. AFML–TR–64–354, pt. II (U.S. Air Force Contract No. 33 (657)–11258), January 1966, 117 pp.
Priceman, S., and L. Sama. Development of Slurry Coatings for Tantalum, Columbium, and Molybdenum Alloys. Sylcor Division of Sylvania Electric Products Inc., Hicksville, N.Y. AFML–TR–65–204 (U.S. Air Force Contract No. 33 (615)–1721), September 1965, 127 pp.
Rausch, J. J. Protective Coatings for Tantalum-Base Alloys. IIT Research Institute, Chicago, Ill., AFML–TR–64–354 (U.S. Air Force Contract 33(657)–11258), November 1964, 49 pp.
Stetson, A. R. Development of Protective Coatings for Tantalum-Base Alloys. Solar Division of International Harvester Co., San Diego, Calif., AFML–TR–65–205, Pt. I (U.S. Air Force Contract No. 33(657)–11259), June 1965, 160 pp.
Wimber, R. T. Development of Protective Coatings for Tantalum-Base Alloys. Solar Division of International Harvester Co., San Diego, Calif., ML–TDR–64–294 (U.S. Air Force Contract No. 33(657)–11259), November 1965, 91 pp.

[16] Holden, F. C., and F. W. Boulger. Third Status Report of the U.S. Government Metalworking Processes and Equipment Program. Battelle Memorial Inst., Columbus, Ohio, DMIC Rept. 218, June 18, 1965, 66 pp.

[17] Rice, William L. R. Nuclear Fuels and Materials Development. U.S. Dept. of Commerce, Clearinghouse for Federal Scientific and Technical Information, TID–11295, 4th ed., June 1965, 145 pp.

service.[18] Because of its corrosion resistance to the molten metals mercury, sodium, sodium potassium (NaK), and lithium, and to cesium vapor, columbium–1zirconium (Cb–1Zr) was proposed for use in the SNAP–50/SPUR power conversion system.

Columbium cladding of sintered uranium-plutonium carbide (UC–PuC) fuel elements remained intact following irradiation while stainless steel cladding failed under similar conditions.[19]

Tantalum and some of its alloys which are insoluble in plutonium were evaluated as cladding materials in fast reactors.[20] Two tantalum-base alloys, Ta–0.1W and Ta–0.75W–0.2Y, and pure tantalum produced by electron-beam melting and by double arc-melting were successfully used to contain a Pu–10Fe nuclear fuel in the Los Alamos Molten Plutonium Fast Breeder Reactor Program.

Because of their useful application as cladding materials for plutonium-bearing alloy fuels, alloys of columbium, vanadium, and molybdenum were developed which had superior creep strength at elevated temperatures.[21]

At the National Reactor Testing Station in Idaho, the Fast Spectrum Refractory Metals Reactor is used to evaluate the high-temperature, high-strength properties of tantalum and tungsten under actual operating conditions.[22]

Ta, Ta–10W, Cb, and Cb–1Zr were evaluated for use at high temperatures in graphite-moderated thermal reactors.[23]

When heated for 120 hours at 1,316° C, Ta rapidly disintegrated from carburization, while Ta–10W, Cb, and Cb–1Zr remained intact.

Hafnium-tantalum (Hf–Ta) alloys were found to have outstanding potential as high-temperature oxidation-resistant materials at temperatures in excess of 4,000° F.[24] The Hf–27Ta composition demonstrated the best overall oxidation resistance in the binary Hf–Ta system.

Simultaneous but independent studies were also conducted on the Hf–Ta system by the IIT Research Institute and led to the development of a Hf–20Ta alloy which forms a tenacious, thermal-, shock-, and heat-resistant scale which retards further oxidation and limits contamination.[25]

Because of its high-temperature potential, NASA issued a contract for the pilot development of this clad alloy on a production basis (see Legislation and Government Programs).

Other studies conducted on the corrosion behavior of Hf–Ta alloys indicated that these alloys were suitable for service as construction materials for use in the Advanced Test Reactor (ATR) at Arco, Idaho.[26]

A report issued on the role of Cb and Ta tubing in energy conversion and propulsive devices indicated that the largest potential for use of this tubing was in space power systems.[27]

Tantalum and tungsten evaluated with uranium oxide (UO) fuel material were found to be compatible up to 2,760° C, the melting point of UO.[28]

The C–129Y alloy (Cb–10W–10Hf–0.1Y) has good strength at temperatures to 3,500° F, excellent formability and weldability, a subzero ductile-to-brittle transformation temperature, and was not adversely affected by silicide-base oxidation-protective coatings.[29]

An evaluation of the compatibility of materials with various rocket propellants and oxidizers indicated that tantalum was at least partially compatible with a large

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[18] Stang, J. H., E. M. Simmons, and J. A. DeMastry. Materials for Liquid-Power Metals Service. Battelle Memorial Inst., DMIC Memo. 209, Oct. 5, 1965, 9 pp. Page VII.2 of work cited in footnote 17.

[19] Pages XXII.3 and XXII.4 of work cited in footnote 17.

[20] Rice, William L. R. Summaries of Fuels and Materials Development Programs, Materials Research Under Reactor Programs. U.S. Department of Commerce, Clearinghouse for Federal Scientific and Technical Information, TID–6506, pt. 2, 3d ed., May 1965, 79 pp.

[21] Miner, William N. Plutonium. Div. Tech. Info., U.S. Atomic Energy Commission, Oak Ridge, Tenn., November 1964, 52 pp. Pages III.3 and III.4 of work cited in footnote 17.

[22] U.S. Atomic Energy Commission. Nuclear Reactor Testing Station. Brochure published by the Idaho Operations Office, Atomic Energy Commission, Idaho Falls, Idaho, December 1965, 33 pp.

[23] U.S. Atomic Energy Commission. Fundamental Nuclear Energy Research—1965. December 1965, 338 pp.

[24] Marnoch, K. High-Temperature Oxidation-Resistant Hafnium-Tantalum Alloys. J. Metals, v. 17, No. 11, November 1965, pp. 1225–1231.

[25] Chemical & Engineering News. A Hafnium-Tantalum Alloy Capable of Withstanding Temperatures of 4000° F. V. 43, No. 49, Dec. 6, 1965, p. 37.

[26] Page 207 of work cited in footnote 14.

[27] National Research Council. Status of Refractory Alloy Tubing—1964. Materials Advisory Board, National Academy of Science, Rept. MAB–208–M, Aug. 16, 1965, 97 pp.

[28] Pages 188 and 189 of work cited in footnote 14.

[29] Page 216 of work cited in footnote 14.

number of the propellants while columbium was compatible with only a few.[30]

Production methods of consolidating and producing sheet of D–43, Cb–752, and Ta–10Cb–7.5V alloys were evaluated and pilot sheet-rolling studies on B–66 (Cb–5Mo–5V–1Zr) FS-85 (Cb–27Ta–10W–1Zr), GE–473 (Ta–7W–3Re), and T–222 (Ta–9.6W–2.4Hf–0.01C) alloys were completed.[31]

Pure tantalum metal was produced with recoveries of 60 to 70 percent by a batch process in which carbochlorination of the ore converted the metal oxides and/or silicates to their respective chlorides for subsequent separation.[32]

The superconducting properties of the intermetallic compound Cb_3Sn and the Cb–Zr alloy system produce high magnetic fields which once required megawatts of power, thousands of gallons of cooling water, and tons of iron and copper.[33]

These superconducting magnets contain only a few pounds of columbium and tin and are operated below —410° F.

The Cb_3Sn superconducting compound was prepared on insulating substrates by simultaneous hydrogen reduction of columbium and tin halides.[34]

Using a chemical extraction process, high-purity columbium oxide was produced from a pyrochlore-perovskite flotation concentrate with recoveries of 96 percent.[35]

Solid electrolyte capacitors were prepared using anodes of porous tantalum derived from tantalum-titanium alloys by the process of titanium volatilization in vacuum at high temperatures.[36]

During the year a comprehensive book was published which consolidated the more pertinent data on the seven refractory metals Cb, Ta, W, Mo, Re, Cr, and V.[37]

A bibliography of refractory metal reports and patents was issued which indicated the extensive work which has been conducted to develop the high-temperature, high-strength properties of Cb and Ta alloys.[38]

The continuing interest in methods of alloying, and coating columbium and tantalum was reflected by some of the patents issued during the year.[39]

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30 Boyd, W. K., W. E. Berry, and E. L. White. Compatibility of Materials With Rocket Propellants and Oxidizers. Battelle Memorial Inst., Columbus, Ohio, DMIC Memo. 201, Jan. 29, 1965, 40 pp.

31 Maykuth, D. J. Department of Defense Refractory Metals Sheet Rolling Program, Status Report No. 3. Battelle Memorial Inst., Columbus, Ohio, DMIC Rept. 212, Jan. 26, 1965, 35 pp.

32 Parker, Sidney G., and Oran W. Wilson. Separation of Metal Chlorides by Distillation. Process Design & Development: Ind. and Eng. Chem. (Quarterly), v. 4, No. 4, October 1965, pp. 365–368.

33 Kunzler, J. E. High-Field Superconductivity. Mat. Res. and Standards, v. 5, No. 4, April 1965, pp. 161–171.

34 Cullen, G. W. Preparation and Properties of Niobium (Columbium) Stannide on Insulating Substrates. Trans. AIME, v. 230 (Met. Soc.), No. 7, December 1964, pp. 1494–1499.

35 Kelly, F. J., and W. A. Gow. The Production of High-Purity Niobium Oxide from Pyrochlore-Perovskite Concentrate. Canadian Min. and Met. Bull., (Montreal, Quebec, Canada), v. 58, No. 640, August 1965, pp. 843–848.

36 Kolski, Thaddeus L., and Harry W. Ling. Solid Electrolyte Capacitors Using Anodes Derived from Tantalum-Titanium Alloys. Electrochem. Technol., v. 3, No. 3–4, March–April 1965, pp. 67–70.

Ling, Harry W., and Thaddeus L. Kolski. Electrolytic Capacitors Utilizing Anodes Derived from Tantalum-Titanium Alloy. Electrochem. Technol., v. 3, No. 3–4, March–April 1965, pp. 71–74.

37 Tietz, T. E., and J. W. Wilson. Behavior and Properties of Refractory Metals. Stanford University Press, Stanford, Calif., 1965, 410 pp.

38 U.S. Department of Commerce. Molybdenum and Tungsten, Selected Bibliography of Government Research Reports, and Translations. U.S. Dept. of Commerce Clearinghouse for Federal Scientific and Technical Information, SB–415, Suppl. 1, 1965, 48 pp.

39 Baranow, Sanford, and Ray C. Lever (assigned to the U.S. Atomic Energy Commission). Coating for Columbium. U.S. Pat. 3,216,851, Nov. 9, 1965.

Begley, Richard T., Raymond W. Buckman, Jr., and Robert L. Ammon (assigned to Westinghouse Electric Corp., Pittsburgh, Pa.). Niobium Alloys. U.S. Pat. 3,206,305, Sept. 14, 1965.

Bradley, Elihu F., and John J. Rausch (assigned to United Aircraft Corp., East Hartford, Conn.). Coated Columbium Alloy Articles. U.S. Pat. 3,206,289, Sept. 14, 1965.

Duffek, Jr., Edward F. (assigned to California Research Corp., San Francisco, Calif.). Columbium-Tantalum Base Alloy, U.S. Pat. 3,186,837, June 1, 1965.

France, Leonard L., Lee S. Richardson, and Duane H. Feisel (assigned to Westinghouse Electric Corp., East Pittsburgh, Pa.). Tantalum Base Alloys. U.S. Pat. 3,166,414, Jan. 19, 1965.

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Javorsky, Charles A., John S. Howe, and Clo E. Armantrout (assigned to U.S. Atomic Energy Commission). Tantalum Brazing Alloy. Belgian Pat. 657,171, Dec. 16, 1964.

Kling, H. P., L. Sama, S. Priceman, B. Brodwin, and A. L. Eiss (assigned to U.S. Atomic Energy Commission). High Temperature Niobium-UO_2 Nuclear Fuel Sheet. U.S. Pat. 3,202,585, Mar. 24, 1965.

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Copper

By F. L. Wideman[1]

Contents

Copper continued in tight supply throughout the year despite an increase of 4 percent in free world mine production. The record production was attained in spite of strikes in Chile and elsewhere that resulted in the loss of an estimated 100,000 tons. Substantial quantities of copper released from the Government stockpile supplemented increased production in the United States. Supply, however, was inadequate to meet a record demand for the metal caused by unprecedented prosperity in the free world and by military action in Viet-Nam. Unabated demand exerted upward pressures on prices which were also influenced to a major extent by pressures from the Governments of Chile and Zambia. Prices on the London Metal Exchange and those charged by dealers in the United States fluctuated widely, reflecting the marginal supply situation and political and labor uncertainties. At yearend they were near record levels.

Consumption of refined copper as reported by consumers in the United States increased 10 percent over that of 1964 and reached a new alltime high. Consumption abroad, however, declined slightly from the previous year as a result of interruptions in supply that occurred outside the United States.

Stocks of refined copper at primary producers dropped sharply until the end of June, after which they turned up moderately. Inventories at yearend were the lowest since the close of 1959.

Exports of refined copper, the chief class, increased 3 percent over those of 1964, whereas general imports of major classes of unmanufactured dropped more than 10 percent

The Bureau of Mines published a comprehensive report that described the copper industry from historical, technological, structural, and statistical standpoints.[2] The report also discussed domestic and international sources of supply, world reserves of primary copper, and the position of secondary copper in the industry. Data and statistics as production, consumption, imports, exports, and employment were included.

Legislation and Government Programs—In January, Business and Defense Services Administration (BDSA) allocated 20,000 tons of copper released from the Defense Production Act inventory to 113 users of copper. The firms, if their applications were approved, would purchase copper from the Government at current market prices, including the usual differential applicable to different forms and shapes. A bill signed by President Johnson on April

[1] Commodity specialist, Division of Minerals.
[2] McMahon, A. D. Copper: A Materials Survey. BuMines Inf. Circ. 8225, 1965, 340 pp.

2 authorized the release of 100,000 tons of copper from the national stockpile for the purpose of relieving domestic shortages, with allocation based on demonstrated need and for domestic use only. On November 17 the Government announced a four-point program to reduce inflationary pressures on the price of copper that might impair the defense effort in Viet-Nam. The program called for release of 200,000 tons of copper from the national stockpile; control of exports of copper and copper scrap for an indefinite period to conserve domestic supply; legislation to suspend the 1.7-cent-per-pound import duty on copper to encourage a greater inflow of metal; and imposition of higher margin requirements on copper trading by directors of the Commodity Exchange Inc., New York, to lessen speculation in the metal. The 200,000-ton release was made up of 114,000 tons of fire-refined copper, 6,000 tons of lake ingot, and 80,000 tons of electrolytic cathode. It was not allocated as of December 31. Copper scrap export limits were put at 30,000 tons in 1966 to all countries except Canada. The scrap limit applied to the copper content of scrap containing more than 40 percent copper and was based on a company's recent trade volume. Copper scrap export control regulations were that one-half of any quantity of the scrap licensed for export that was not moved as of December 1 would not be allowed to leave the country. That was to hold through February 28, 1966. Scrap that was not loaded on an exporting carrier by February 28 would be automatically canceled. Copper exports other than scrap were not limited.

BDSA in July amended schedule A to order M-11A covering set-aside percentages, with August 16 as effective date. The amendment applied to authorized controlled material orders calling for delivery after September 30 and provided for a new base period (calendar year 1964) for the determination of average shipments against which set-aside percentages would be applied. Some percentages were trimmed back to compensate for the large increase in production in 1964 over the previous base year, 1960.

Production of three-layered quarters began at the Philadelphia Mint late in August and the new quarters went into circulation on November 1. Late in the year, minting three-layered dimes began, and on December 30 production of the new half dollar began at the Denver Mint. The new dimes and half dollars will be in circulation early in 1966. The new quarters and dimes have faces of cupro-nickel (75 percent copper and 25 percent nickel) bonded to a core of pure copper. The outer faces of the new half dollars are an alloy of 80 percent silver and 20 percent copper. The inner core is 21 percent silver and 79 percent copper.

The Supreme Court upheld the 1964 ruling of the U.S. District Court for the Southern District of New York that the acquisition of the Okonite Co. in 1958 by Kennecott Copper Corp. was in violation of section 7 of the Clayton Antitrust Act. Divesture proceedings were begun.

A settlement by agreement of the Government's civil antitrust suit of 1962 against Newmont Mining Corp. was pending at the end of 1965. The suit challenged Newmont's stockholdings in Magma Copper Co. and Phelps Dodge Corp. and various common directorships with these companies. Newmont plans to divest itself of its Phelps Dodge holdings within 3 years and shall not acquire any Phelps Dodge stock within 10 years nor have any director or officer in common with that company. Newmont's interest in Magma remains unchanged.

DOMESTIC PRODUCTION

PRIMARY COPPER

Mine Production.—The copper mining industry in the United States was essentially free from interruptions. This, together with expansion of producing facilities, led to an alltime record output. The Mineral Park mine of Duval Corp. experienced its first year of full production. Late in the year The Eagle-Picher Co. began opencast mining of a thin bed of shale occurring in the Permian Red Beds in southwestern Oklahoma. In September, The Anaconda Company began stripping about 600 feet of waste material from a low-grade copper deposit in the Twin Buttes area, Ariz. Expansion of the capacity of several mines and concentrators was completed or in progress during the year. The search for new deposits of copper was intense, and exploration activities were conducted in all major producing areas as well as in others not noted for production.

Arizona supplied 52 percent (55 percent in 1964) of the total U.S. output and continued to lead all States by a large margin. Utah ranked second among the major cop-

Table 1.—Salient copper statistics

	1956-60 (average)	1961	1962	1963	1964	1965
United States:						
Ore produced..thousand short tons..	123,005	142,722	150,217	146,450	155,200	173,286
Average yield of copper percent..	0.76	0.75	0.75	0.74	0.73	0.70
Primary (new) copper produced—						
From domestic ores, as reported by—						
Mines............short tons..	1,015,072	1,165,155	1,228,421	1,213,166	1,246,780	1,351,734
Value.........thousands..	$661,574	$699,093	$756,707	$747,310	$812,901	$957,028
Smelters..........short tons..	1,026,746	1,162,480	1,282,126	1,258,126	1,301,115	1,402,806
Percent of world total.....	24	23	24	23	23	23
Refineries..........short tons..	1,010,017	1,181,015	1,214,146	1,219,342	1,259,852	1,335,660
From foreign ores, matte, etc., refinery reports..short tons..	363,284	369,124	397,584	377,009	396,543	376,133
Total new refined, domestic and foreign...short tons..	1,373,301	1,550,139	1,611,730	1,596,351	1,656,395	1,711,793
Secondary copper recovered from old scrap only.......short tons..	444,944	411,110	415,674	421,843	473,521	513,436
Imports, general:						
Unmanufactured ..short tons..	556,263	457,669	478,851	539,396	586,064	522,230
Refined................do....	167,857	66,855	98,820	119,219	139,974	137,443
Exports:						
Metallic copper..........do....	368,703	482,824	366,585	344,960	381,432	379,498
Refined................do....	309,339	428,718	336,525	311,479	316,230	324,965
Stocks Dec. 31: Producers:						
Refined............short tons..	70,000	49,000	71,000	52,000	37,000	35,000
Blister and materials in solution short tons..	261,000	236,000	246,000	252,000	246,000	246,000
Total................do....	331,000	285,000	317,000	304,000	283,000	281,000
Withdrawals (apparent) from total supply on domestic account:						
Primary copper....short tons..	1,219,000	1,237,000	1,352,000	1,423,000	1,495,000	1,526,000
Primary and old copper (old scrap only)......short tons..	1,663,000	1,648,000	1,768,000	1,845,000	1,969,000	2,039,000
Price: Weighted average cents per pound..	32.3	30.0	30.8	30.8	32.6	35.4
World:						
Production:						
Mine.............short tons..	4,030,000	4,850,000	5,090,000	5,200,000	5,340,000	5,600,000
Smelter................do....	4,256,000	5,120,000	5,340,000	5,480,000	5,730,000	6,020,000
Price: London, average cents per pound..........................	30.76	28.73	29.33	29.25	43.88	58.52

per-producing States; output increased 30 percent over that of 1964 as a result of uninterrupted and expanded production by Utah Copper Division, Kennecott Copper Corp. The State's share of the total output was 19 percent (16 percent in 1964).

Output from Montana, which was in third place, increased 11 percent as a result of a continuing expansion program by The Anaconda Company. Production in New Mexico rose 15 percent, principally as a result of uninterrupted operations of the Chino Mines Division, Kennecott Copper Corp. The State was in fourth place and produced 7 percent of the Nation's total. Production from fifth ranked Michigan increased 3 percent. In September, White Pine Copper Co. poured its billionth pound of copper, approximately 11 years after the company was formed. Although production from the Liberty pit of Nevada Mines Division, Kennecott Copper Corp., continued to be adversely affected by slides that occurred early in 1964, output from the mine increased somewhat. An increase in copper output from the Yerington pit of The Anaconda Company also contributed to the 7 percent increase in mine production from Nevada. Output from Tennessee, Idaho, and Pennsylvania—seventh, eighth, and ninth-ranking States—increased 7 percent, 10 percent, and 20 percent, respectively.

Classification of production by methods showed that approximately 73 percent of the recoverable copper and 78 percent of the copper ore came from open pits. Copper produced by precipitation from mine water and leach solutions was 10 percent of the mine production in 1965.

Smelter Production.—Total output of copper produced from materials at primary smelters in the United States continued a rising trend that began in 1964 and was 7 percent more than production in 1964. A record output of 1.4 million tons from domestic ores registered an 8-percent gain that was partially offset by a 16-percent decrease in production from foreign material. Recovery of copper from

Table 2.—Salient copper statistics

(All figures in short tons, except price and tenor of ore)

Year	United States												World production (smelter)
	Mine production	Average yield of copper ores (percent)	Refinery production from—			Imports (refined) [1]	Exports (refined) [1]	Apparent consumption of new copper [2]	Quoted price at New York [3] (cents per pound)	Production from scrap as metal and in alloys			
			Domestic ores	Foreign ores	Total					Old scrap	New scrap	Total	
1924	803,083	1.59	837,107	292,931	1,130,038	72,955	504,812	677,371	13.16	266,200	122,100	388,300	1,493,600
1925	839,059	1.54	841,448	260,839	1,102,287	49,887	484,033	700,506	14.16	291,010	129,200	420,210	1,546,500
1926	862,638	1.46	865,649	295,594	1,161,243	85,283	428,062	785,068	13.93	337,300	142,500	479,800	1,608,300
1927	824,980	1.41	859,476	303,406	1,162,882	51,640	461,233	711,480	13.05	339,400	150,800	490,200	1,673,300
1928	904,898	1.41	895,899	347,905	1,243,804	42,365	474,737	804,269	14.68	365,500	170,900	536,400	1,880,500
1929	997,555	1.41	991,366	378,690	1,370,056	67,007	411,227	889,293	18.23	404,350	222,200	626,550	2,098,800
1930	705,074	1.43	695,612	382,918	1,078,530	43,105	297,057	632,509	13.11	342,200	125,000	467,200	1,760,000
1931	528,875	1.50	537,303	213,418	750,721	87,225	202,698	451,032	8.24	261,300	85,700	347,000	1,536,000
1932	238,111	1.83	222,539	117,895	340,434	83,897	110,977	259,602	5.67	180,980	67,200	248,180	1,027,000
1933	190,643	2.11	240,669	130,120	370,789	5,432	124,582	339,350	7.15	260,300	77,800	338,100	1,143,000
1934	237,401	1.92	233,029	212,331	445,360	27,417	262,366	322,638	8.53	310,900	66,500	377,400	1,448,000
1935	380,491	1.89	338,321	250,484	588,805	18,071	260,735	441,371	8.76	361,700	87,200	448,900	1,681,000
1936	614,516	1.54	645,462	177,027	822,489	4,782	220,390	656,179	9.58	382,700	101,900	484,600	1,895,000
1937	841,998	1.29	822,253	244,561	1,066,814	7,487	295,064	694,906	13.27	408,900	123,200	532,100	2,585,000
1938	557,763	1.34	552,574	239,842	792,416	1,802	370,545	406,994	10.10	267,300	92,500	359,800	2,254,000
1939	728,320	1.25	704,873	304,642	1,009,515	16,264	372,777	714,873	11.07	286,900	212,800	499,700	2,396,000
1940	878,086	1.20	927,239	386,317	1,313,556	68,337	356,431	1,008,785	11.40	333,890	198,156	532,046	2,734,000
1941	958,149	1.15	975,408	419,901	1,395,309	346,994	108,602	1,641,550	11.87	412,699	313,697	726,396	2,905,000
1942	1,080,061	1.09	1,064,792	349,769	1,414,561	401,436	131,406	1,608,000	11.87	427,122	500,633	927,755	3,076,000
1943	1,090,818	1.04	1,082,079	297,184	1,379,263	402,762	175,859	1,502,000	11.87	427,521	658,526	1,086,047	3,038,000
1944	972,549	.99	973,852	247,335	1,221,187	492,395	68,373	1,504,000	11.87	456,710	494,232	950,942	2,850,000
1945	772,894	.93	775,738	332,861	1,108,599	531,367	48,563	1,415,000	11.87	497,095	509,421	1,006,516	2,486,000
1946	608,737	.91	578,429	300,233	878,662	154,871	52,629	1,391,000	13.92	406,453	397,093	803,546	2,067,000
1947	847,563	.90	909,213	250,757	1,159,970	149,478	147,642	1,286,000	21.15	503,376	458,365	961,741	2,490,000
1948	834,813	.92	860,022	247,424	1,107,446	249,124	142,598	1,214,000	22.20	505,464	467,324	972,788	2,580,000
1949	752,750	.91	695,015	232,912	927,927	275,811	137,827	1,072,000	19.36	383,548	329,595	713,143	2,600,000
1950	909,343	.89	920,748	319,086	1,239,834	317,363	144,561	1,447,000	21.46	485,211	492,028	977,239	2,915,000
1951	928,330	.90	951,559	255,429	1,206,988	238,972	133,305	1,304,000	24.37	458,124	474,158	932,282	3,085,000
1952	925,359	.85	923,192	254,504	1,177,696	346,960	174,135	1,360,000	24.37	414,635	488,562	903,197	3,105,000
1953	926,448	.85	932,232	360,885	1,293,117	274,111	109,580	1,435,000	28.92	429,388	529,076	958,464	3,275,000
1954	835,472	.83	841,717	370,202	1,211,919	215,086	215,951	1,235,000	29.82	407,066	432,841	839,907	3,275,000
1955	998,570	.83	997,499	344,960	1,342,459	202,312	199,819	1,336,000	37.39	514,585	474,419	989,004	3,630,000
1956	1,104,156	.78	1,080,207	362,426	1,442,633	191,745	223,103	1,367,000	41.88	468,489	462,175	930,664	3,990,000
1957	1,086,859	.77	1,050,496	403,680	1,454,176	162,309	346,025	1,239,000	29.99	444,492	397,395	841,887	4,040,000
1958	979,329	.79	1,001,645	350,875	1,352,520	128,464	384,868	1,157,000	26.13	411,367	386,021	797,388	3,950,000
1959	824,846	.74	796,452	301,795	1,098,247	214,058	158,938	1,183,000	30.82	471,007	459,563	930,570	4,190,000
1960	1,080,169	.73	1,121,286	397,641	1,518,927	142,709	433,762	1,148,000	32.16	429,365	442,023	871,388	5,040,000
1961	1,165,155	.75	1,181,015	369,124	1,550,139	66,855	428,718	1,237,000	30.14	411,110	437,829	848,939	r 5,120,000
1962	1,228,421	.75	1,214,146	397,584	1,611,730	98,820	336,525	1,352,000	30.82	415,674	506,154	921,828	r 5,340,000
1963	1,213,166	.74	1,219,342	377,009	1,596,351	119,219	311,479	1,423,000	30.82	421,843	552,583	974,426	r 5,480,000
1964	1,246,780	.73	1,259,852	396,543	1,656,395	r 139,974	316,230	r 1,495,000	32.17	473,521	619,500	1,093,021	r 5,730,000
1965	1,351,734	.70	1,335,660	376,133	1,711,793	137,443	324,965	1,526,000	35.19	513,436	739,814	1,253,250	6,020,000

r Revised.
[1] Imports and exports may include some refined copper produced from scrap. Categories not wholly comparable from year to year.
[2] Adjusted for changes in stocks.
[3] American Metal Market price for electrolytic copper in New York; f. o. b. refinery through August 1927, New York refinery equivalent thereafter.

scrap increased 6 percent over 1964 but was 4 percent less than output in 1963.

Smelter production data are based on reports from domestic primary smelters handling copper-bearing materials. Blister copper is accounted for in terms of copper content. Production of furnace-refined copper in Michigan is included in smelter and refinery output.

It was reported that renovation of the Kennecott Copper Corp. smelter at Garfield, Utah, was on schedule. When completed by 1967, the smelter will have three new direct-charge reverberatory furnaces and nine converters with automatic finishers and improved flux handling equipment.

Table 3.—Copper produced from domestic ores, by sources
(Short tons)

Year	Mine	Smelter	Refinery
1961	1,165,155	1,162,480	1,181,015
1962	1,228,421	1,282,126	1,214,146
1963	1,213,166	1,258,126	1,219,342
1964	1,246,780	1,301,115	1,259,852
1965	1,351,734	1,402,806	1,335,660

Table 4.—Copper ore and recoverable copper produced, by mining methods
(Percent)

Year	Open pit		Underground	
	Ore	Copper	Ore	Copper
1948	76	68	24	32
1949	78	70	22	30
1950	81	74	19	26
1951	84	74	16	26
1952	85	77	15	23
1953	83	75	17	25
1954	83	79	17	21
1955	83	77	17	23
1956	78	73	22	27
1957	77	72	23	28
1958	76	71	24	29
1959	79	74	21	26
1960	80	75	20	25
1961	80	74	20	26
1962	81	75	19	25
1963	81	74	19	26
1964	82	75	18	25
1965	84	77	16	23

Table 5.—Mine production of recoverable copper in the United States, by months
(Sort tons)

Month	1964	1965
January	107,167	115,496
February	107,294	106,826
March	111,932	121,742
April	111,678	116,920
May	115,267	118,882
June	113,639	116,621
July	73,754	105,625
August	77,502	109,170
September	92,193	107,894
October	114,535	114,626
November	110,047	110,101
December	111,772	107,831
Total	1,246,780	1,351,734

Refinery Production.—Production of refined copper from all materials processed at primary refineries continued to rise and totaled 2.1 million tons, an increase of 7 percent over that of 1964. Output from domestic primary material increased 6 percent, but the gain was offset somewhat by a decrease of 5 percent in output from foreign sources. Production of refined copper from secondary materials by primary producers rose to 388,000 tons, resulting in an increase of 29 percent over the previous record established in 1964.

Wire bars continued to account for 63 percent of the forms cast at primary refineries. Outputs of other forms were—billets 11 percent (11 percent in 1964), cakes 10 percent (8 percent), ingot and ingot bars 9 percent (9 percent), and cathodes 6 percent (8 percent).

Of the 16 plants termed primary refineries, 8 used the electrolytic-refining method exclusively. Three plants used fire-refining methods (Lake copper refineries) and four used both electrolytic and fire-refining techniques. A smelter in New Mexico fire-refined part of its blister copper and shipped the remainder to an electrolytic plant for refining. Inspiration Consolidated Copper Co. at Inspiration, Ariz., produced electrolytic copper from leaching solutions; a substantial part of this copper was shipped as cathodes to other refineries for melting and casting into commercial shapes.

Copper Sulfate.—Production and shipments of copper sulfate increased 13 percent and 4 percent, respectively. Producers' reports divided total shipments of 45,600 tons into agricultural uses, 23,600 tons; industrial uses, 20,200 tons; and other uses, chiefly exports, 1,800 tons. Stocks of the compound at yearend were 48 percent above those at the end of 1964.

Byproduct Sulfuric Acid.—Sulfuric acid produced at copper, lead, and zinc smelters from domestic and foreign ores totaled 1.3 million tons, an increase in output of 6 percent over that of 1964. Copper and lead smelters together produced 369,300 tons of byproduct acid, an increase of 11 percent above their 1964 output.

SECONDARY COPPER AND BRASS

As a result of a strong demand for copper in all forms and despite a wide disparity between prices of scrap and refined copper, all segments of the domestic secondary industry established new highs. Recovery of copper in the United States, in alloyed and unalloyed form, from all classes of purchased copper-base scrap ex-

Table 6.—Mine production of recoverable copper in the United States, with production of maximum year, and cumulative production from earliest record to end of 1965, by States

(Short tons)

State	Maximum production [1]		Production by years						Total production from earliest record through 1965
	Year	Quantity	1956–60 (average)	1961	1962	1963	1964	1965	
Alabama	1907	42	--	--	--	--	--	--	64
Alaska	1916	59,927	16	92	--	--	11	32	686,127
Arizona	1965	703,377	495,301	587,053	644,242	660,977	690,988	703,377	20,482,028
California	1909	28,644	861	1,382	1,162	916	1,035	1,165	643,048
Colorado	1938	14,171	3,945	4,141	4,534	4,169	4,653	3,828	320,356
Georgia	1917	465	--	--	--	--	--	--	1,117
Idaho	1958	9,846	7,467	4,328	3,861	4,172	4,666	5,140	193,058
Maine	1918	383	--	--	--	--	--	--	NA
Maryland	1917	146	--	--	--	--	--	--	NA
Massachusetts	1906	5	--	--	--	--	--	--	NA
Michigan	1916	136,846	57,923	70,245	74,099	75,262	69,040	71,749	5,711,010
Missouri	1949	3,670	1,415	1,479	2,752	1,816	2,059	2,331	[2] 58,991
Montana	1916	176,464	87,301	104,000	94,021	79,762	103,806	115,489	8,077,038
Nevada	1942	83,663	71,914	78,022	82,602	81,738	67,272	71,332	3,033,680
New Hampshire	1908	[3] 94	--	--	--	--	--	--	NA
New Mexico	1965	98,658	60,867	79,606	82,683	83,037	86,104	98,658	2,690,322
North Carolina	1930	6,695	(4)	(4)	(4)	(5)	--	--	W
Oklahoma	1965	W	--	--	--	--	--	[6] 282	W
Oregon	1916	1,791	9	(4)	(4)	(5)	15	(6)	W
Pennsylvania [7]	1942	6,410	6,840	8,934	6,108	4,434	3,614	4,354	NA
South Carolina	1938	4	--	--	--	--	--	--	10
South Dakota	1918	32	(8)	--	--	1	--	--	108
Tennessee	1965	14,823	10,712	12,272	14,298	13,717	13,889	14,823	575,807
Texas	1928	224	--	--	--	--	--	--	1,384
Utah	1943	323,989	208,082	213,534	218,018	203,095	199,588	259,138	9,271,898
Vermont	1954	4,352	1,457	--	--	--	--	--	NA
Virginia	1944	291	--	--	--	--	--	--	NA
Washington	1940	9,612	961	66	41	[9] 70	35	30	121,957
Wisconsin	1914	5	--	--	--	--	--	--	(2)
Wyoming	1900	2,102	1	1	--	--	5	6	16,347
Total	1965	1,351,734	1,015,072	1,165,155	1,228,421	1,213,166	1,246,780	1,351,734	[10, 11] 52,216,526

NA Not available. W Withheld to avoid disclosing individual company confidential data.
[1] For Missouri and States east of the Mississippi River, maximum since 1905.
[2] Small quantity for Wisconsin included with Missouri.
[3] The 1908 volume of Mineral Resources credits this figure to Massachusetts and New Hampshire; the 1909 volume credits it to New Hampshire alone.
[4] Included with Pennsylvania to avoid disclosing individual company confidential data.
[5] Included with Washington to avoid disclosing individual company confidential data.
[6] Oklahoma and Oregon combined to avoid disclosing individual company confidential data.
[7] Includes North Carolina for 1956–62 and Oregon for 1961–62 to avoid disclosing individual company confidential data.
[8] Less than ½ unit.
[9] Includes North Carolina and Oregon to avoid disclosing individual company confidential data.
[10] For States east of the Mississippi River, except Michigan, largely smelter production instead of mine production.
[11] Includes 332,181 tons for States indicated by NA and W.

Table 7.—Twenty-five leading copper-producing mines in the United States in 1965 in order of output

Rank	Mine	State	County	Operator	Source of copper
1	Utah Copper	Utah	Salt Lake	Kennecott Copper Corp	Copper, gold ores.
2	Morenci	Arizona	Greenlee	Phelps Dodge Corp	Copper, gold-silver ores.
3	Butte Mines (includes Berkeley)	Montana	Silver Bow	The Anaconda Company	Copper, zinc ores.
4	Chino	New Mexico	Grant	Kennecott Copper Corp	Copper ore.
5	San Manuel	Arizona	Pinal	Magma Copper Co	Do.
6	Ray Pit	do	do	Kennecott Copper Corp	Do.
7	New Cornelia	do	Pima	Phelps Dodge Corp	Copper, gold-silver ores.
8	Copper Queen-Lavender Pit	do	Cochise	do	Copper, silver ores.
9	White Pine	Michigan	Ontonagon	White Pine Copper Co	Copper ore.
10	Mission	Arizona	Pima	American Smelting and Refining Co	Do.
11	Inspiration	do	Gila	Inspiration Consolidated Copper Co	Do.
12	Yerington	Nevada	Lyon	The Anaconda Company	Do.
13	Liberty Pit	do	White Pine	Kennecott Copper Corp	Do.
14	Esperanza	Arizona	Pima	Duval Corp	Do.
15	Silver Bell	do	do	American Smelting and Refining Co	Do.
16	Bagdad	do	Yavapai	Bagdad Copper Corp	Do.
17	Copper Cities	do	Gila	Miami Copper Co	Do.
18	Magma	do	Pinal	Magma Copper Co	Copper, gold-silver ores.
19	Mineral Park	do	Mohave	Duval Corp	Copper ore.
20	Pima	do	Pima	Pima Mining Co	Do.
21	Copperhill	Tennessee	Polk	Tennessee Copper Co	Copper-zinc ore.
22	Miami	Arizona	Gila	Miami Copper Co	Copper precipitates.
23	Christmas	do	do	Inspiration Consolidated Copper Co	Copper ore.
24	Ahmeek Group	Michigan	Houghton and Hancock	Calumet & Hecla, Inc	Do.
25	Cornwall	Pennsylvania	Lebanon	Bethlehem Mines Corp	Magnetite pyrite ore.

Table 8.—Copper ore sold or treated in the United States in 1965, with copper, gold, and silver content in terms of recoverable metals [1]

State	Ore sold or treated (short tons)	Recoverable metal content: Copper: Pounds	Copper: Percent	Gold (troy ounces)	Silver (troy ounces)	Value of gold and silver per ton of ore
Alaska	58	64,100	55.26		1,102	$24.57
Arizona	92,859,535	1,308,809,700	.70	133,830	5,352,850	.12
California	50	5,900	5.90	3	80	4.16
Colorado	17,255	1,292,500	3.75	2,296	299,078	27.07
Idaho	84,713	3,141,000	1.85	1,600	9,986	.81
Michigan [2]	8,978,949	143,498,000	.80		457,851	.07
Montana	14,460,366	213,604,000	.74	15,985	3,318,664	.34
Nevada	14,698,606	136,897,500	.47	34,220	130,104	.09
New Mexico	8,470,639	135,161,000	.80	6,365	92,602	.04
Oklahoma	[3] 26,893	[3] 561,000	[3] 1.04	[3] 8	[3] 1,524	[3] .08
Oregon	(3)	(3)	(3)	(3)	(3)	(3)
Tennessee [4]	1,520,755	29,646,000	.97	122	94,142	.08
Utah	32,168,351	458,194,000	.71	373,101	3,043,630	.53
Wyoming	28	4,300	7.68	1	25	2.39
Total	173,286,198	2,430,879,000	.70	567,531	12,801,638	.21

[1] Excludes copper recovered from precipitates as follows: Arizona, 89,282,500 pounds; Idaho, 8,700 pounds; Montana, 15,675,500 pounds; New Mexico, 59,764,000 pounds. Also excludes some copper recovered from precipitates in California, Nevada, and Utah; figures withheld to avoid disclosing individual company confidential data.
[2] Includes tailings.
[3] Production of Oklahoma and Oregon combined to avoid disclosing individual company confidential data.
[4] Copper-zinc ore.

Table 9.—Copper ore concentrated in the United States in 1965, with content in terms of recoverable copper [1]

State	Ore concentrated (short tons)	Recoverable copper content: Pounds	Percent
Arizona	92,393,443	1,281,363,000	0.69
Colorado	5,687	233,300	2.06
Idaho	84,240	3,042,300	1.81
Michigan	[2] 8,978,949	[2] 143,498,000	.80
Montana	14,460,309	213,598,300	.74
Nevada	14,609,873	135,652,200	.46
New Mexico	8,414,833	135,024,700	.80
Oklahoma	W	W	W
Tennessee [3]	1,520,755	29,646,000	.97
Utah	32,166,600	457,952,900	.71
Total	172,634,689	2,400,010,700	.70

W Withheld to avoid disclosing individual company confidential data; not included in total.
[1] Includes all methods of concentration: "Dual process" (leaching followed by flotation concentration); LPF (leach-precipitation-flotation); tank or vat leaching; heap leaching; and froth flotation.
[2] Includes tailings.
[3] Copper-zinc ore.

Table 10.—Copper ore shipped to smelters in the United States in 1965, with content in terms of recoverable copper

State	Ore shipped to smelters: Short tons	Recoverable copper content: Pounds	Percent
Alaska	58	64,100	55,26
Arizona	466,092	27,446,700	2.94
California	50	5,900	5.90
Colorado	11,568	1,059,200	4,58
Idaho	473	98,700	10.43
Montana	57	5,700	5.00
Nevada	88,733	1,245,300	.70
New Mexico	[1] 55,806	136,300	.12
Oregon	W	W	W
Utah	1,751	241,100	6.88
Wyoming	28	4,300	7,68
Total	624,616	30,307,300	2.43

W Withheld to avoid disclosing individual company confidential data; not included in total.
[1] Primarily smelter fluxing material.

Table 11.—Copper ores produced in the United States, and average yield in copper, gold, and silver

Year	Smelting ores: Short tons	Smelting ores: Yield in copper, percent	Concentrating ores: Short tons	Concentrating ores: Yield in copper, percent	Total: Short tons [1,2]	Total: Yield in copper, percent	Yield per ton in gold, ounce	Yield per ton in silver, ounce	Value per ton in gold and silver
1956–60 (average)	700,472	4.10	120,693,101	0.75	123,005,188	0.76	0.0041	0.078	$0.21
1961	734,112	3.39	141,975,386	.74	142,721,798	.75	.0037	.073	.20
1962	598,519	3.25	145,580,048	.72	150,216,710	.75	.0032	.073	.19
1963	615,570	3.32	141,284,319	.72	146,449,540	.74	.0030	.070	.19
1964	553,493	3.20	149,834,616	.71	155,200,464	.73	.0028	.074	.19
1965	[3] 624,616	2.43	[4,5] 172,634,689	.70	[6] 173,286,198	.70	.0033	.074	.21

[1] Includes some ore classed as copper-zinc ore.
[2] Includes copper ore leached.
[3] Oregon withheld to avoid disclosing individual company confidential data; not included in total.
[4] Oklahoma withheld to avoid disclosing individual company confidential data; not included in total.
[5] Includes all methods of concentration: "Dual process" (leaching followed by flotation concentration), LPF (leach-precipitation-flotation), tank or vat leaching, heap leaching, and froth flotation.
[6] Includes Oklahoma and Oregon.

Table 12.—Copper produced by primary smelters in the United States

(Short tons)

	Domestic	Foreign	Secondary	Total
1956–60 (average)	1,026,746	84,049	69,704	1,180,499
1961	1,162,480	44,874	78,377	1,285,731
1962	1,282,126	40,488	86,903	1,409,517
1963	1,258,126	38,574	97,986	1,394,686
1964	1,301,115	37,318	88,365	1,426,798
1965	1,402,806	31,244	93,895	1,527,945

Table 13.—Copper produced (smelter output from domestic ores) in the United States

Year	Short tons	Value (thousands)	Year	Short tons	Value (thousands)	Year	Short tons	Value (thousands)
1845	112	$45	1886	78,881	$17,512	1927	842,020	$220,609
1846	169	57	1887	90,739	25,044	1928	912,950	262,930
1847	336	124	1888	113,181	38,029	1929	1,001,432	352,504
1848	560	218	1889	113,388	30,615	1930	697,195	181,271
1849	784	349	1890	129,882	40,523	1931	521,356	94,887
1850	728	320	1891	142,061	36,368	1932	272,005	34,273
1851	1,008	334	1892	172,499	40,020	1933	225,000	28,800
1852	1,232	542	1893	164,677	35,570	1934	244,227	39,076
1853	2,240	985	1894	177,094	33,648	1935	381,294	63,295
1854	2,520	1,108	1895	190,307	40,726	1936	611,410	112,499
1855	3,360	1,814	1896	230,031	49,687	1937	834,661	201,988
1856	4,480	2,419	1897	247,039	59,289	1938	562,328	110,216
1857	5,376	2,688	1898	263,256	65,288	1939	712,675	148,236
1858	6,160	2,833	1899	284,333	97,242	1940	909,084	205,453
1859	7,056	3,104	1900	303,059	100,615	1941	966,072	227,993
1860	8,064	3,709	1901	301,036	100,546	1942	1,087,991	[1] 256,766
1861	8,400	3,696	1902	329,754	80,460	1943	1,092,939	[1] 257,934
1862	10,580	4,655	1903	349,022	95,632	1944	1,003,379	[1] 236,797
1863	9,520	6,473	1904	406,269	104,005	1945	782,726	[1] 184,723
1864	8,960	8,422	1905	444,392	138,650	1946	599,656	[1] 172,701
1865	9,520	7,473	1906	458,903	177,136	1947	862,872	[1] 360,680
1866	9,968	6,828	1907	434,498	173,799	1948	842,477	365,635
1867	11,200	5,682	1908	471,285	124,419	1949	757,931	298,625
1868	12,992	5,976	1909	546,476	142,084	1950	911,352	379,122
1869	14,000	6,790	1910	540,080	137,180	1951	930,774	450,495
1870	14,112	5,977	1911	548,616	137,154	1952	927,365	448,845
1871	14,560	7,023	1912	621,634	205,139	1953	943,391	541,506
1872	14,000	9,956	1913	612,242	189,795	1954	834,381	492,285
1873	17,360	9,721	1914	575,069	152,968	1955	1,007,311	751,454
1874	19,600	8,624	1915	694,005	242,902	1956	1,117,580	949,943
1875	20,160	9,152	1916	963,925	474,288	1957	1,081,055	650,795
1876	21,280	8,937	1917	943,060	514,911	1958	992,918	522,275
1877	23,520	8,937	1918	954,267	471,408	1959	799,329	490,788
1878	24,080	7,994	1919	643,210	239,274	1960	1,142,848	733,708
1879	25,760	9,582	1920	604,531	222,467	1961	1,162,480	697,488
1880	30,240	12,943	1921	252,793	65,221	1962	1,282,126	789,790
1881	35,840	13,046	1922	475,143	128,289	1963	1,258,126	775,006
1882	45,323	17,313	1923	717,500	210,945	1964	1,301,115	848,327
1883	57,763	19,062	1924	817,125	214,087	1965	1,402,806	993,187
1884	72,473	18,843	1925	837,435	237,832			
1885	82,938	17,915	1926	869,811	243,547			

[1] Exclusive of bonus payments of the Office of Metals Reserve under Premium Price Plan, which covered the period February 1, 1942, to June 30, 1947, inclusive.

Table 14.—Primary and secondary copper produced by primary refineries in the United States

(Short tons)

	1956–60 (average)	1961	1962	1963	1964	1965
Primary:						
From domestic ores, etc.: [1]						
Electrolytic	899,351	1,037,489	1,098,032	1,095,377	1,139,494	1,200,532
Lake	57,151	70,061	67,072	64,146	62,598	71,241
Casting	53,515	73,465	49,042	59,819	57,760	63,887
Total	1,010,017	1,181,015	1,214,146	1,219,342	1,259,852	1,335,660
From foreign ores, etc.: [1]						
Electrolytic	342,042	355,009	379,236	357,015	371,003	332,593
Casting and best select	21,242	14,115	18,348	19,994	25,540	43,540
Total refinery production of primary copper	1,373,301	1,550,139	1,611,730	1,596,351	1,656,395	1,711,793
Secondary:						
Electrolytic [2]	212,855	231,836	237,472	240,620	276,954	368,232
Casting	10,363	11,294	12,214	17,993	23,172	19,879
Total secondary	223,218	243,130	249,686	258,613	300,126	388,111
Grand total	1,596,519	1,793,269	1,861,416	1,854,964	1,956,521	2,099,904

[1] The separation of refined copper into metal of domestic and foreign origin is only approximate, as accurate separation is not possible at this stage of processing.
[2] Includes copper reported from foreign scrap.

Table 15.—Copper cast in forms at primary refineries in the United States

Form	1964		1965	
	Thousand short tons	Percent	Thousand short tons	Percent
Billets	222	11	229	11
Cakes	165	8	205	10
Cathodes	151	8	119	6
Ingots and ingot bars	168	9	201	9
Wirebars	1,234	63	1,330	63
Other forms	17	1	16	1
Total	1,957	100	2,100	100

Table 16.—Production, shipments, and stocks of copper sulfate

(Short tons)

Year	Production		Shipments	Stocks Dec. 31 [1]
	Quantity	Copper content		
1956–60 (average)	56,875	14,219	56,043	4,209
1961	48,584	12,146	46,544	6,740
1962	39,984	9,996	40,332	5,572
1963	41,636	10,409	41,188	5,480
1964	41,908	10,477	43,684	3,416
1965	47,340	11,835	45,640	5,048

[1] Some small quantities are purchased and used by producing companies, so that the figures given do not balance exactly.

Table 17.—Byproduct sulfuric acid [1] (100-percent basis) produced in the United States

(Short tons)

Year	Copper plants [2]	Zinc plants [3]	Total	Year	Copper plants [2]	Zinc plants [3]	Total
1956–60 (average)	411,544	795,134	1,206,678	1963	358,503	861,763	1,220,266
1961	362,630	776,109	1,138,739	1964	330,273	924,100	1,254,373
1962	403,683	815,322	1,219,005	1965	369,321	961,591	1,330,912

[1] Includes acid from foreign materials.

[2] Includes acid produced at a lead smelter. Excludes acid made from pyrites concentrates in Arizona, Montana, Tennessee, and Utah.

[3] Excludes acid made from native sulfur.

Table 18.—Secondary copper produced in the United States

(Short tons)

	1956–60 (average)	1961	1962	1963	1964	1965
Copper recovered as unalloyed copper	267,608	290,805	301,374	314,643	366,197	462,811
Copper recovered in alloys [1]	606,771	558,134	620,454	659,783	726,824	790,439
Total secondary copper	874,379	848,939	921,828	974,426	1,093,021	1,253,250
Source:						
New scrap	429,435	437,829	506,154	552,583	619,500	739,814
Old scrap	444,944	411,110	415,674	421,843	473,521	513,436
Percentage equivalent of domestic mine output	87	73	75	80	88	93

[1] Includes copper in chemicals, as follows: 1956–60 (average), 12,249; 1961, 10,708; 1962, 9,986; 1963, 10,191; 1964, 7,755; and 1965, 6,129.

Table 19.—Copper recovered from scrap processed in the United States, by kinds of scrap and form of recovery

(Short tons)

Kind of scrap	1964	1965	Form of recovery	1964	1965
New scrap:			As unalloyed copper:		
Copper-base	610,332	730,024	At primary plants	300,126	388,111
Aluminum-base	8,951	9,573	At other plants	66,071	74,700
Nickel-base	202	202			
Zinc-base	15	15	Total	366,197	462,811
Total	619,500	739,814	In brass and bronze	691,202	750,624
			In alloy iron and steel	2,416	2,945
Old scrap:			In aluminum alloys	25,282	30,552
Copper-base	468,336	507,046	In other alloys	169	189
Aluminum-base	4,494	5,657	In chemical compounds	7,755	6,129
Nickel-base	654	678			
Tin-base	22	20	Total	726,824	790,439
Zinc-base	15	35			
			Grand total	1,093,021	1,253,250
Total	473,521	513,436			
Grand total	1,093,021	1,253,250			

Table 20.—Copper recovered as refined copper, in alloys and in other forms from copper-base scrap processed in the United States

(Short tons)

	From new scrap		From old scrap		Total	
	1964	1965	1964	1965	1964	1965
Recovered by—						
Secondary smelters	52,717	58,995	242,258	254,974	294,975	313,969
Primary copper producers	165,222	230,638	134,904	157,473	300,126	388,111
Brass mills	372,999	419,184	16,870	21,648	389,869	440,832
Foundries and manufacturers	17,998	19,654	68,053	68,413	86,051	88,067
Chemical plants	1,396	1,553	6,251	4,538	7,647	6,091
Total	610,332	730,024	468,336	507,046	1,078,668	1,237,070

Table 21.—Production of secondary copper and copper-alloy products in the United States

(Short tons)

Item produced from scrap	1964	1965
Unalloyed copper products:		
Refined copper by primary producers	300,126	388,111
Refined copper by secondary smelters	50,924	56,941
Copper powder	13,636	15,484
Copper castings	1,511	2,275
Total	366,197	462,811
Alloyed copper products:		
Brass and bronze ingots:		
Tin bronze	18,753	16,928
Leaded tin bronze	18,051	18,528
Leaded red brass	92,407	101,380
Leaded semired brass	81,582	84,944
High-leaded tin bronze	38,506	41,997
Leaded yellow brass	12,427	12,525
Nickel silver	3,877	4,362
Low brass	2,564	2,825
Conductor bronze	775	800
Manganese bronze	13,636	14,152
Aluminum bronze	9,259	9,810
Silicon bronze	4,616	5,736
Copper-base hardeners and special alloys	15,658	19,509
Total	312,111	333,496
Brass-mill products	497,584	576,284
Brass and bronze castings	72,772	68,618
Brass powder	1,472	1,456
Copper in chemical products	7,755	6,129
Grand total	1,257,891	1,448,794

Table 22.—Composition of secondary copper-alloy production

(Short tons)

Year	Copper	Tin	Lead	Zinc	Nickel	Aluminum	Total
Brass and bronze production:[1]							
1964	244,126	15,261	20,685	31,321	639	79	312,111
1965	262,749	15,661	21,317	33,034	659	76	333,496
Secondary metal content of brass-mill products:							
1964	389,928	335	4,581	100,306	2,400	34	497,584
1965	441,142	301	5,174	126,356	3,282	29	576,284
Secondary metal content of brass and bronze castings:							
1964	56,745	2,877	8,506	4,599	36	9	72,772
1965	53,718	2,665	7,860	4,280	44	51	68,618

[1] About 95 percent from scrap and 5 percent from other than scrap.

Table 23.—Stocks and consumption of purchased copper scrap in the United States in 1965

(Short tons)

Class of consumer and type of scrap	Stocks Jan. 1	Receipts	Consumption			Stocks Dec. 31
			New scrap	Old scrap	Total	
Secondary smelters:						
No. 1 wire and heavy copper	2,244	37,914	4,182	33,533	37,715	2,443
No. 2 wire, mixed heavy and light copper	2,475	74,501	7,633	66,852	74,485	2,491
Composition or red brass	4,642	104,753	31,767	73,304	105,071	4,324
Railroad-car boxes	79	1,204	---------	963	963	320
Yellow brass	6,465	64,759	9,244	55,594	64,838	6,386
Cartridge cases and brass	68	942	---------	914	914	96
Auto radiators (unsweated)	5,073	53,460	---------	55,119	55,119	3,414
Bronze	1,776	34,878	6,530	28,536	35,066	1,588
Nickel silver	838	4,758	500	4,342	4,842	754
Low brass	314	3,229	1,955	1,287	3,242	301
Aluminum bronze	179	536	367	176	543	172
Low-grade scrap and residues	5,554	44,059	32,011	10,995	43,006	6,607
Total	29,707	424,993	94,189	331,615	425,804	28,896
Primary producers:						
No. 1 wire and heavy copper	2,359	112,212	67,163	44,182	111,345	3,226
No. 2 wire, mixed heavy and light copper	9,528	209,104	144,026	68,746	212,772	5,860
Refinery brass	534	7,555	4,963	2,178	7,141	948
Low-grade scrap and residues	36,725	267,607	92,099	177,736	269,835	34,497
Total	49,146	596,478	308,251	292,842	601,093	44,315
Brass mills:[1]						
No. 1 wire and heavy copper	4,460	118,056	107,640	10,416	118,056	8,676
No. 2 wire, mixed heavy and light copper	2,575	40,825	40,757	68	40,825	3,657
Yellow brass	10,928	259,373	259,373	-------	259,373	14,645
Cartridge cases and brass	2,659	88,239	71,977	16,262	88,239	4,126
Bronze	834	3,082	3,082	-------	3,082	698
Nickel silver	4,176	13,391	13,391	-------	13,391	4,026
Low brass	2,905	40,496	40,496	-------	40,496	2,778
Aluminum bronze	326	294	294	-------	294	264
Mixed alloy scrap	10,746	21,786	21,786	-------	21,786	12,312
Total[1]	39,609	585,542	558,796	26,746	585,542	51,182
Foundries, chemical plants, and other manufacturers:						
No. 1 wire and heavy copper	2,878	24,404	10,655	13,655	24,310	2,972
No. 2 wire, mixed heavy and light copper	1,687	23,473	4,948	18,300	23,248	1,912
Composition or red brass	782	4,466	1,750	2,855	4,605	643
Railroad-car boxes	1,999	38,635	-------	39,503	39,503	1,131
Yellow brass	1,177	8,362	3,939	4,612	8,551	988
Auto radiators (unsweated)	2,752	6,995	-------	8,387	8,387	1,360
Bronze	836	1,814	962	1,297	2,259	391
Nickel silver	3	117	-------	117	117	3
Low brass	187	895	334	531	865	217
Aluminum bronze	332	645	383	421	804	173
Low-grade scrap and residues	1,486	12,403	2,744	7,299	10,043	3,846
Total	14,119	122,209	[2] 25,715	[2] 96,977	[2] 122,692	13,636

Table 23.—Stocks and consumption of purchased copper scrap in the United States in 1965—Continued

(Short tons)

Class of consumer and type of scrap	Stocks Jan. 1	Receipts	Consumption: New scrap	Consumption: Old scrap	Consumption: Total	Stocks Dec. 31
Grand total:						
No. 1 wire and heavy copper	11,941	292,586	189,640	101,786	291,426	17,317
No. 2 wire, mixed heavy and light copper	16,265	347,903	197,364	153,966	351,330	13,920
Composition or red brass	5,424	109,219	33,517	76,159	109,676	4,967
Railroad-car boxes	2,078	39,839	-------	40,466	40,466	1,451
Yellow brass	18,570	332,494	272,556	60,206	332,762	22,019
Cartridge cases and brass	2,727	89,181	71,977	17,176	89,153	4,222
Auto radiators (unsweated)	7,825	60,455	-------	63,506	63,506	4,774
Bronze	3,446	39,774	10,574	29,833	40,407	2,677
Nickel silver	5,017	18,266	13,891	4,459	18,350	4,783
Low brass	3,406	44,620	42,785	1,818	44,603	3,296
Aluminum bronze	837	1,475	1,044	597	1,641	609
Low-grade scrap and residues [3]	44,299	331,624	131,817	198,208	330,025	45,898
Mixed alloy scrap	10,746	21,786	21,786	-------	21,786	12,312
Total	132,581	1,729,222	986,951	748,180	1,735,131	138,245

[1] Brass-mill stocks include home scrap; purchased scrap consumption assumed equal to receipts, so lines in brass-mill and grand total sections do not balance.

[2] Of the totals shown, chemical plants reported the following: Unalloyed copper scrap, 969 tons of new and 3,457 old; copper-base alloy scrap 2,528 tons of new and 4,944 old.

[3] Includes refinery brass.

Table 24.—Consumption of copper and brass materials in the United States, by principal consuming groups

(Short tons)

Year and item	Primary producers	Brass mills	Wire mills	Foundries, chemical plants, and miscellaneous users	Secondary smelters	Total
1964:						
Copper scrap	484,481	505,784	---------	122,533	399,802	1,512,600
Refined copper [1]	---------	690,406	1,097,518	32,636	4,721	1,825,281
Brass ingot	---------	6,557	---------	[2] 301,987	---------	308,544
Slab zinc	---------	122,793	---------	3,812	8,490	135,095
Miscellaneous	---------	---------	---------	100	9,103	9,203
1965:						
Copper scrap	601,093	585,542	---------	122,692	425,804	1,735,131
Refined copper [1]	---------	739,906	1,223,432	34,828	6,457	2,004,623
Brass ingot	---------	6,483	---------	[2] 324,707	---------	331,190
Slab zinc	---------	115,280	---------	3,968	7,600	126,848
Miscellaneous	---------	---------	---------	100	8,386	8,486

[1] Detailed information on consumption of refined copper will be found in table 29.

[2] Shipments to foundries by smelters minus increase in stocks at foundries.

Table 25.—Foundry consumption of brass ingot, by types, in the United States

(Short tons)

Type of ingot	1956–60 (average)	1961	1962	1963	1964	1965
Tin bronze	12,327	11,152	9,677	8,295	9,334	9,999
Leaded tin bronze	24,533	22,876	27,034	25,655	27,683	31,331
Leaded red brass	146,524	149,405	158,047	163,153	176,423	181,773
High-leaded tin bronze	21,617	16,739	17,916	18,850	21,014	22,930
Leaded yellow brass	16,563	12,672	10,632	11,815	12,938	19,767
Manganese bronze	10,298	8,429	8,564	8,497	9,264	9,816
Hardeners	2,192	2,439	2,711	3,889	4,071	4,349
Nickel silver	3,076	2,792	3,303	2,789	3,084	3,398
Aluminum bronze	(1)	(1)	7,688	8,053	7,820	8,122
Low brass [2]	7,665	7,505	928	1,316	1,929	2,503
Total	244,795	234,009	246,500	252,312	273,560	293,988

[1] Included with low brass.

[2] Includes aluminum bronze for 1956–61.

Table 26.—Foundry consumption of brass ingot by types, refined copper, and copper scrap, in the United States in 1965, by geographic divisions and States

(Short tons)

Geographic division and State	Tin bronze	Leaded tin bronze	Leaded red brass	High-leaded tin bronze	Leaded yellow brass	Manganese bronze	Hardeners	Nickel silver	Aluminum bronze	Low brass	Total brass ingot	Refined copper consumed	Copper scrap consumed
New England:													
Connecticut	197	639	5,198	244	1,962	130	16	20	116	59	8,581	445	1,368
Massachusetts	756	2,282	8,636	450	113	421	39	329	67	363	13,456	678	1,167
Maine, New Hampshire, Rhode Island, and Vermont	83	280	2,425	128	231	140	4	296	22	23	3,632	148	10
Total	1,036	3,201	16,259	822	2,306	691	59	645	205	445	25,669	1,271	2,545
Middle Atlantic:													
New Jersey	567	482	3,736	202	580	221	15	61	100	177	6,141	1,412	5,743
New York	752	2,268	16,512	935	558	1,000	84	204	1,244	202	23,759	848	7,552
Pennsylvania	1,304	6,223	20,471	3,623	1,510	1,467	1,748	417	402	128	37,293	6,924	13,431
Total	2,623	8,973	40,719	4,760	2,648	2,688	1,847	682	1,746	507	67,193	9,184	26,726
East North Central:													
Illinois	483	2,579	16,666	742	108	555	474	195	992	374	23,168	2,239	5,741
Indiana	85	598	17,427	780	956	252	840	301	57	168	21,464	1,389	5,374
Michigan	178	465	11,430	411	6,063	1,787	78	28	412	50	20,902	4,016	1,584
Ohio	1,592	10,369	23,163	8,475	1,385	1,579	267	99	974	523	46,956	4,394	8,831
Wisconsin	813	939	8,699	3,215		239	401	979	974		17,729	5,597	777
Total	3,151	14,950	77,385	13,623	8,512	4,412	2,060	1,602	3,409	1,115	130,219	17,635	22,307
West North Central:													
Iowa, Kansas, and Minnesota	615	233	5,478	95	34	287	151	78	164	176	7,255	388	2,657
Missouri, Nebraska, and South Dakota	57	174	1,270	752	500	108	13		602		3,532	674	19,528
Total	672	407	6,748	847	534	395	164	78	766	176	10,787	1,062	22,185
South Atlantic:													
Delaware, District of Columbia, Florida, Georgia, and Maryland	716	884	554	56	194	160	14	48	132	5	2,760	356	204
North Carolina, South Carolina, Virginia, and West Virginia	310	206	7,094	288	1,017	178		--	343		9,439	780	9,628
Total	1,026	1,090	7,648	344	1,211	338	14	48	475	5	12,199	1,136	9,832
East South Central: Alabama, Kentucky, Mississippi, and Tennessee	395	830	13,703	1,045	3,501	316	47	75	303	87	20,302	449	5,544
West South Central: Arkansas, Louisiana, Oklahoma, and Texas	205	1,216	8,446	552	725	423	96	144	935	3	12,745	421	4,540
Mountain: Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, and Utah	111	37	469	11	40	85	5	8	20	99	885	172	534
Pacific:													
California	658	603	10,019	651	161	412	57	116	250	42	12,969	324	12,386
Oregon and Washington	122	24	377	275	129	56	--	---	13	24	1,020	750	4,195
Total	780	627	10,396	926	290	468	57	116	263	66	13,989	1,074	16,581
Grand total	9,999	31,331	181,773	22,930	19,767	9,816	4,349	3,398	8,122	2,503	293,988	32,404	110,794

Table 27.—Dealers' monthly average buying price for copper scrap and consumers' alloy-ingot prices at New York in 1965

(Cents per pound)

Grade	Jan.	Feb.	Mar.	Apr.	May	June
No. 2 copper scrap	26.20	27.78	30.72	34.08	[1] 32.15	[1] 35.09
No. 1 composition scrap	25.25	25.33	26.06	27.78	[1] 29.10	[1] 28.66
No. 1 composition ingot	38.35	38.25	38.25	40.20	41.25	41.25

Grade	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
No. 2 copper scrap	33.50	35.85	38.36	40.54	41.53	38.07	34.49
No. composition scrap	27.39	27.52	28.42	29.37	29.71	29.79	27.87
No. 1 composition ingot	41.25	41.25	41.25	41.42	41.42	41.42	41.02

[1] Nominal.

Source: Metal Statistics, 1966.

Table 28.—Primary refined copper supply and withdrawals on domestic account

(Short tons)

Supply and withdrawals	1956–60 (average)	1961	1962	1963	1964	1965
Production from domestic and foreign ores etc.	1,373,301	1,550,139	1,611,730	1,596,351	1,656,395	1,711,793
Imports [1]	167,857	66,855	98,820	119,219	[r] 139,974	137,443
Stock Jan. 1 [1]	58,000	98,000	49,000	71,000	52,000	37,000
Total available supply	1,599,158	1,714,994	1,759,550	1,786,570	[r] 1,848,369	1,886,236
Copper exports [1]	309,339	428,718	336,525	311,479	316,230	324,965
Stock Dec. 31 [1]	70,000	49,000	71,000	52,000	37,000	35,000
Total	379,339	477,718	407,525	363,479	353,230	359,965
Apparent withdrawals on domestic account [2]	1,220,000	1,237,000	1,352,000	1,423,000	[r] 1,495,000	1,526,000

[r] Revised.

[1] May include some copper refined from scrap.

[2] Includes copper delivered by industry to the Government stockpiles.

Table 29.—Refined copper consumed, by classes of consumers

(Short tons)

Year and class of consumer	Cathodes	Wire bars	Ingots and ingot bars	Cakes and slabs	Billets	Other	Total
1964:							
Wire mills	-------	1,086,215	10,424	-------	-------	879	1,097,518
Brass mills	129,944	44,756	111,506	184,434	219,651	115	690,406
Chemical plants	-------	---------	1,621	-------	-------	550	2,171
Secondary smelters	2,291	---------	2,308	9	-------	113	4,721
Foundries	3,792	61	9,654	-------	310	1,122	14,939
Miscellaneous [1]	1,023	38	7,565	(2)	700	[3] 6,200	15,526
Total	137,050	1,131,070	143,078	184,443	220,661	8,979	1,825,281
1965:							
Wire mills	100	1,212,234	10,286	-------	-------	812	1,223,432
Brass mills	121,815	35,312	156,107	195,742	230,816	114	739,906
Chemical plants	-------	---------	1,701	-------	-------	723	2,424
Secondary smelters	3,506	---------	2,670	2	-------	279	6,457
Foundries	2,918	70	11,806	-------	448	1,266	16,508
Miscellaneous [1]	1,126	26	7,047	(2)	719	[3] 6,978	15,896
Total	129,465	1,247,642	189,617	195,744	231,983	10,172	2,004,623

[1] Includes iron and steel plants, primary smelters producing alloys other than copper, consumers of copper powder and copper shot, and miscellaneous manufacturers.

[2] Included with "Other" to avoid disclosing individual company confidential data.

[3] Includes "Cakes and slabs" to avoid disclosing individual company confidential data.

ceeded 1.25 million tons in 1965 and was 15 percent more than in 1964. Copper recovered in all forms from copper-base scrap rose 6 percent at secondary smelters, 29 percent at primary producers, 13 percent at brass mills, and 2 percent at foundries, but decreased 20 percent at chemical plants. Copper recovered from new scrap was 59 percent of the total (57 percent in 1964).

Consumption of purchased copper-base scrap totaled 1,735,000 tons and increased 15 percent over that of 1964. Use at secondary smelters increased to 425,800 tons, of which 78 percent (79 percent in 1964) was old scrap. Primary producers used 601,100 tons, of which 49 percent (52 percent) was old scrap. Of the 585,500 tons used at brass mills, 95 percent (96 percent) was new scrap. Foundries and other plants consumed 97,000 tons (99,400 tons) of old scrap and 25,700 tons (23,200 tons) of new scrap.

Primary producers recovered 388,100 tons of refined copper from secondary materials, 29 percent more than in 1964. Secondary smelters recovered 56,900 tons of refined copper (50,900 tons in 1964) and a total of 17,800 tons (15,100 tons) of copper powder and copper castings was produced. Production of brass-mill products and output of brass and bronze ingots rose 16 percent and 7 percent, respectively.

CONSUMPTION

Demand for copper continued strong throughout 1965 and was without a sharp seasonal drop in July, August, and September. Apparent withdrawals of primary copper rose 2 percent, and consumption of new copper was the largest since 1942.

Actual consumption of refined copper exceeded 2 million tons and increased 10 percent over that of 1964. These data are based on consumers' reports of quantities entering processing, with no adjustments of stock changes of material in process. Unlike table 28, in which only new copper is included as far as possible, table 29 does not distinguish between old and new copper, but includes all copper in refined form.

Distribution of actual consumption by use-groups followed the usual pattern, with wire mills consuming 61 percent (60 percent in 1964) and brass mills 37 percent (38 percent) of the total. Consumption exceeded 160,400 tons in January and rose to 179,400 tons in June. Use dropped to 122,100 tons in July, but rose to 173,700 tons in August and averaged 172,000 tons for the last 5 months of the year. Production of silverless, three-layered dimes and quarters and reduction of the silver content of half dollars, increased the consumption of copper in coins in 1965.

STOCKS

A high rate of consumption and a tight supply situation caused stocks of refined copper at primary producers in the United States to drop from 57,700 tons at the end of January to 29,100 tons on June 30. After a buildup to 37,000 tons in July, inventories again decreased and totaled 35,000 tons at yearend. Stocks of unrefined material decreased from 246,000 to 228,000 tons in January and rose to 251,000 tons in April. They then decreased to 214,000 tons by August 31 and rose to 261,000 tons, the year's high, in November. Inventories were 246,000 tons at yearend.

Fabricators' stocks of refined copper, including in-process metal and primary fabricated shapes, were 462,500 tons at yearend, 8 percent more than at the beginning of the year. Working stock inventories increased 13,700 tons during the year.

Table 30.—Stocks of copper at primary smelting and refining plants in the United States, Dec. 31

(Short tons)

Year	Refined copper [1]	Blister and materials in process of refining [2]
1956–60 (average)	70,000	261,000
1961	49,000	236,000
1962	71,000	246,000
1963	52,000	252,000
1964	37,000	246,000
1965	35,000	246,000

[1] May include some copper refined from scrap.

[2] Includes copper in transit from smelters in the United States to refineries therein.

Table 31.—Stocks of copper in fabricators' hands Dec. 31

(Short tons)

Year	Stocks of refined copper [1] (1)	Unfilled purchases of refined copper from producers (2)	Working stocks (3)	Unfilled sales to customers (4)	Excess stocks over orders booked [2] (5)
1961	461,252	89,745	361,286	144,344	45,367
1962	465,592	81,297	385,239	138,089	23,561
1963	474,875	100,357	382,692	163,558	28,982
1964	429,989	107,244	381,677	225,366	−69,810
1965	462,519	129,349	395,396	288,681	−92,209

[1] Includes in-process metal and primary fabricated shapes. Also includes small quantities of refined copper held at refineries for fabricators' account.
[2] Columns (1) plus (2) minus (3) and minus (4) equal column (5).
Source: United States Copper Association.

PRICES

Reports from copper-selling agencies indicated that 1,211,003 tons of domestic primary refined copper was delivered to purchasers at an average price of 35.4 cents per pound. Total sales of domestic refined copper from primary and secondary materials were reported as 1,394,524 tons at an average price of 36.7 cents per pound. The average price of foreign copper delivered in the United States was 36.5 cents per pound.

The price of electrolytic copper quoted by U.S. primary producers was 34 cents per pound, delivered, at the beginning of the year. From May 4 to May 6, producers in the United States increased the price of refined copper to 36 cents per pound, following a similar increase in prices abroad. Effective November 1, Copper Range Co. increased its price of copper 2 cents per pound to correspond with the foreign price of 38 cents. By November 10, other domestic producers, except Kennecott Copper Corp., had followed this action. Two large producers, however, rescinded the last price rise on November 22. Copper Range Co. withdrew its price increase November 29 and thereby the domestic price for all U.S. producers was reestablished at 36 cents per pound.

The price of copper on commodity exchanges in the United States and abroad fluctuated widely. Dealers' price in the United States declined from a high of 65 cents per pound in early December 1964 to 45½ cents on February 5, 1965. Thereafter, it began to rise and reached 62 cents in May. After dropping to 56 cents in late June, dealers' price rose to 67½ cents by November 8, but soon thereafter began to drop as a result of the release of copper from Government stockpiles. Dealers' price at yearend was 50 cents per pound.

London Price.—Prices on the London Metal Exchange were characterized by wide fluctuations with differences of as much as 8 cents per pound from one day to the next. The spot price for wire bar opened the year at the equivalent of 50 cents per pound and thereafter trended upward to 65½ cents per pound by May 18. The price declined to 49¾ cents by mid-July but began to rise thereafter. As 1965 drew to a close, prices for wire bar increased rapidly and the spot price closed the year at the equivalent of 70¾ cents per pound.

According to the American Metal Market, prices paid on January 2 for No. 1 scrap were 30.25 to 31.00 cents per pound and for no. 2 scrap were 27.00 to 27.50 cents per pound. Prices for scrap dropped in January but began to rise early in February and continued to increase until April 21, when the price of No. 1 scrap was 38.00 to 38.50 and No. 2 scrap was 36.00 to 36.50 cents per pound. Prices fluctuated until the end of July, after which they began to increase steadily, and by November 12, prices of No. 1 scrap and No. 2 scrap were 46.00 to 47.00 and 42.00 to 43.00 cents per pound, respectively. Trading in scrap was nominal after the announcement of the stockpile release of copper. When quotes were resumed on November 29, prices of No. 1 and No. 2 scrap were 39.50 to 42.00 and 36.00 to 38.00 cents. Early in December, prices for scrap began to move upward again and closed the year at 43.00 to 44.50 cents for No. 1 and 39.00 to 40.00 for No. 2.

Table 32.—Average weighted prices of copper deliveries, [1] consumer plants

(Cents per pound)

Year	Domestic copper	Foreign copper
1961	30.0	30.4
1962	30.8	30.6
1963	30.8	30.7
1964	32.6	33.0
1965	35.4	36.5

[1] Covers copper produced in the United States and delivered here and abroad and copper produced abroad and delivered in the United States; excludes copper both produced and delivered abroad, whether or not handled by U.S. selling agencies.

Table 33.—Average monthly quoted prices of electrolytic copper for domestic and export shipments, f.o.b. refineries, in the United States and for spot copper at London

(Cents per pound)

Month	1964				1965			
	Domestic, f.o.b. refinery [1]	Domestic, f.o.b. refinery [2]	Export, f.o.b. refinery [2]	London spot [3 4]	Domestic, f.o.b. refinery [1]	Domestic, f.o.b. refinery [2]	Export, f.o.b. refinery [2]	London, spot [3 4]
January	30.82	30.600	28.566	29.69	33.82	33.600	33.376	45.15
February	30.82	30.600	28.629	31.40	33.82	33.600	32.994	53.15
March	31.35	31.116	29.127	33.74	33.82	33.600	33.191	55.80
April	31.82	31.600	29.636	39.01	33.82	33.600	33.223	60.94
May	31.82	31.600	29.670	37.49	35.68	35.454	35.921	62.28
June	31.82	31.600	29.830	36.53	35.82	35.600	36.107	59.04
July	31.82	31.600	29.960	38.58	35.82	35.600	36.052	51.15
August	31.82	31.600	30.977	45.01	35.82	35.600	35.688	54.63
September	32.44	32.230	32.694	52.19	35.82	35.600	35.605	60.02
October	33.82	33.607	34.141	61.05	35.82	35.678	38.083	63.58
November	33.82	33.664	34.192	62.99	36.35	36.414	38.460	66.62
December	33.82	33.701	34.392	57.16	35.82	35.861	38.549	68.81
Average	32.17	31.960	30.985	43.88	35.19	35.017	35.604	58.52

1 American Metal Market.
2 E&MJ Metal and Mineral Markets.
3 Metal Bulletin (London).
4 Based on average monthly rates of exchange by Federal Reserve Board.

Table 34.—U.S. exports of copper by classes and countries

(Short tons)

Year and country	Ore, concentrates, matte (copper content)	Refined	Scrap	Pipes and tubing	Plates and sheets	Wire and cable, bare	Wire and cable, insulated	Other copper manufactures
1956-60 (average)	10,988	309,339	33,222	1,207	316	6,782	17,836	2,857
1961	4,478	428,718	35,257	949	355	1,995	15,550	7,362
1962	1,916	336,525	12,608	864	349	2,875	13,364	6,768
1963	1,210	311,479	13,690	1,158	338	3,150	15,145	5,811
1964	5,395	316,230	43,749	1,433	398	5,186	14,436	4,470
1965:								
North America:								
Canada	50	6,160	480	220	326	503	4,888	1,135
Mexico	1	409	---	19	98	41	527	35
Other	1	81	---	104	15	214	1,556	923
Total	52	6,650	480	343	439	758	6,971	2,093
South America:								
Argentina	---	6,794	54	(1)	---	4	51	---
Brazil	---	6,039	---	2	---	67	13	145
Colombia	50	32	10	26	1	110	267	1,021
Peru	1,149	91	---	18	4	40	373	7
Other	---	79	---	45	73	122	998	1,373
Total	1,199	13,035	64	91	78	343	1,702	2,546
Europe:								
Belgium-Luxembourg	2,642	1,241	2,768	2	1	15	41	49
France	---	38,597	2	(1)	2	11	201	9
Germany, West	1,820	34,281	4,386	5	1	4	483	37
Italy	4	51,734	1,201	11	7	1	70	7
Netherlands	---	9,833	149	7	65	8	121	2
Spain	593	3,769	9,710	8	1	12	104	---
Sweden	388	4,919	120	1	---	24	84	---
Switzerland	1	4,184	---	9	---	17	103	63
United Kingdom	1,044	68,953	118	35	16	6	111	80
Other	---	7,568	7,650	31	(1)	45	647	266
Total	6,492	225,079	26,104	109	93	143	1,965	513
Africa	---	586	1,123	96	2	493	995	113
Asia:								
India	---	51,047	575	36	116	1,350	803	364
Japan	7,767	22,052	3,249	4	125	68	172	149
Other	---	112	55	207	5	1,388	3,588	25
Total	7,767	73,211	3,879	247	246	2,806	4,563	538
Oceania	---	6,404	110	9	72	17	192	2
Grand total	15,510	324,965	31,760	895	930	4,560	16,388	5,805

1 Less than ½ unit.

FOREIGN TRADE

Exports.—Refined copper, again the principal class of exports, increased 3 percent over 1964. India, Italy, and the United Kingdom were the major recipients; France, West Germany, and Japan also received substantial quantities; and some other countries received less than 10,000 tons apiece.

Exports of ore, concentrate, and matte increased 187 percent over those of 1964 and were the highest since 1957.

Imports.—Total entries of crude and refined copper into the United States declined 11 percent compared with 1964 figures. Imports from nations of the Western Hemisphere constituted 84 percent of the total supply as follows: Chile, 41 percent; Peru, 25 percent; Canada, 16 percent; Mexico, 2 percent; Bolivia and others, less than 1 percent. The Philippines supplied 34 percent of the imports of copper in ore and concentrate, the total of which decreased 29 percent. Imports of blister copper were down 15 percent compared with 1964 totals; strikes reduced the quantity obtained from Chile by 25 percent. Imports of refined copper declined 2 percent. The quantity of copper in scrap received was 242 percent over that of 1964 and was the highest since 1950, when 38,800 tons were imported.

Tariff.—The price of copper was above 24 cents per pound throughout 1965 and the 1.7-cent-per-pound excise tax, effective July 1, 1958, was applicable to imported copper.

Table 35.—U.S. exports of copper by classes

Year	Ore, concentrates, and matte (copper content)		Refined copper and semi-manufactures		Other copper manufactures		Total	
	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value
1956–60 (average)	10,988	$7,223,372	368,703	$245,414,844	2,857	$2,197,923	382,548	$254,836,139
1961	4,478	2,474,679	482,824	295,397,080	7,362	5,260,315	494,664	303,132,074
1962	1,916	1,045,181	366,585	234,604,915	6,768	5,106,603	375,269	240,756,699
1963	1,210	638,177	344,960	225,648,628	5,811	4,273,403	351,981	230,560,208
1964	5,395	2,970,822	381,432	262,741,291	4,470	3,667,512	391,297	269,379,625
1965	15,510	8,368,699	379,498	317,337,627	5,805	5,435,911	400,813	331,142,237

Table 36.—U.S. exports of copper-base alloy (including brass and bronze), by classes

Class	1964		1965	
	Short tons	Value	Short tons	Value
Ingots	1,987	$2,040,846	1,519	$1,392,397
Scrap and other forms	68,670	33,580,336	65,325	35,998,600
Bars, rods, and shapes	1,041	1,504,435	2,073	3,596,398
Plates, sheets, and strips	1,114	2,510,768	3,435	6,353,195
Pipes and tubing	1,366	2,154,755	1,879	3,065,415
Pipe fittings	1,529	3,477,341	2,840	7,611,758
Plumbers' brass goods	2,729	7,054,779	555	7,088,030
Welding rods and wire	941	2,255,560	816	1,961,944
Castings and forgings	668	1,312,192	422	960,240
Powder	475	632,267	969	1,374,348
Semifabricated forms, not elsewhere classified	93	181,503	216	713,541
Total	80,613	56,704,782	80,049	70,115,866

Table 37.—U.S. exports of unfabricated copper-base alloys [1] ingots, bars, rods, shapes, plates, sheets, and strips

Year	Short tons	Value
1956–60 (average)	1,753	$3,225,247
1961	1,705	3,658,503
1962	2,391	4,227,640
1963	2,046	3,491,256
1964	4,142	6,056,049
1965	7,027	11,341,990

[1] Includes brass and bronze.

Table 38.—U.S. exports of copper sulfate (blue vitriol)

Year	Short tons	Value
1956–60 (average)	17,716	$3,959,477
1961	7,575	1,542,212
1962	1,916	455,665
1963	851	226,758
1964	1,087	275,477
1965	2,135	1,287,809

Table 39.—U.S. imports and exports of brass and copper scrap
(Short tons)

	1956–60 (average)	1961	1962	1963	1964	1965
Exports:						
Copper-base alloy scrap (new and old)	60,113	116,654	36,209	34,717	68,670	65,325
Copper scrap	33,222	35,257	12,608	13,690	43,749	31,760
Imports for consumption:						
Brass scrap (gross weight)	4,763	608	2,141	1,516	989	2,274
Copper scrap (copper content)	4,384	1,643	3,846	2,130	r 2,055	16,756

r Revised.

Table 40.—U.S. imports for consumption and exports of copper scrap by countries
(Short tons)

Country	Imports: Unalloyed copper scrap (copper content)		Imports: Copper alloy scrap (gross weight)		Exports: Unalloyed copper scrap		Exports: Copper alloy scrap	
	1964	1965	1964	1965	1964	1965	1964	1965
North America:								
Canada	r 1,125	3,280	768	1,729	1,567	480	448	981
Mexico	549	1,945	21	60	8	---	37	59
Other	271	396	199	362	11	---	34	---
Total	1,945	5,621	988	2,151	1,586	480	519	1,040
South America	r 1	10,531	---	11	113	64	14	67
Europe:								
Belgium-Luxembourg	---	41	---	---	4,495	2,768	724	3,937
France	45	---	---	---	3	2	550	509
Germany, West	5	13	---	15	5,741	4,386	8,290	8,840
Italy	---	1	---	---	636	1,201	793	8,131
Netherlands	4	1	---	---	524	149	406	1,192
Spain	---	44	---	---	6,904	9,710	321	1,695
Sweden	---	1	---	---	212	120	2,934	3,891
United Kingdom	4	54	---	10	132	118	594	1,234
Yugoslavia	---	---	---	---	2,119	7,451	---	1,595
Other	8	7	1	---	98	199	35	462
Total	66	162	1	25	20,864	26,104	14,647	31,486
Africa	---	84	---	6	758	1,123	11	---
Asia:								
India	---	---	---	---	1,137	575	139	75
Japan	43	335	---	---	19,138	3,249	53,150	32,513
Other	---	---	---	---	153	55	114	113
Total	43	335	---	---	20,428	3,879	53,403	32,701
Oceania	---	23	---	81	---	110	76	31
Grand total	r 2,055	16,756	989	2,274	43,749	31,760	68,670	65,325

r Revised.

Table 41.—U.S. imports [1] of copper (unmanufactured) by classes and countries
(Short tons, copper content)

Year and country	Ore and concentrates	Matte	Blister	Refined	Scrap	Total
1956–60 (average)	93,806	6,537	282,565	167,857	5,498	556,263
1961	45,788	1,606	339,189	66,855	4,231	457,669
1962	42,917	635	331,686	98,820	4,793	478,851
1963	47,501	907	368,900	119,219	2,869	539,396
1964:						
North America:						
Canada	25,005	35	2	r 84,480	1,104	r 110,626
Mexico	1,026	---	12,386	112	549	14,073
Other	---	2	---	(2)	277	279
Total	26,031	37	12,388	r 84,592	1,930	r 124,978
South America:						
Chile	1,767	311	251,092	r 3,345	2,428	r 258,943
Peru	8,041	203	75,664	28,502	---	112,410
Other	1,492	36	956	---	52	2,536
Total	11,300	550	327,712	r 31,847	2,480	r 373,889

Table 41.—U.S. imports[1] of copper (unmanufactured) by classes and countries—Continued

(Short tons, copper content)

Year and country	Ore and concentrates	Matte	Blister	Refined	Scrap	Total
1964—Continued						
Europe:						
Belgium-Luxembourg	---	---	1,087	r 958	---	r 2,045
Norway	---	---	61	773	---	834
United Kingdom	---	---	---	2,516	4	2,520
Other	---	---	---	1,135	16	1,151
Total	---	---	1,148	r 5,382	20	r 6,550
Africa:						
Rhodesia and Malawi	---	---	7,393	r 12,704	---	r 20,097
South Africa, Republic of	3,607	r 1	39,162	1,105	---	r 43,875
Other	11	---	667	r 4,014	---	r 4,692
Total	3,618	r 1	47,222	17,823	---	r 68,664
Asia:						
India	---	---	---	330	---	330
Philippines	9,472	15	---	---	---	9,487
Other	---	---	1,109	---	43	1,152
Total	9,472	15	1,109	330	43	10,969
Oceania: Australia	1,014	---	---	---	---	1,014
Grand total	51,435	r 603	389,579	r 139,974	4,473	r 586,064
1965:						
North America:						
Canada	6,387	21	---	72,583	4,982	83,973
Mexico	104	---	6,733	215	2,069	9,121
Other	10	1	---	---	446	457
Total	6,501	22	6,733	72,798	7,497	93,551
South America:						
Bolivia	1,991	---	---	---	---	1,991
Chile	2,933	223	187,841	15,623	6,100	212,720
Peru	10,117	247	82,421	35,623	909	129,317
Other	---	8	---	---	84	92
Total	15,041	478	270,262	51,246	7,093	344,120
Europe:						
Germany, West	---	---	1,107	2	1	1,110
Netherlands	---	---	---	530	---	530
Norway	---	---	---	1,346	---	1,346
United Kingdom	---	---	---	342	54	396
Other	---	---	---	911	49	960
Total	---	---	1,107	3,131	104	4,342
Africa:						
South Africa, Republic of	1,660	---	44,332	560	---	46,552
Zambia, Southern Rhodesia, and Malawi	---	---	---	3,189	---	3,189
Other	---	---	1,222	653	---	1,875
Total	1,660	---	45,554	4,402	---	51,616
Asia:						
Japan	---	---	667	1,530	577	2,774
Philippines	12,378	8	---	---	---	12,386
Turkey	---	---	8,237	---	---	8,237
Total	12,378	8	8,904	1,530	577	23,397
Oceania: Australia	845	---	---	4,336	23	5,204
Grand total	36,425	508	332,560	137,443	15,294	522,230

r Revised.

[1] Data are "general" imports, that is, they include copper imported for immediate consumption plus material entering the country under bond.

[2] Less than ½ unit.

Table 42.—U.S. imports[1] of copper (unmanufactured) by countries

(Short tons, copper content)

Country	1956–60 (average)	1961	1962	1963	1964	1965
North America:						
Canada	109,097	78,354	98,753	90,670	r 110,626	83,973
Mexico	40,551	20,963	23,779	22,344	14,073	9,121
Other	13,577	308	368	197	279	457
Total	163,225	99,625	122,900	113,211	r 124,978	93,551

See footnotes at end of table.

Table 42.—U.S. imports[1] of copper (unmanufactured) by countries—(Cont.)

(Short tons, copper content)

Country	1956-60 (average)	1961	1962	1963	1964	1965
South America:						
Bolivia	3,099	905	1,580	1,520	r 1,492	1,991
Chile	224,469	226,971	225,394	227,001	r 258,943	212,720
Peru	47,050	90,435	72,133	99,578	r 112,410	129,317
Other	639	(2)	28	80	1,044	92
Total	275,257	318,311	299,135	328,179	r 373,889	344,120
Europe:						
Belgium-Luxembourg	2,496	---	---	12,657	r 2,045	40
Germany, West	8,510	14	---	2	268	1,110
Netherlands	332	---	23	334	502	530
Norway	1,257	---	---	---	834	1,346
United Kingdom	5,435	1,316	846	1,064	2,520	396
Other	9,264	11	725	128	381	920
Total	27,294	1,341	1,594	14,185	r 6,550	4,342
Africa:						
South Africa, Republic of	25,923	23,474	24,460	36,368	43,875	46,552
Zambia, Southern Rhodesia, and Malawi	29,315	10	18,997	26,581	r 20,097	3,189
Other	8,958	21	784	4,698	r 4,692	1,875
Total	64,196	23,505	44,241	67,647	r 68,664	51,616
Asia:						
Philippines	13,977	13,898	10,126	14,907	9,487	12,386
Turkey	2,363	---	---	---	1,109	8,237
Other	183	---	35	90	373	2,774
Total	16,523	13,898	10,161	14,997	10,969	23,397
Oceania:						
Australia	9,767	826	751	1,149	1,014	5,204
Other	1	163	69	28	---	---
Total	9,768	989	820	1,177	1,014	5,204
Grand total	556,263	457,669	478,851	539,396	r 586,064	522,230

r Revised.

1 Data are "general" imports, that is, they include copper imported for immediate consumption plus material entering the country under bond.

2 Less than ½ unit.

Table 43.—U.S. imports for consumption of old brass and clippings from brass or Dutch metal[1]

Year	Short tons: Gross weight	Short tons: Copper content	Value (thousands)	Year	Short tons: Gross weight	Short tons: Copper content	Value (thousands)
1956-60 (average)	4,763	2,944	$1,626	1963	1,516	945	$ 558
1961	608	390	173	1964	989	641	415
1962	2,141	1,289	738	1965	2,275	1,490	1,151

1 For remanufacture.

Table 44.—U.S. imports for consumption of copper (copper content), by classes[1]

Year	Ore and concentrates		Matte		Blister	
	Short tons	Value (thousands)	Short tons	Value (thousands)	Short tons	Value (thousands)
1956–60 (average)	57,729	$33,059	4,556	$2,824	143,309	$94,426
1961	24,501	14,042	95	57	5,929	3,508
1962	2,322	1,414	22	12	1,119	669
1963	6,490	3,714	2,756	1,647	21,831	13,109
1964	r 33,033	r 17,235	r 88	r 47	121,365	73,300
1965	1,441	777	83	72	75,122	45,262

Year	Refined		Scrap		Total value (thousands)
	Short tons	Value (thousands)	Short tons	Value (thousands)	
1956–60 (average)	177,415	$114,415	4,384	$2,386	$247,110
1961	87,206	51,852	1,643	870	70,329
1962	130,197	76,995	3,846	2,242	81,332
1963	122,147	70,818	2,130	1,219	90,507
1964	r 113,018	r 67,468	r 2,011	r 1,372	r 159,422
1965	103,269	70,937	7,646	6,410	123,458

r Revised.
[1] Excludes imports for manufacture in bond and export, classified as "imports for consumption" by the Bureau of the Census.

WORLD REVIEW

Growing economies in the free world continued to create a strong demand for copper. However, the growth rate of estimated consumption of refined copper in 1965 was 2 percent, compared with 11 percent in 1964. Despite strikes in Chile and work stoppages and other production difficulties in Africa, mine production increased 4 percent over the high established in 1964. New records of production were set in Canada, Zambia, and the United States. Although output from the Congo (Léopoldville) increased, it did not reach a previously attained high. A multiple-price structure developed as a result of strong demand in the free world and interruption of production and transportation in some major producing countries.

NORTH AMERICA

Canada.—Mine production of copper in Canada reached a new high of 517,200 tons, with gains registered in all copper-producing Provinces except Saskatchewan and British Columbia.[3] Output from the latter Province was adversely affected by a prolonged strike at the plant of its largest producer. Controls were imposed in Canada on copper exports as a precautionary measure in case of emergency and to prevent exports of copper of United States origin. No control restrictions, however, were placed on the exports of copper from Canada to the United States. An apparent shortage of copper developed in the last quarter despite diversion of primary copper from export markets to local fabricators.

Copper-producing mines in Ontario, the leading copper-producing Province in Canada, operated at near capacity; output from the Province increased 11 percent. Approximately 4.5 million tons of overburden, composed of muskeg and clay, was removed from the Kidd Creek open pit mine of Texas Gulf Sulphur Co. Bulk metallurgical testing of the ore was begun at the nearby Kam-Kotia mill. Construction of a concentrator and related facilities progressed rapidly.

Mines of The International Nickel Company of Canada, Ltd. (Inco), Canada's leading producer, produced at record level of 19.8 million tons of ore. Deliveries of copper totaled 138,000 tons, compared with 143,200 tons in 1964. Sinking a new shaft was begun at the Creighton mine in Ontario. When completed, the shaft will be 7,150 feet deep, the deepest mine shaft continuous from the surface in the Western Hemisphere. By the end of 1965 underground development workings in operating mines totaled about 590 miles.

[3] A substantial part of the information in this section was taken from the following publication: Killan, A. F. The Canadian Mineral Industry in 1965, Preliminary. Department of Mines and Technical Surveys, Miner. Res. Div. (Ottawa, Canada), Miner. Inf. Bull. MR 81, 1966, pp. 26–33.

Table 45.—World mine production of copper (content of ore) recoverable where indicated, by countries[1]

(Short tons)

Country	1961	1962	1963	1964	1965 p 2
North America:					
Canada 3	439,088	457,385	452,558	r 486,900	517,247
Cuba e	5,500	6,000	6,600	6,600	6,600
Haiti	r 3,154	r 4,718	r 6,486	r 5,544	4,365
Mexico	54,359	51,945	61,576	57,878	76,237
Nicaragua	6,919	8,016	8,028	10,185	11,228
United States 3	1,165,155	1,228,421	1,213,166	1,246,780	1,351,734
Total	r 1,674,175	r 1,756,485	r 1,748,414	r 1,813,887	1,967,411
South America:					
Argentina	607	446	r 431	r 380	e 390
Bolivia (exports)	2,294	2,646	3,300	5,160	5,215
Brazil e	r 2,315	r 2,200	r 2,800	r 3,100	3,100
Chile	607,233	653,613	665,951	r 685,265	642,179
Ecuador	111	r 194	r 314	203	e 200
Peru	3 218,315	3 183,854	3 195,609	r 194,497	195,513
Total	r 830,875	r 842,953	r 868,405	r 888,605	846,597
Europe:					
Albania e	2,600	2,800	2,800	2,800	2,800
Austria	2,105	2,190	2,078	1,725	1,678
Bulgaria e	19,600	21,500	r 23,400	r 22,500	22,800
Finland	37,500	38,700	37,400	35,600	32,800
France 4	402	248	302	r 294	462
Germany:					
East e	28,000	29,000	26,000	r 25,000	31,000
West	2,393	2,202	r 2,515	1,726	1,064
Ireland	6,534	2,632	----------	----------	----------
Italy 5	2,658	2,974	e 2,700	e 2,500	e 2,000
Norway	15,379	17,124	r 15,724	r 16,439	16,526
Poland e	13,000	15,100	14,600	r 16,000	16,600
Portugal	r 3,351	r 3,742	r 3,627	r 4,812	4,799
Spain 6	r 10,566	r 8,702	r 7,534	r 9,159	8,261
Sweden	20,047	21,044	r 19,029	r 22,046	22,046
U.S.S.R. e 7 8	r 610,000	720,000	770,000	770,000	830,000
Yugoslavia	41,787	57,008	68,447	r 69,648	68,949
Total e 7	r 816,000	r 945,000	r 996,000	r 1,000,000	1,062,000
Africa:					
Algeria	732	859	1,142	1,204	1,130
Angola	1,022	1,965	r 71	----------	----------
Congo, Republic of (Brazzaville)	176	926	320	----------	----------
Congo, Republic of the (Leopoldville) 8	325,443	327,371	299,097	r 304,880	318,124
Morocco	1,915	2,752	1,991	r 1,927	2,076
Rhodesia, Southern	15,243	15,146	18,489	18,341	19,800
South Africa, Republic of	57,952	51,115	60,792	65,579	66,640
South-West Africa	27,778	24,971	35,774	r 38,698	43,456
Tanzania 9	111	----------	----------	----------	----------
Uganda 8	14,742	17,173	17,875	r 20,128	18,895
Zambia	r 633,536	619,856	648,239	r 697,047	766,924
Total	r 1,078,650	1,062,134	r 1,083,790	r 1,147,804	1,237,045
Asia:					
Burma e	125	165	190	140	150
China, mainland e	88,000	99,000	99,000	99,000	99,000
Cyprus (exports)	31,586	27,734	29,001	r 18,513	21,515
India	9,700	10,913	11,034	11,553	11,153
Israel	6,893	6,514	8,510	e 8,800	e 8,900
Japan	106,273	114,221	118,186	r 117,037	117,512
Korea:					
North e	7,000	9,000	9,000	11,000	13,000
South	351	474	678	r 717	e 1,500
Philippines	57,182	60,327	r 70,202	r 66,643	69,807
Taiwan	2,460	2,323	1,785	1,916	1,855
Turkey	31,793	r 34,700	r 32,200	r 38,030	35,950
Total e 7	341,000	r 365,000	r 380,000	r 373,000	380,000
Oceania: Australia	107,102	119,809	r 126,523	r 117,200	102,268
World total e	r 4,850,000	r 5,090,000	r 5,200,000	r 5,340,000	5,600,000

e Estimate. p Preliminary. r Revised.

1 Czechoslovakia, Iran, and Hungary also produce copper, but production data are not available. Kenya and Malaya also produce a small amount of copper. No estimates for these countries are included in the total.

2 Compiled mostly from data available July 1966.

3 Recoverable.

4 Includes copper content of auriferous ores.

5 Includes copper content of cupriferous pyrites.

6 Revised according to the Spanish annual report entitled "Estadistica Minera y Metalurgica."

7 Output from U.S.S.R. in Asia included with U.S.S.R. in Europe.

8 Smelter production.

9 Copper content of exports and local sales.

Table 46.—World smelter production of copper, by countries

(Short tons)

Country	1961	1962	1963	1964	1965 [p 1]
North America:					
Canada	406,359	382,868	378,911	r 407,942	433,553
Mexico	52,498	50,177	60,005	56,234	74,604
United States [2]	1,207,354	1,322,614	1,296,700	1,338,433	1,434,050
Total	1,666,211	1,755,659	1,735,616	r 1,802,609	1,942,207
South America:					
Brazil [3]	1,829	2,200	2,200	r 3,300	e 3,300
Chile	578,068	614,235	r 614,388	r 647,005	611,222
Peru	200,699	164,920	r 173,606	167,624	172,034
Total	780,596	781,355	r 790,194	r 817,929	786,556
Europe:					
Albania	1,421	2,050	r 2,249	e 2,200	e 2,200
Austria [3]	13,044	14,186	14,385	16,140	17,950
Bulgaria	20,834	21,385	22,622	23,259	e 25,000
Finland	37,800	37,400	41,664	36,571	33,645
Germany:					
East [e]	35,000	r 22,000	r 22,000	r 23,000	e 21,000
West [3]	335,488	339,778	333,799	370,728	393,946
Norway	24,218	21,113	r 20,059	r 16,314	19,290
Poland	r 21,164	r 21,561	r 26,588	r 26,191	29,630
Spain (blister) [4]	r 20,737	r 22,318	r 25,919	r 23,595	33,141
Sweden	22,816	25,100	r 29,698	r 31,636	34,271
U.S.S.R. [e 5]	r 610,000	720,000	770,000	770,000	830,000
Yugoslavia	34,027	50,421	54,048	57,255	62,120
Total [e 5,6]	r 1,177,000	r 1,297,000	r 1,363,000	r 1,397,000	1,502,000
Africa:					
Angola	937	877	112		
Congo, Republic of the (Leopoldville)	325,443	327,371	299,097	r 304,880	318,124
Rhodesia, Southern	12,915	13,599	16,187	16,798	e 18,900
South Africa, Republic of	57,562	50,905	60,085	60,090	60,022
South-West Africa		1,338	22,904	31,428	32,745
Uganda	14,742	17,173	17,875	r 20,128	18,895
Zambia	r 627,133	r 602,302	r 635,871	r 709,214	755,197
Total	r 1,038,732	r 1,013,565	r 1,052,131	r 1,142,538	1,203,883
Asia:					
China, mainland [e]	110,000	110,000	110,000	110,000	110,000
India	9,189	10,781	r 10,574	r 10,422	10,318
Japan	232,659	233,828	274,515	311,056	338,312
Korea:					
North (electrolytic) [e]	9,000	11,000	11,000	11,000	13,000
South	1,456	2,436	2,622	3,097	2,973
Taiwan	r 2,481	2,745	1,633	1,769	2,078
Turkey	22,040	28,412	27,326	28,639	28,991
Total [e 5]	387,000	399,000	438,000	476,000	506,000
Oceania: Australia	69,997	97,818	99,111	r 90,562	83,054
World total [e]	r 5,120,000	r 5,340,000	r 5,480,000	r 5,730,000	6,020,000

e Estimate. p Preliminary. r Revised.

1 Compiled mostly from data available July 1966.

2 Smelter output from domestic and foreign ores, exclusive of scrap. Production from domestic ores only, exclusive of scrap, was as follows: 1961, 1,162,480; 1962, 1,282,126; 1963, 1,258,126; 1964, 1,301,115; and 1965, 1,402,806.

3 Includes secondary copper.

4 Revised according to the Spanish annual report entitled "Estadistica Minera y Metalurgica."

5 Output from U.S.S.R. in Asia included with U.S.S.R. in Europe.

6 Belgium reports a large output of refined copper which is believed to be produced principally from crude copper from Congo, Republic of the (Kinshasa, formerly Leopoldville); it is not shown here, as that would duplicate output reported under latter country.

Table 47.—Canada: Copper production (mine output), by Provinces

(Short tons)

Province	1964	1965 p
British Columbia	57,561	44,069
Manitoba	29,777	31,011
New Brunswick	9,296	9,696
Newfoundland	13,615	17,348
Northwest Territories	----	425
Nova Scotia	204	205
Ontario	197,917	219,183
Quebec	158,088	176,074
Saskatchewan	20,442	19,236
Total	486,900	517,247

p Preliminary.
Source: Dominion Bureau of Statistics, Department of Trade and Commerce, Government of Canada. Preliminary Report on Mineral Production, 1965.

Falconbridge Nickel Mines Ltd., treated 2.34 million tons of ore in 1965, compared with 1.96 million tons in 1964. The delivery of 16,900 tons of copper (12,500 tons in 1964) was limited to refinery production, because the company had no excess inventory at the beginning of the year.

Geco Mines Ltd., produced 1.33 million tons of ore from a copper-zinc ore body in Manitouwadge District, Ontario. The concentrate produced contained 24,700 tons of copper and was shipped to the Noranda smelter. McIntyre Porcupine Mines Ltd., milled 549,000 tons of ore (383,000 tons in 1964) from which 4,570 tons of copper (3,200 tons) were recovered.

North Cold Stream Mines Ltd., milled 365,000 tons of ore and the concentrate produced contained 6,500 tons of copper. Willroy Mines Ltd., milled 577,000 tons of ore, averaging 0.79 percent copper, compared with 530,000 tons, averaging 1.13 percent copper, in 1964. As a result of mining lower-grade ore, copper contained in the concentrate decreased to 1,900 tons.

The 11-percent increase in production from Quebec was attributed chiefly to the rise in production by Lake Dufault Mines Ltd., and at the Horne mine of Noranda Mines Ltd. Lake Dufault Mines Ltd., in the Noranda area, experienced its first full year of production. The mill treated 475,000 tons of ore, from which 26,600 tons of copper was recovered.

Gaspé Copper Mines Ltd., Canada's second-ranking copper producer, mined 2.66 million tons of ore averaging 1.17 percent copper from mines in Quebec. Of the total, 43 percent came from the Needle Mountain open pit mine. The smelter treated 243,000 tons of copper concentrate and fluxing ore, including 60,400 tons of custom concentrate. Anodes produced contained 43,300 tons of copper. Some 2.0 million tons of waste rock were removed from the ore body of the Copper Mountain mine and expansion of the concentrator to a rated daily capacity of 11,000 tons was reported on schedule.

Noranda Mines Ltd., produced 1.15 million tons of ore averaging 2.08 percent copper from the Horne mine. Of the total, 771,000 tons was milled and 169,400 tons of concentrate was produced. The remainder of the ore was smelted directly. A total of 1.72 million tons of ore, concentrate, flux, and scrap, including 723,000 tons of custom material, was smelted. Anodes produced contained 183,400 tons of copper. Output of copper by Canadian Copper Refiners Ltd., a subsidiary of Noranda, increased to 273,000 tons, reflecting higher receipts from the Noranda smelter. However, these receipts were partly offset by a lower throughput of copper scrap.

Campbell Chibougamau Mines Ltd., milled 937,000 tons of ore, averaging 1.84 percent copper in the fiscal year that ended June 30, 1965. The Henderson Division supplied 355,000 tons, or 37 percent of the total ore produced. The Main Mine Division produced 322,000 tons compared with 362,100 tons in 1963–64. Ore production from Cedar Bay Division was 216,000 tons compared with 154,000 tons in the previous year. Output of copper increased despite the decrease in grade resulting from mining several blocks of lower-grade ore by open stope methods. Surface pillars blasted at Kokko Creek were placed on a salvage basis. The mine produced 43,300 tons of ore compared with 27,800 tons in 1963–64. Concentrate shipments totaled 71,200 tons and contained 16,300 tons of copper.

The concentrator of Quemont Mining Corp. Ltd., treated 650,000 tons of ore (753,000 tons in 1964) and the concentrate produced contained 6,400 tons of copper. Normetal Mining Corp. Ltd., milled 350,100 tons of ore averaging 1.58 percent copper and containing zinc and small quantities of gold. The 22,000 tons of copper concentrate produced was shipped to the Noranda smelter and 5,100 tons of copper was recovered therefrom.

In the year ended August 31, 1965, Sullico Mines Ltd., a subsidiary of East Sullivan Mines Ltd., mined 993,000 tons of ore averaging 0.54 percent copper. Copper production was 4,700 tons. Solbec Copper Mines Ltd., a subsidiary of Hastings Mining and Development Co. Ltd., treated 497,000 tons of ore averaging 1.71 percent copper. Concentrate produced contained 6,900 tons of copper. Cupra Mines Ltd., began treating ore in September 1965 at nearby facilities of Solbec Copper Mines Ltd.

Opemiska Copper Mines (Quebec) Ltd.,

milled 746,000 tons of ore in 1965, compared with 749,000 tons in 1964. The average grade of ore treated was lower, and copper in concentrates was 20,200 tons (20,400 tons in 1964). Copper production by Copper Rand Mines Division, The Patiño Mining Corp., decreased from 15,200 tons in 1964 to 13,900 tons, as a result of a decline in ore grade and labor scarcity. Copper Rand mine produced 353,000 tons of ore; Bouzan mine, 36,000 tons; Jaculet mine, 77,000 tons; Portage mine, 151,000 tons; and Quebec Chibougamau Goldfields mine, which was operated on a long-term lease, 46,000 tons.

The concentrator of Mattagami Lake Mines Ltd., milled 1.4 million tons of ore averaging 0.69 percent copper and 11.7 percent zinc. Copper concentrate, totaling 38,300 tons with a grade of 19.61 percent copper, was shipped to the smelter of Noranda Mines Ltd. Orchan Mines Ltd., milled 368,900 tons of zinc-copper ore from which 4,000 tons of copper in concentrate was recovered. During the year ending August 31, 1965, New Hosco Mines Ltd., mined 326,000 tons of ore with an average grade of 2.45 percent copper that was milled at the concentrator of Orchan Mines Ltd. Mixed concentrate shipments to the smelter at Noranda contained 6,100 tons of copper compared with the output of 4,800 tons of metal in fiscal 1964.

An increase in production from Manitoba offset a decrease in output from Saskatchewan, and the combined production from the two Provinces remained unchanged.

Hudson Bay Mining and Smelting Co. Ltd., milled 1.64 million tons of ore, 55,000 tons more than in 1964, from mines in Manitoba and Saskatchewan. The grade of the ore treated, however, decreased from an average of 2.83 percent copper in 1964 to 2.64 percent in 1965. Of the ore treated, the Flin Flon mine supplied 53 percent, Chisel Lake 18 percent, Stall Lake 17 percent, Coronation 5 percent, and Schist Lake 7 percent. The smelter treated 362,400 tons of Hudson Bay concentrate and residue (396,300 tons in 1964); also 14,100 tons (15,500) of custom materials were treated. Blister copper output totaled 40,400 tons, and 39,900 tons of refined copper was produced.

Sherritt Gordon Mines Ltd., milled 1.4 million tons of nickel-copper ore at the concentrator at Lynn Lake. Concentrate produced contained 6,200 tons of copper (6,500 tons in 1964).

Decrease in production from British Columbia was attributed to a prolonged strike at the Merritt mine of Craigmont Mines Ltd. The strike began in October and continued to the end of the year, resulting in an estimated monthly loss of 1,500 tons of copper.

During the fiscal year that ended October 31, 1965, Craigmont Mines Ltd., the largest producer of copper in British Columbia, milled 1.6 million tons of ore averaging 1.16 percent copper. Concentrate produced contained 1,700 tons of copper. The Phoenix Copper Division of the Granby Mining Co. Ltd., treated 703,000 tons of ore averaging 0.80 percent copper. Salable copper produced totaled 4,300 tons compared with 3,800 tons in 1964.

Bethlehem Copper Corp. Ltd., milled 2.0 million tons of ore (1.4 million tons in 1964) averaging 0.69 percent copper during the fiscal year that ended February 28, 1966. Concentrate containing 11,500 tons of copper was shipped to Japan. Coast Copper Co. Ltd., a subsidiary of Consolidated Mining & Smelting Co. of Canada Ltd., produced 292,000 tons of copper ore averaging 1.67 percent copper that was treated at the mill of the latter company. Copper production was 14,900 tons, compared with 19,300 tons in 1964.

The Sunro mine workings of Cowichan Copper Co. Ltd., were rehabilitated late in 1965 after being idle for about 2 years as a result of flooding by the Jordan River. Operations were resumed by The Anaconda Company (Canada) Ltd., at Britannia Beach after a 7-month strike. Copper production was 1,600 tons.

In New Brunswick, copper production increased slightly and was derived from ores of three mines. Heath Steele Mines Ltd., milled approximately 750 tons per day from B and D ore bodies and treated ore from the Wedge mine of the Consolidated Mining & Smelting Co. of Canada Ltd. (Cominco). The latter mine produced 272,000 tons of ore from which 39,000 tons of concentrate was produced and shipped to Japan. Brunswick Mining & Smelting Corp. Ltd., produced complex zinc-lead-copper ore at the rate of 4,500 tons a day.

Newfoundland, with five mines that produced ore containing copper, registered a 30-percent increase in output. Consolidated Rambler Mines Ltd., was expanding the capacity of its concentrator from 500 to 1,500 tons per day. The Whalesback Pond mine of British Newfoundland Corp. Ltd., began production in July. Concentrate from the 2,000-ton-per-day mill was shipped to the Murdockville smelter of Gaspé Copper Mines Ltd.

Atlantic Coast Copper Corp. Ltd., milled 292,000 tons compared with 318,000 tons in 1964. Copper output, however, rose from 2,700 tons to 3,100 tons as a result of mining better-grade ore and improved metal recovery at the mill. First Maritime Mining Corp. Ltd., continued to produce low-grade ore from the Tilt Cove mine. The company was developing the Gull Pond mine of Gullbridge Mines Ltd., and was building a 1,500-ton-per-day concentrator that was scheduled to begin production in 1966. American Smelting and Refining Company continued to operate its Buchans mine in central Newfoundland.

Production of refined copper in Canada reached a new high of 430,000 tons, increasing 5 percent over that of 1964. Consumption of refined copper rose for the fifth consecutive year and reached 214,000 tons, 6 percent more than the previous high set in 1964.

Exports of copper in ore, concentrate, and matte dropped to 87,000 tons, as a result of increased domestic consumption. Of the total, 52,600 tons (65,200 tons in 1964) went to Japan, 15,500 tons (12,400) to Norway, and 7,200 tons (13,200) to the United States. Sweden received 4,600 tons (7,200), Belgium-Luxembourg 2,600 tons (2,000), West Germany 1,900 tons (2,500), and the United Kingdom 1,700 tons (1,600). Exports of ingots, bars, and billets were as follows:

Destination	Short tons 1964	Short tons 1965
United Kingdom	110,396	106,098
United States	85,293	71,057
France	15,666	11,525
Germany, West	2,907	3,680
Sweden	2,303	2,421
Belgium-Luxembourg	1,835	1,316
Italy	1,735	968
Switzerland	1,373	1,439
Portugal		729
Other countries	2,765	597
Total	224,273	199,830

In addition, 43,600 tons (43,900 tons in 1964) of rods, strips, sheet, tubing, and other shapes was exported, of which 11,800 tons went to the United States, 9,300 tons to Norway, and 3,200 tons each to Switzerland and the United Kingdom. Pakistan received 3,000 tons, Denmark 2,900 tons, New Zealand 2,500 tons, Spain 1,900 tons, and Venezuela 1,300 tons.

Mexico.—Output of blister copper by Compañia Minera de Cananea S.A. de C.V., was 30,100 tons, 6 percent less than in 1964. All mining operations were at the Sonora Hill and La Cananea open pits after June when underground mining stopped. Blister copper produced at Cananea was shipped to Cobre de Mexico S.A., Mexico City, D.F., for refining. An underground crusher and conveying system were under construction and were scheduled for completion in the second quarter of 1966. The modified and expanded concentrator was planned to be in operation in 1966.

SOUTH AMERICA

Chile.—Major strikes of 37 days' duration and other labor difficulties at mines and other establishments of the two large American-controlled companies were the principal reasons for a 6-percent decrease in production of copper.

Output of copper by Chile Exploration Co., a subsidiary of The Anaconda Company, was 278,600 tons, compared with 317,500 tons in 1964. A daily average of 195,000 tons of ore and waste was removed from the mine. A project which was undertaken to test the feasibility of reprocessing leach-ore residue included construction of an impermeable pad on which the residue will be treated. In addition, cementation launders were being built for the recovery of copper from the leach solutions. Andes Copper Mining Co., another Anaconda subsidiary, produced 81,700 tons of copper (84,300 tons in 1964) from its mine at El Salvador. A new anode furnace, utilizing a diesel-steam poling process was placed in operation at the smelter at Potrerillos early in 1965. The new electrolytic refinery was being enlarged to an eventual capacity of 12 million pounds per month. La Africana mine of Santiago Mining Co., another Anaconda subsidiary, produced 30,700 tons of concentrate with a copper content of 26.97 percent in 1965.

Despite a 5-week strike, Braden Copper Co., a subsidiary of Kennecott Copper Corp., mined and milled 12 million tons of ore compared with 11.5 million tons in the previous year. Lower-grade ore mined (1.80 percent in 1965, compared with 1.88 percent in 1964) resulted in lower-grade concentrate treated at the smelter. Copper output was 168,200 tons, 9 percent less than in 1964.

Peru.—Operations of the Cerro de Pasco Corp. (Cerro-Peru) continued to be uninterrupted by work stoppages and copper production increased 7 percent over the previous record established in 1964. Purchased ore was the source of 37 percent of the 44,500 tons of copper produced. Construction of a precipitating plant to increase output of cement copper at the Cerro de Pasco mine was expected to be completed by mid-1966. Increased production of 5,000 tons of cement copper at this plant will be supplemented for a few years by further shipments of direct smelting ore, but these increases will be partially offset by the ending of shipments of direct smelting ore from the Yauricocha mine.

Southern Peru Copper Corp. produced 11.2 million tons of ore averaging 1.29 percent copper from the Toquepala mine, compared with production in 1964 of 11.1 million tons of ore containing 1.34 percent copper. Output of blister copper increased from 127,500 tons to 131,300 tons. The completion of an addition to the concentrator increased its capacity to 40,000 tons per day. The increased capacity will offset, for the present, the lower grade of ore available so that copper production can be maintained at the present level.

Table 48.—Chile: Exports of copper, by principal types

(Short tons)

Destination	1964 r				1965			
	Refined		Blister	Total	Refined		Blister	Total
	Electrolytic	Fire refined			Electrolytic	Fire refined		
Argentina	6,413	------	-------	6,413	3,624	------	-------	3,624
Belgium	-------	280	6,628	6,908	336	------	-------	336
Brazil	17,162	1,482	-------	18,644	6,293	412	-------	6,705
Finland	1,926	------	-------	1,926	1,646	------	-------	1,646
France	12,501	7,073	-------	19,574	14,512	4,924	-------	19,436
Germany, West	13,920	6,166	11,751	31,837	17,349	8,825	9,017	35,191
Italy	14,160	9,742	-------	23,902	15,442	11,033	-------	26,475
Netherlands	32,739	916	-------	33,655	54,481	1,903	-------	56,384
Sweden	21,646	1,041	2,827	25,514	18,742	604	2,384	21,730
United Kingdom	24,106	29,348	43,442	96,896	18,739	24,147	40,228	83,114
United States	11,246	------	234,400	245,646	13,573	------	187,599	201,172
Total	155,819	56,048	299,048	510,915	164,737	51,848	239,228	455,813

r Revised.

Table 49.—Peru: Copper production

(Short tons)

Year	Blister	Refined	Other	Total
1961	161,722	37,256	19,337	218,315
1962	125,017	37,940	20,897	183,854
1963	130,398	40,689	24,522	195,609
1964	125,935	41,679	26,883	194,497
1965	131,285	44,598	23,482	199,365

Source: Bureau of Mines. Mineral Trade Notes. V. 63, No. 2, August 1966.

EUROPE

Increases of consumption of refined copper in Belgium, Spain, Sweden, Switzerland, and the United Kingdom were offset by decreases in use in other countries and total consumption in West Europe remained virtually unchanged. Consumption was as follows:

Country	Thousand short tons				
	1961	1962	1963	1964	1965
Belgium	82.1	72.0	65.7	99.9	116.8
France	268.6	268.7	276.0	321.4	313.7
Germany, West	619.4	551.8	544.0	631.3	617.9
Italy	222.7	235.9	251.3	222.7	209.0
Spain	60.1	55.1	60.6	66.5	70.1
Sweden	103.0	100.4	105.8	106.5	115.4
Switzerland	58.2	44.5	41.8	41.7	45.5
United Kingdom	583.0	579.9	615.1	697.6	711.4
Other	177.0	184.1	184.4	200.5	193.2
Total	2,174.1	2,092.4	2,144.7	2,388.1	2,393.0

Source: British Bureau of Nonferrous Metal Statistics.

Finland.—Ore produced from mines of Outokumpu Oy. remained essentially unchanged at 2.7 million tons. Decreased copper output reported from Outokumpu, Vihanti, and Kotalahti more than offset a small increase from Pyhäsalmi. Copper production was as follows:

Mine	Ore (short tons)	Copper concentrate (short tons)	Copper (short tons)
Outokumpu	609,400	96,900	22,100
Ylöjärvi	322,400	9,400	2,000
Vihanti	537,900	9,200	2,400
Kotalahti	519,600	3,400	1,000
Pyhäsalmi	716,000	23,600	5,300
Total	2,705,300	142,500	32,800

The Pori refinery produced 33,600 tons of cathodes.

United Kingdom.—The free world's second-largest copper-consuming country, the United Kingdom, consumed a total of 711,400 tons of primary and secondary copper compared with 697,600 tons in 1964.[4] In addition, 173,400 tons (171,700 tons in 1964) of copper in scrap was used. Output of semimanufactured products consumed 691,100 tons of refined copper and 108,100 tons of scrap; whereas castings, manufacture of copper sulfate, and miscellaneous products used 20,300 tons of refined copper and 65,400 tons of scrap. Production of copper sulfate was 26,900 tons (29,100 tons in 1964).

Exports and reexports of refined copper increased to 48,000 tons and 3,700 tons, respectively. Total exports and reexports were 21 percent larger than in 1964. Imports of unwrought copper totaled 647,000 tons, 11 percent more than in 1964.

Table 50.—United Kingdom: Imports of copper, by countries

(Short tons)

Country	1964 r			1965		
	Blister	Electrolytic	Fire refined	Blister	Electrolytic	Fire refined
Zambia	[1] 56,583	209,755	-------	[1] 51,316	234,246	-------
Canada	-------	109,865	-------	-------	111,331	-------
Chile	46,311	26,867	35,060	40,378	18,504	35,151
United States	-------	49,358	1,809	224	57,336	3,356
Netherlands	-------	1,784	140	-------	16,125	699
Peru	8,797	562	-------	13,330	2,297	-------
Germany, West	-------	8,096	590	-------	14,112	1,128
Belgium	61	5,992	-------	-------	10,075	-------
Sweden	-------	28	-------	-------	9,958	-------
U.S.S.R.	-------	706	-------	-------	9,896	-------
South Africa, Republic of	336	84	8,639	-------	986	5,590
Congo (Léopoldville)	-------	3,416	-------	-------	3,479	-------
Australia	-------	5,895	-------	-------	2,820	-------
Rhodesia, Southern	-------	-------	-------	529	-------	1,460
Norway	-------	610	-------	-------	879	-------
Other countries	-------	1,922	28	112	1,577	82
Total	112,088	424,940	46,266	105,889	493,621	47,466

r Revised.
[1] Includes fire refinable anodes.
Source: British Bureau of Nonferrous Metal Statistics.

Table 51.—United Kingdom: Exports and reexports, by countries

(Short tons)

Destination	1964 r	1965	Destination	1964 r	1965
Germany, West	8,029	9,356	Portugal	175	237
Netherlands	10,203	9,283	Brazil	15	221
China	2,690	6,158	Pakistan	279	207
Czechoslovakia	560	4,919	United States	2,017	130
Argentina	3,840	4,361	Hungary	----	112
Belgium	50	3,467	Poland	56	112
India	521	2,472	Spain	427	10
Sweden	2,658	2,452	Other countries	1,193	1,206
Australia	741	2,206			
France	4,097	1,689	Total	42,657	51,737
Italy	594	1,064			
Norway	561	1,045			
United Arab Republic (Egypt)	1,915	422			
Denmark	339	320			
Yugoslavia	1,697	288			

r Revised.

Source: British Bureau of Nonferrous Metal Statistics.

[4] British Bureau of Nonferrous Metal Statistics. World Non-Ferrous Metal Statistics. V. 19, No. 2, February 1966, pp. 9–10, 13.

Yugoslavia.—Mine production in 1965 totaled 6.9 million tons of ore, much of which was mined at Majdanpek. Grade of ore mined at Majdanpek ranged from 0.5 percent to 0.9 percent, whereas ore mined at Bor graded from 1.6 percent to 3.6 percent. Output of electrolytic copper was 62,100 tons. Expansion of annual output to about 100,000 tons by 1970 was planned.

AFRICA

Côngo (Léopoldville), Republic of the.—Satisfactory conditions were maintained in the Katanga region and copper production by Union Minière du Haut-Katanga increased 4 percent. Ore extraction from the Western and Central Groups was increased as the result of the arrival of new equipment and the addition to the workshop staff that was gradually brought up to strength.

Ore production increased to 8.7 million tons and nearly 22.6 million cubic yards of waste was removed. The Western Group produced 5.5 million tons of ore, Musonoi 2.5 million, Kamoto open pit mine 1.5 million, and Ruwe 1.5 million. Development work at the Kamoto underground mine was hampered by influx of water and the mine produced only 6,600 tons of ore. Production from the Kipushi mine in the Southern Group increased slightly and totaled 1.15 million tons. Ore was transported by conveyors which lead to an increase in production despite a considerable decrease in the number of workers employed. In the Central Group, the Kambove-West open pit production was increased to complete mining operations before the rainy season set in. The mine produced 925,000 tons. Kambove-West underground mine produced 178,000 tons by top slicing, and the Kakanda mine yielded 663,000 tons of ore. Removal of overburden from the Sesa mine began after a river was diverted from the mine area by a tunnel.

The Kolwezi concentrator treated 4.14 million tons of ore, of which 3.22 million tons was siliceous oxide ore, together with 920,000 tons of mixed oxide and sulfide ore supplied chiefly by Musonoi and Kamoto. Concentrate production was 618,400 tons averaging 25.51 percent copper from oxide ore; 54,100 tons of sulfide concentrate averaging 43.33 percent copper; and 54,100 tons of dolomitic oxide concentrate containing 18.9 percent copper. During the year the Kipushi concentrator treated 1.14 million tons of ore from the Kipushi mine by differential flotation and produced 187,800 tons of 25.97-percent-copper concentrate, and 204,100 tons of 58.37-percent-zinc concentrate. Capacity of the Kambove concentrator was increased to 85,000 tons per month and the plant processed 883,000 tons of mixed and sulfide ore from the Kambove open pit and underground mines, and produced 50,400 tons of sulfide concentrate averaging 51.17 percent copper and 84,600 tons of dolomitic oxide concentrate averaging 18.65 percent copper and 1.24 percent cobalt. The washing plant treated 184,100 tons of ore taken from stockpiles and recovered 114,800 tons of material averaging 6.24 percent copper that was fed to the Kambove concentrator. Output from the Kakanda concentrator was 94,700 tons of 23.23 percent copper concentrate derived from 640,000 tons of siliceous oxide ore. The feed of the Ruwe washery was composed of 1.41 million tons of breccia. Production was 83,600 tons of gravelly and fine concentrates containing 24.88 percent copper and 31,800 tons of washed product containing 9.37 percent copper for reprocessing at the concentrator.

The Lubumbashi plants (Elisabethville) produced blister copper for 9½ months and the remaining time made crude copper for soluble anodes at Shituru. Sulfide concentrate from Kipushi was the major part of the feed. Output of the Shituru (Jadotville) plants continued on a reduced basis as a result of repairing the transformer station. Output at the Luilu plants (Kolwezi) increased. Total output of copper for the financial year was—

	Short tons
Electrolytic copper ingot	169,696
Cathodes	80,020
Crude copper (blister and other types	72,352
Copper in various products	8
Total	322,076

Rhodesia, Southern.—Southern Rhodesia unilaterally declared independence on November 11, 1965. Statistics were not available for production after this action. Practically all the production came from three mines of Messina (Transvaal) Development Co., Ltd., and its subsidiary M.T.D. (Mangula) Ltd. In the fiscal year that ended September 30, 1965, 88,000 tons of ore and tailing averaging 2.17 percent copper was processed in the concentrator at Umkondo. Concentrate produced contained 1,800 tons of copper. At Alaska, concentrate produced from milling 272,000 tons of ore contained 5,100 tons of copper. The ore averaging 2.10 percent copper was derived from open pit mining and development work performed to change from open pit to underground mining. At Mangula 1.07 million tons of ore averaging 1.18 percent copper yielded 13,100 tons of copper in concentrate. Output of the Alaska smelter of Messina Rhodesia Smelting and Refining Co. Ltd., was 16,300 tons, an increase of 3 percent over that of fiscal 1964.

South Africa, Republic of.—Smelter production of copper by O'okiep Copper Co. Ltd., reached a new record of 46,100 tons compared with 46,000 tons produced in the fiscal year that ended June 30, 1964. A total of 2.8 million tons of ore averaging 1.79 percent copper was mined and milled during the fiscal year that ended June 30, 1965. Nabobeep Kloof mine was expected to be in production towards the end of 1965; 3,300 tons of ore was mined as a result of stope preparation. Heap-leaching at Carolusberg produced 900 tons of copper, and 100 tons was produced at Spektakel. The mine at Jan Coctzee was expected to be in operation in 1966. O'okiep sulfide ore reserves totaled 27.7 million tons and oxide ore reserves totaled 456,000 tons.

In Northern Transvaal, Messina (Transvaal) Development Co. Ltd., milled 914,000 tons of ore averaging 1.32 percent copper in the fiscal year that ended September 30, 1965. Concentrates smelted totaled 35,600 tons compared with 37,200 tons in 1964. Refined copper output was 12,200 tons.

Construction of production facilities and preparation of the mine of Palabora Mining Co. Ltd., in North Eastern Transvaal were ahead of schedule and operations were expected to begin early in 1966.

South-West Africa.—In the fiscal year that ended June 30, 1965, the Tsumeb mine and mill of Tsumeb Corp. Ltd., produced and treated a total of 812,100 tons of complex sulfide and oxide ore averaging 3.98 percent copper. The Kombat operation mined and milled 243,400 tons of ore averaging 4.31 percent copper. Blister copper output totaled 32,400 tons, 20 percent more than in 1964. Ore at the Tsumeb mine totaled 9 million tons containing 4.91 percent copper; at the Kombat mine, positive reserves totaled 1.1 million tons containing 2.64 percent copper and probable ore totaling 2.6 million tons with 2.29 percent copper.

Uganda.—Kilembe Mines Ltd., mined about 1.04 million tons of ore grading 1.96 percent copper. Severe drought conditions caused a water shortage that did not permit realization of the planned production rate. The method of mining was changed from open stope mining to cut and fill stoping. About 1.03 million tons of ore were milled and 18,900 tons of blister copper were produced, 6 percent less than in 1964. In 1965, ore reserves were 6,466,000 tons grading 2 percent copper and 2,700,000 tons grading 1.89 percent.

Zambia.—Operations at mines and plants in Zambia were not seriously affected by work stoppages, and record outputs were achieved. Mine production increased 10 percent, smelter output 14 percent, and refinery output 15 percent.

In the fiscal year that ended June 30, 1965, Luanshya Division of Roan Selection Trust Ltd. (RST Group), produced 6.79 million tons of ore averaging 1.75 percent total copper and 0.11 percent oxide copper. Production of ore from Roan Extension was 78 percent of the total, compared with 70 percent in fiscal 1964. As in previous years, Roan Basin supplied the remainder of the ore. Smelter output totaled 107,300 tons, 3 percent more than in fiscal 1964.

During the same period, Chibuluma Mines Ltd., mined 698,400 tons of ore with an average total copper content of 4.01 percent. Production of copper concentrate totaled 82,200 tons, of which 81,600 tons was smelted at the Mufulira smelter. Output from the concentrate was 22,600 tons of fire refinable copper, compared with 26,400 tons in fiscal 1964.

In the fiscal year that ended June 30, 1965, Mufulira Copper Mines Ltd., produced 7.98 million tons of ore averaging 2.53 percent total copper and 0.04 percent oxide copper. All stoping was above the 1900 level. Block caving methods produced 54.2 percent of the ore; cascade and open stoping, 36.2 percent; and development, 9.6 percent. Changes in mining methods involving increased mechanization of drilling, loading, and transportation continued throughout the year. Increased tonnage was derived from the sublevel caving method and production has commenced in the initial cascade section. The average daily pumping rate was nearly 18 million gallons. Output of finished copper was 179,200 tons compared with 175,900 tons in fiscal 1964. In addition to production from Mufulira materials, 2,538 tons of copper were cast on a toll basis for other mines of the Group.

During the fiscal year, 4.14 million cubic yards of overburden, 1.12 million cubic yards of oxide ore, and 5,000 cubic yards of sulfide ore were excavated at the Chambishi mine. The primary and secondary plants and the vat leaching section of the metallurgial plant were commissioned in March. The electrowinning plant was run on a reduced load from April and three batches of 8,000 high-quality cathodes each were produced by the end of the year. Output of finished copper totaled about 900 tons.

Ore reserves of the Roan Selection Trust Ltd., as of June 30, 1965, were as follows:

Mine	Short tons [1]	Percent: Total copper [2]	Percent: Oxide copper
Mufulira	176,776,000	3.34	Trace
Luanshya Division (Roan Basin, Roan Extension and Muliashi Special Grant)	94,964,000	2.87	0.10
Chibuluma	8,451,000	4.83	0.18
Chambishi	35,000,000	3.37	Trace

[1] Gross tons subject to mining losses.
[2] Grades subject to dilution in mining.

Ndola Copper Refineries Ltd., produced 131,600 tons of copper, in all forms, of which 99.6 percent was for associated companies of the RST Group. Output in 1964 was 117,800 tons, of which 97.8 percent was for the associated companies.

Nchanga Consolidated Copper Mines Ltd., mined 5.7 million short tons of ore averaging 5.38 percent copper during the year that ended March 31, 1965. The lower and upper ore bodies of Nchanga mined together supplied 3.2 million tons, Nchanga open pit 1.6 million tons, and Chingola open pit 0.8 million tons. Output of finished copper established a record of 260,200 tons—65,000 tons of blister and 195,200 tons of electrolytic copper. In the 9-month period ending March 31, 1965, Bancroft milled 989,400 tons of its own copper ore and 324,200 tons of Nchanga ore. Bancroft became a part of Nchanga in 1965 and the fiscal year ending in June was changed to conform with Nchanga's, which ends on March 31. Output of 24,013 tons of primary copper for Bancroft Mines Ltd., was reported on a 9-month basis ending March 31, 1965. Production of refined copper during the same 9-month period was 26,600 tons. Bancroft milled Nchanga ore at more than 100,000 tons per month. The estimated ore reserves for Nchanga on March 31, 1965, were 240 million tons containing 4.28 percent copper; Bancroft reserves were estimated to total 94 million tons with an average grade of 3.56 percent copper. Treatment at the leach plant of high-grade oxide concentrate produced at Bancroft from Nchanga ore began in November. The roaster at the leach plant began operating in June 1964 and treated 84,600 tons of low-grade sulfide concentrates during the remainder of the financial year.

Rhokana Corporation Ltd., mined and milled 5.5 million tons of copper ore in the fiscal year that ended June 30, 1965. Concentrate production was 335,300 tons containing 34.14 percent copper and 1.16 percent cobalt. Ore reserves totaled 119.4 million tons averaging 2.95 percent copper. Stripping of overburden at the Mindola open pit mine was completed. Ore from the pit will be the principal source of ore to be used in the TORCO plant (treatment of refractory copper ores) that has been built. Evaluation of the new plant was in progress. Smelter output totaled 297,500 tons of anode and blister copper. Of the total, 30,200 tons of blister and 84,100 tons of anodes were recovered for Rhokana; 62,500 tons of blister and 90,700 tons of anodes for Nchanga; and 4,400 tons of blister and 25,600 tons of anodes for Bancroft.

ASIA

Cyprus.—The political situation in Cyprus was comparatively stable, and tonnage milled and treated by Cyprus Mines Corp. reached an alltime high. The average grade of ore was 1.91 percent, compared with 2.33 percent in 1964. Shipments in 1965 consisted of 46,900 tons of copper concentrate, 119,500 tons of cupreous pyrite, and 6,900 tons of copper precipitate. In addition, 460,500 tons of pyrite concentrate was produced by flotation.

India.—Production of copper ore was 515,000 tons averaging 2.16 percent copper. The entire output of copper of about 11,000 tons was produced by the Indian Copper Corp.

Israel.—Timna Copper Mines, Ltd., produced 17,600 tons of cement copper averaging 78 percent copper from leaching 716,500 tons of ore. The ore mined averaged about 1.7 percent copper.

Japan.—Mine production of copper increased slightly and was 117,500 tons. Smelter production increased 9 percent and totaled 338,300 tons.

Late in June, the first copper concentrate was fed to the new reverberatory furnace of Onahama Seiren, Ltd., of Japan. The furnace, one of the largest in the world, measured 32 by 110 feet. It had a designed capacity of 60,000 tons annually.

Philippines.—Output of copper in ore and concentrate totaled 69,800 tons compared with 66,700 tons in 1964. Atlas Consolidated Mining & Development Corp. ceased operating the Lutopan open pit following difficulty with the hanging wall. Most of the production came from the lower grade Biga Road pit. Copper content in concentrate produced totaled 29,000 tons compared with 27,700 tons in 1964. Marinduque Mining & Industrial Corp. produced 4,400 tons and 11,600 tons of copper from the Baqacay and Sipalay projects, respectively.

Lepanto Consolidated Mining Co., milled 488,500 tons of ore with an average grade of 2.80 percent copper compared with 477,500 tons of ore with an average copper content of 2.91 percent. As a result, copper production decreased to 12,900 tons. A mill expansion program was completed by the end of 1965 and capacity was increased from 1,300 to 2,000 tons per day. Philex Mining Corp. produced 7,500 tons of copper.

Small outputs of copper were reported by Samar Mining Co., Inc., 2,000 tons; Surigao Consolidated Mining Co., Inc., 300 tons; Copper Belt Mining Co., 400 tons; and Acoje Mining Co., Inc., which began production during 1965, 1,600 tons.

Turkey.—Output of blister copper from Etibank's Ergani and Murgul smelters was 20,400 and 8,600 tons, respectively. Grade of ore mined at Ergani decreased somewhat as the flotation mill was expanded to treat lower grade ores.

Production of ore and precipitate in 1965 was as follows:

Mine	Tons of ore	Average percent copper	Tons of blister copper
Ergani:			
Direct smelting	250,000	7.32	20,400
Milling	105,000	2,72	----
Cement copper	1,500	74,28	----
Murgul	546,000	1.93	8,600
Küre	9,000	10.00	[1] 800
	146,000	2.69	[1] 3,500

[1] Estimated copper content.

OCEANIA

Australia.—Mount Isa Mines Ltd., Queensland, a subsidiary of American Smelting and Refining Co., treated 1.4 million tons of copper ore grading 3.1 percent copper in the year that ended June 30, 1965. In addition, 0.7 million tons of ore from the opencut mine was stockpiled for future treatment. Blister copper production was 39,400 tons. Output of refined copper by Copper Refineries Pty. Ltd., was severely curtailed by the reduction of blister received from Mount Isa and totaled 44,500 tons of refined copper, of which 17,300 tons was wire bars; 3,200 tons, cathode; 10,000 tons, cakes and billets; and 14,000 tons, rod and wire. Reduced production of cakes and billets was due mainly to the cessation of exports of shapes after November 1964 when export of copper was prohibited.

In the fiscal year that ended June 28, 1965, Mount Morgan Ltd., again milled 1.42 millions tons of ore averaging 0.64 percent copper and removed 3.34 million tons of overburden. Blister copper produced was 7,300 tons compared with 9,000 tons in the preceding year.

The Mount Lyell Mining and Railway Co. Ltd., Tasmania, mined 2.2 million tons of ore averaging 0.72 percent copper from open pit and underground mines in the fiscal year that ended June 30, 1965. Recoverable copper in concentrate increased from 14,800 tons to 14,900 tons. Blister copper production was 15,300 tons (16,900 tons in 1964) and output of electrolytic copper was 13,600 tons (13,200).

TECHNOLOGY

A report published by the Bureau of Mines described the technology of copper mining, recovery, and fabrication.[5] Another publication described development of mining methods that resulted in a caving method with improved efficiency in mining operations over a long productive period.[6] The report outlined early prospecting and exploration of the deposit, methods of sampling and estimating ore reserves, and early mining methods, especially those that influenced developments in a caving method. Relationships between drilling cost and desired precision of the estimate of grade of ore were used to determine economic drill-hole spacing.[7] Assay data from approximately 50 copper deposits were studied, and drilling requirements for various precisions of estimates of grade were computed for some of the deposits. Results obtained by a study of removing copper cladding or attachments from steel were published.[8] Testing copper-clad steel in a muffle furnace in an airstream at high temperatures indicated the possibility of removing light-gage copper coatings and components from copper scrap by oxidation in an incineration process.

The Geological Survey publications described the geology of the Battle Mountain District in Humboldt and Lander Counties, Nev.[9] Mining activity was revived recently in the district when development of open pit copper-mining operations began.

Two publications described deposition of massive sulfide deposits in Canada[10] The first paper discussed masses of pyritic copper and zinc ores entrapped along contact zones between two volcanic groups in the Matagami area. The sulfides were deformed and intruded by folded dikes. According to the second paper, the cupreous deposits in Cyprus have many similarities to massive copper-zinc deposits in Canada.

Mixing and placing concrete for use in ground support at San Manuel has developed from a small operation using a ½-cubic-yard mixer into which cement was dumped from sacks opened by hand into an automated mixing plant and underground remixing station.[11] The automated mixing plant was operated by one man located in a central position.

The growth of the copper-mining industry in the Soviet Union in the past 40 years was reported.[12] The report contained several tables on production from various mines, smelting capacity in the U.S.S.R., and results of beneficiation and reduction plants. Although technological level remained below that of the United States, a well organized group of scientists was developed since the early 1930's.

The Geological Survey of Canada investigated the geology, geophysics, and origin of the ore body of the Coronation mine, Saskatchewan. The mine is about 14 miles southwest of Flin Flon, Manitoba.[13] Numerous specimens of cores from diamond drill holes were examined microscopically. Mineralogical cross sections of ore bodies were prepared from the analysis for a study of ore deposition.

Metallurgical processes to obtain maximum copper from ore produced from the Chambishi mine were described as the

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[5] Work cited in footnote 2.

[6] Hardwick, W. R. Block-Caving Copper Mining Methods and Costs at the Miami Mine, Miami Copper Company, Gila County, Ariz. BuMines Inf. Circ. 8271, 1965, 96 pp.

[7] Hewlett, Richard F. Design of Drill-Hole Grid Spacings for Evaluating Low-Grade Copper Deposits. BuMines Rept. of Inv. 6634, 1965, 46 pp.

[8] Leary, P. J. Removing Copper from Copper-Clad Steel by Oxidation. BuMines Rept. of Inv. 6647, 1965, 12 pp.

[9] Roberts, Ralph J. Stratigraphy and Structure of the Antler Peak Quadrangle, Humboldt and Lander Counties, Nev. Geol. Survey Prof. Paper 459–A, 1964, 93 pp.

Roberts, Ralph J., and D. C. Arnold. Ore Deposits of the Antler Peak Quadrangle, Humboldt and Lander Counties, Nev. Geol. Survey Prof. Paper 459–B, 1965, 94 pp.

[10] Sharpe, John I. Field Relations of Matagami Sulphides Masses and Their Deposition in Time and Space. Canadian Min. and Met. Bull. (Montreal), v. 58, No. 641, September 1965, pp. 951–963.

Hutchinson, R. W. Genesis of Canadian Massive Sulphides Reconsidered by Comparison with Cyprus Deposits. Canadian Min. and Met. Bull. (Montreal), v. 58, No. 641, September 1965, pp. 972–986.

[11] Seaney, H. W., and R. L. Tobie. Concreting at the San Manuel Mine. Min. Eng., v. 17, No. 11, November 1965, pp. 70–73.

[12] Sutulov, Alexander. Why Russia's Copper Industry Has Top Priority for Major Expansion. Min. World, v. 19, No. 10, September 1965, pp. 64–69.

[13] Gilliland, J. A. A Proposed Ore Control at the Coronation Mine, Saskatchewan. Canadian Min. and Met. Bull. (Montreal), v. 58, No. 637, May 1965, pp 522–529.

most complex of any on the Copperbelt.[14] Research and pilot plant testing proved that two leaching processes and two flotation processes were necessary for optimum copper recovery. Fine oxide ore, minus 100 mesh, was given an agitation leach and the coarse oxide fraction, minus 3/8 inch plus 100 mesh, was treated by batch percolation. Maximum recovery of sulfide minerals could be achieved by producing two concentrates.

A process was developed to leach copper ore with cyanide and recovering copper from cyanide solutions.[15] Previous methods of leaching copper in low-grade ore and tailing by cyanide were unsuccessful because leaching time was high and reagent consumption was too expensive. In the tests, leaching time was reduced from 48 hours to 4 hours or less, inorganic and organic cyanide were used as extractants, and soluble sulfides were used as precipitants.

Research was conducted on the recovery of copper from dilute solutions with liquid ion exchange reagents.[16] The process consisted of two stages—extraction and stripping. Organic solutions containing the chemical extractant and copper-bearing leach solutions were mixed and agitated vigorously in tanks. The copper content of the organic solution increased as it moved through the tanks and aqueous raffinate—liquor without copper—was withdrawn from the tanks and either recirculated through leach piles or treated for waste disposal.

Flotation characteristics of oxide copper minerals, malachite, azurite, and cuprite have not presented the difficulty for concentration as have those of chrysocolla, the copper silicate.[17] Pure chrysocolla was floated with chelating agents that form insoluble complexes with copper at ambient temperatures. Complete flotation was obtained with potassium octyl hydroxamate as collector at pH6. Flotation of a natural ore using 0.4 pound of the same material per ton of ore recovered 76 percent of the copper in a concentrate containing 31.6 percent copper.

The environmental and nutritional characteristics necessary for maximum copper extraction from low-grade ore by a strain of microorganisms was explored, as have many of the limiting parameters.[18] Percolator tests conducted under optimum conditions resulted in a significant increase in the quantity of copper microbially extracted over that extracted under conditions considered to be standard.

Results of studies of production of magnetite (Fe_3O_4) in copper smelting were discussed.[19] An inductance bridge magnetite meter was developed to overcome the unreliability of conventional wet chemical magnetite analysis. It was concluded that the solubility of ferrosoferric (Fe_3O_4) in copper smelting slag is nil at 700°C and below; the meter method of magnetite analysis provides a satisfactory means of determining the amount of magnetite in the slag; magnetite is not the only magnetic compound present in copper smelter matte, reverberatory walls, and hearth accretions; the accretions on walls and bottoms of reverberatory furnaces consist of a mixture of magnetic ompounds of which magnetite is a minor constituent.

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[14] Mining and Minerals Engineering (London). First Copper From Chambishi. V. 1, No. 10, June 1965, pp. 370–375.

Skillings' Mining Review. R.S.T.'s New Chambishi Open Pit Mine, Zambia. V. 54, No. 44, Oct. 30, 1965, p. 6.

[15] Lower, George W. (assigned to American Cyanamide Co., Stamford, Conn.). Leaching of Copper from Ores with Cyanide and Recovery of Copper from Cyanide Solutions. U.S. Pat. 3,-189,435, Dec. 1, 1964.

Lower, George W., and Robert B. Booth. Recover of Copper by Cyanidation. Min. Eng., v. 17, No. 11, November 1965, pp. 56–60.

[16] Chemical & Engineering News. New Ion Exchange Resin for Solvent Extraction Increases Copper Recovery. V. 43, No. 42, Oct. 18, 1965, pp. 48–49.

[17] Peterson, H. D., M. C. Fuerstenaw, R. S. Pickard, and J. D. Miller, Chrysocolla Flotation by the Formation of Insoluble Surface Chelates. Trans. AIME, v. 232, 1965.

[18] Corrick, John D., and J. A. Sutton. Copper Extraction From a Low-Grade Ore by Ferrobacillus Ferrooxidans: Effect of Environmental and Nutritional Factors. BuMines Rept. of Inv. 6714, 1965, 21 pp.

[19] Legasacchi, Attelio. A Study of Magnetite and Magnetic Compounds in Copper Reverberatory Smelting. Trans. AIME, v. 233, No. 10, 1965, pp. 1848–1856.

Diatomite

By Benjamin Petkof [1]

The United States continued to dominate world diatomite production. Domestic production and valuation rose almost 11 percent in quantity and about 9 percent in value. Based on the 3-year production total, an average of 580,000 tons of material was produced in 1965.

DOMESTIC PRODUCTION

California was the largest domestic diatomite producer. Nevada followed by Washington, Arizona, and Oregon supplied smaller quantities.

Cyprus Mine Corp. acquired the Aquafil Company diatomite assets in Nevada consisting of two diatomaceous earth deposits containing a proven reserve of 2.5 million tons, and a processing plant near Reno, Nev.

Table 1.—Diatomite sold or used by producers in the United States, 3-year totals [1]

	1948–50	1951–53	1954–56	1957–59	1960–62	1963–65
Domestic production (sales) short tons	722,670	908,448	1,105,279	1,349,340	1,446,625	1,740,833
Average value per ton	$25.55	$29.97	$39.21	$45.73	$50.08	$50.40

[1] Annual figures are company confidential.

CONSUMPTION AND USES

Diatomite's primary use continued to be filtration; the quantity used for this purpose increased 4 percent over that of 1964. Filler grade consumption decreased 7 percent from that of 1964, while the quantity used for insulation increased 50 percent. Diatomite for miscellaneous uses increased by 33 percent, revealing a growing use pattern. Miscellaneous uses included applications such as abrasives, absorbents, insecticides, lightweight aggregates, paints, pozzolans, and soil conditioners.

[1] Commodity specialist, Division of Minerals.

Table 2.—Domestic consumption of diatomite, by principal use, in percent of total consumption

Use	1961	1962	1963	1964	1965
Filtration	48	48	47	47	44
Fillers	24	23	23	r 24	20
Insulation	5	5	5	r 4	6
Miscellaneous	23	24	25	25	30

r Revised.

PRICES

Diatomite prices varied from those of the previous year, increasing slightly for material used for filtration and fillers, and decreasing for insulation, abrasives, and miscellaneous uses.

Table 3.—Average annual value per ton of diatomite, by uses

Use	1964	1965
Filtration	$61.92	$62.97
Insulation	51.66	41.54
Abrasives	137.00	135.00
Fillers	47.37	55.89
Miscellaneous	32.39	28.72
Weighted average	50.62	49.94

Table 4.—U.S. exports of diatomite

Year	Short tons (thousand)	Value (thousand)
1958	60	$4,234
1959	71	5,051
1960	92	6,479
1961	95	6,807
1962	109	7,960
1963	112	8,446
1964	128	9,659
1965	114	9,752

FOREIGN TRADE

Diatomite was exported from the United States throughout the world. This material is probably used mainly for filtration.

Most of the 176 short tons of diatomite imported was from Canada. The average value was $52.35 per ton.

WORLD REVIEW

The United States led world production. Other principal free world producers were France, West Germany, Italy, and Denmark.

Iceland.—The Government has continued its plans to develop the high-grade diatomite deposits at Lake Myvatn. Discussions have taken place with Johns-Manville Corp. of New York, and a joint venture is indicated.[2]

[2] Bureau of Mines. Mineral Trade Notes. V. 61, No. 6, December 1965, p. 14.

Table 5.—World production of diatomite, by countries [1]
(Short tons)

Country	1961	1962	1963	1964	1965 p [2]
North America:					
Canada	214	211	798	r 1,143	1,200
Costa Rica	717	827	e 2,000	e r 4,000	e 4,000
Nicaragua	2,976	1,414	e 1,760		
United States	r [3] 482,208	r [3] 482,208	r [4] 580,278	r [4] 580,278	[4] 580,278
South America:					
Argentina	r 3,833	r 3,741	r 6,256	r 8,567	[5] 8,567
Colombia	330	165	2,425	r 255	[5] 255
Peru	2,048	1,624	r 2,733	r 2,756	[5] 2,756
Europe:					
Austria	5,993	4,613	4,339	r 4,224	e 4,590
Denmark:					
Diatomite e	21,500	22,000	22,000	r 20,393	[5] 20,393
Moler e [6]	212,900	230,800	212,000	210,762	e 125,000
Finland	805	1,320	2,535	r 2,392	[5] 2,392
France [7]	118,429	140,093	r 146,304	e r 146,600	e 146,600
Germany, West (marketable) [7]	72,200	67,800	r 47,289	r 109,356	e 55,120
Italy	63,050	r 62,379	r 65,509	e r 66,140	e 66,140
Portugal [7]	847	1,598	2,067	r 2,207	[5] 2,207
Spain [7]	19,346	13,352	11,229	e 11,000	e 11,000
Sweden (marketable) [8]	732	252	r 400	r 220	[5] 220
U.S.S.R. e	330,000	330,000	340,000	340,000	350,000
United Kingdom	24,920	r 22,412	r 15,946	e r 16,540	e 16,540
Yugoslavia	e 5,000	5,000	e 11,600	e 11,600	e 11,600
Africa:					
Algeria	35,213	30,565	19,401	r 22,489	[5] 22,489
Kenya	3,537	3,207	3,677	r 3,368	[5] 3,368
Mozambique	397	385			
Rhodesia, Southern [7]	409	423	301	347	e 530
South Africa, Republic of	137	647	220	r 546	e 1,090
United Arab Republic (Egypt)	332	55	r 916	r 44,080	80,375
Asia: Korea, South	1,989	758	r 1,916	r 41,031	e 490
Oceania:					
Australia	6,067	8,189	6,533	r 9,780	e 2,760
New Zealand	3,961	2,099	1,796	r 1,881	[5] 1,881
World total	1,645,000	1,665,000	1,740,000	1,890,000	1,750,000

e Estimate. p Preliminary. r Revised.
[1] Diatomaceous earth is produced in Brazil, Bulgaria, and Japan, but data on output are not available, estimates are included in total. Hungary and Rumania may produce diatomaceous earth but data are not available and no estimates are included in total.
[2] Compiled mostly from data available April 1966.
[3] Average annual production 1960–62.
[4] Average annual production 1963–65.
[5] 1964 data.
[6] Data represents estimates of moler earth used as a raw material in making refractory bricks plus moler earth exported in bulk form.
[7] Includes tripoli.
[8] Includes calcined.

TECHNOLOGY

Diatomite deposits of Maryland and Virginia were described and discussed in two papers.[3] The mining history of the deposits was reviewed. Limited additional testing was described, and recommendation was made for possible use. One paper recognized that these deposits are inferior to western deposits, but indicated that might substitute for materials such as fuller's earth and activated bentonite.

Experimental work was conducted to determine the toxicity of diatomite in white rats. The rats were fed a diet containing 5 percent diatomite for 90 days. No effect was observed on the animals, and residual silica did not increase in the body organs. The growth rate of the test rats was greater than the control group. Additional tests using smaller quantities of diatomite were made.[4]

A report was published reviewing municipal use of diatomite filters. Specifications were presented on diatomite filter aids, filter, and filter components, and design procedure recommendations were made.[5]

The city of Lompoc, Calif., has made improvements to its municipal water supply system and has incorporated diatomite filters in its system.[6]

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[5] Journal American Water Works Association. Municipal Use of Diatomite Filters. Task Group Report. V. 57, No. 2, February 1965, pp. 157–180.

[6] Lawrance, Charles H. Quality Improvement for Lompoc, Calif., J. Am. Water Works Assoc., v. 57, No. 5, May 1965, pp. 607–624.

Feldspar, Nepheline Syenite, and Aplite

By J. Robert Wells [1]

FELDSPAR

Production of feldspar in the United States, under the impulse of three substantial annual increases in succession, reached a level in 1965 that was well beyond that of 1964 and the highest yet recorded. The glass industry, largely because of sustained growth in automobile production but also to satisfy the continuing high demand for all types of glass products, consumed 5 percent more feldspar than in 1964. The transition to no deposit, no return bottles for soft drinks was an expansive influence just beginning to be felt. About 8 percent less feldspar was used for pottery manufacture than in 1964.

DOMESTIC PRODUCTION

Crude Feldspar.—North Carolina, the primary producing State for more than two decades, and California, in second place for many years, provided almost two thirds of the total domestic supply of crude feldspar. Connecticut and Georgia, likewise continuing the production pattern of recent years, ranked third and fourth, respectively, in feldspar output. As in 1963 and 1964, more than 90 percent of the North Carolina feldspar was produced as flotation concentrate.

[1] Commodity specialist, Division of Minerals.

Table 1.—Salient feldspar statistics

	1956–60 (average)	1961	1962	1963	1964	1965
United States:						
Crude:						
Sold or used by producers ____long tons__	515,728	496,808	492,476	548,954	587,194	624,598
Value__thousands__	$5,039	$5,120	$5,076	$5,524	$5,389	$6,263
Average value per long ton__	$9.77	$10.31	$10.31	$10.06	$9.18	$10.03
Imports for consumption_______long tons__	98	24	33	68	10	16
Value__thousands__	$6	$2	$1	$2	$1	$2
Average value per long ton__	$60.87	$84.38	$39.55	$23.29	$84.00	$95.00
Consumption, apparent [1] long tons__	515,826	496,832	492,509	549,022	587,204	624,614
Ground:						
Sold by merchant mills short tons__	533,977	541,626	527,347	598,706	646,974	664,138
Value__thousands__	$7,459	$6,694	$6,703	$7,353	$7,644	$7,757
Average value per short ton__	$13.97	$12.36	$12.71	$12.28	$11.82	$11.68
Imports for consumption long tons__	4,813	2,529	3,297	3,006	3,170	3,439
Value__thousands__	$78	$63	$87	$81	$85	$92
Average value per long ton__	$16.29	$24.86	$26.45	$26.88	$26.95	$26.87
World: Production___long tons__	1,286,000	1,600,000	1,600,000	1,710,000	1,815,000	1,900,000

[1] Measured by quantity sold or used by producers plus imports.

Table 2.—Crude feldspar sold or used by producers in the United States

Year	Derivation of feldspar [1]							
	Hand-cobbed		Flotation concentrate		Feldspar-silica mixtures [2]		Total	
	Long tons	Value (thousands)	Long tons	Value (thousands)	Long tons	Value (thousands)	Long tons	Value (thousands)
1956–60 (average)	195,733	$1,533	249,866	$2,867	70,129	$639	515,728	$5,039
1961	116,503	788	307,468	3,580	72,837	752	496,808	5,120
1962	113,168	783	324,462	3,806	54,846	487	492,476	5,076
1963	93,488	643	364,676	3,885	90,790	996	548,954	5,524
1964	88,046	804	r 380,787	r 3,367	118,361	1,218	r 587,194	r 5,389
1965	126,811	1,072	369,585	3,974	128,202	1,217	624,598	6,263

r Revised. [1] Partly estimated. [2] Feldspar content.

Table 3.—Ground feldspar sold by merchant mills [1] in the United States

Year	Mills	Domestic feldspar	
		Short tons	Value (thousands)
1956–60 (average)	24	[2] 533,977	[2] $7,459
1961	21	541,626	6,694
1962	21	527,347	6,703
1963	22	598,706	7,353
1964	20	r 646,974	r 7,644
1965	20	664,138	7,757

r Revised.
[1] Excludes potters and others who grind for consumption in their own plants.
[2] Includes Canadian feldspar, 1958–60.

Minerals & Chemicals Philipp Corp. announced tentative plans for the purchase of Georgia Marble Co., whose Consolidated Quarries Division produces silica-feldspar concentrate in Georgia for glass manufacture. Federal Geological Survey engineers, investigating California zeolites, discovered a potentially valuable source of high-grade potash feldspar in the Mojave Desert near Barstow in San Bernardino County.

Ground Feldspar.—In 1965, 20 mills produced ground feldspar in 11 States. Sales of ground material by merchant mills were higher, 3 percent in volume and 2 percent in value, than in 1964. North Carolina, California, Connecticut, and Georgia were also foremost in production of ground feldspar with a combined output of 81 percent of the total.

Table 4.—Ground feldspar sold by merchant mills in the United States, by derivation [1] and uses

(Short tons)

Year	Glass	Pottery	Enamel	Other	Total	Glass	Pottery	Enamel	Other	Total
	Hand-cobbed					Flotation concentrate				
1956–60 (average)	47,910	97,528	26,173	22,109	193,720	189,425	66,683	[2] 263	13,539	269,910
1961	23,248	56,875	17,160	26,083	123,366	232,365	88,170	4,012	12,135	336,682
1962	26,323	45,612	W	45,650	117,585	215,941	96,828	W	35,605	348,374
1963	6,863	58,497	W	39,128	104,488	240,783	W	W	151,777	392,560
1964	W	51,703	W	45,952	97,655	255,907	W	W	[r] 163,548	[r] 419,455
1965	W	32,535	W	75,055	107,590	256,000	W	W	162,014	418,014
	Feldspar-silica mixtures [3]					Grand total [4]				
1956–60 (average)	59,017	3,192	[2] 483	7,655	70,347	296,352	167,403	26,919	43,303	533,977
1961	65,950	6,983	------------	8,645	81,578	321,563	152,028	21,172	46,863	541,626
1962	50,993	4,726	------------	5,669	61,388	293,257	147,166	27,391	59,533	527,347
1963	65,541	W	------------	36,117	101,658	313,187	195,510	24,068	65,941	598,706
1964	W	W	------------	129,864	129,864	349,715	[r] 189,853	21,925	85,481	[r] 646,974
1965	W	W	------------	138,534	138,534	368,120	174,537	42,268	79,213	664,138

[r] Revised.
W Withheld to avoid disclosing individual company confidential data; included with "Other."
[1] Partly estimated.
[2] Average for 1960 only.
[3] Feldspar content.
[4] "Other" includes soaps, abrasives, and other ceramic and miscellaneous uses.

CONSUMPTION AND USES

Crude Feldspar.—Almost all crude feldspar is subjected to some processing before being sold or used in industry, although some manufacturers continued their established custom of buying minor amounts in the as-mined condition for supervised treatment in their own grinding mills.

Ground Feldspar.—The glass, pottery, and enamel industries, taken together, consumed 88 percent of the ground feldspar produced in the United States in 1965. Glass manufacture absorbed 55 percent of the total quantity of ground feldspar sold, an increase of 18,000 tons from 1964 when the proportion was 54 percent. Of all the ground feldspar sold in 1965, pottery making consumed 26 percent and enamel manufacture 6 percent, 15,000 tons less and 20,000 tons more, respectively, than in 1964.

California, Ohio, Illinois, New Jersey, and Tennessee, in that order, were the States that led in ground feldspar consumption in 1965, accounting collectively for 54 percent of the total quantity sold.

Consumption of feldspar and nepheline syenite as fillers in foam latex products, a substantial new application established in the last 5 years, was at a rate of approximately 30,000 tons per year.

Table 5.—Ground feldspar shipped from merchant mills in the United States

(Short tons)

Destination	1961	1962	1963	1964	1965
California	99,149	79,075	78,164	120,804	111,174
Illinois	55,815	46,283	49,822	73,967	66,160
Indiana	39,700	19,139	20,688	20,998	W
Maryland	14,092	11,748	11,636	W	W
Massachusetts	6,235	4,603	4,231	4,407	4,787
New Jersey	38,245	53,640	62,336	58,089	57,096
New York	16,850	21,696	23,631	22,117	26,037
Ohio	67,304	76,287	122,242	80,119	87,873
Pennsylvania	55,947	34,843	40,567	37,805	30,281
Texas	22,994	22,502	W	W	W
West Virginia	27,384	W	18,714	26,638	W
Wisconsin	8,727	W	W	W	W
Other destinations [1]	89,184	157,531	166,675	r 202,030	280,730
Total	541,626	527,347	598,706	r 646,974	664,138

r Revised.
W Withheld to avoid disclosing individual company confidential data; included with "Other destinations."
[1] Includes Alabama (1961–62); Arkansas; Colorado; Connecticut; Florida (1961); Georgia (1963–65); Hawaii (1961); Idaho (1965); Kentucky; Louisiana; Michigan; Minnesota; Mississippi; Missouri; Oklahoma; Rhode Island; Tennessee; South Carolina (1962–65); Vermont (1962–65); Washington (1961–62 and 1964); shipments that cannot be separated by States; and shipments indicated by symbol W. Also includes exports to Africa (1965); Canada; Colombia (1961); England (1962); Mexico; Panama; Philippines (1963–64); Venezuela (1961–63); and small quantities to other countries.

PRICES

Average prices reported to the Bureau of Mines for crude and ground feldspar in 1965 are shown in table 1. The value per ton of feldspar in feldspar-silica mixtures and that of the hand-cobbed material both declined in 1965, but there was a notable increase in the average unit value of flotation concentrate feldspar.

Illinois reported the highest average price for ground feldspar in 1965, $26.09 per short ton. New Hampshire followed with $21.36, and Virginia was third with $20.36. The grade of ground feldspare commanding the highest average price, $20.37 per ton, was that used for enamel manufacture.

Ground feldspar prices quoted in E&MJ Metal and Mineral Markets for November 15, 1965, all somewhat higher than the corresponding 1964 quotations, were as follows: North Carolina, bulk, 20 mesh granular $10 to $12.50 per ton; 40 mesh glass grade $13.50 to $15 per ton; 200 mesh $17.50 to $21 per ton; and 325 mesh $18.50 to $23 per ton.

STOCKS

Feldspar producers maintained working stocks only.

FOREIGN TRADE

According to information supplied to the Bureau of Mines by feldspar grinders, 1965 exports of feldspar exceeded those of 1964

Table 6.—U.S. imports for consumption of feldspar [1]

Year	Crude Long tons	Crude Value	Ground Long tons	Ground Value
1956–60 (average)	98	$5,965	4,813	$78,419
1961	24	2,025	2,529	62,859
1962	33	1,305	3,297	87,205
1963	68	1,584	3,006	80,795
1964	10	840	3,170	85,434
1965	16	1,513	3,439	92,399

[1] All from Canada, except 39 long tons ($1,724) of ground feldspar from Norway in 1963 and 30 long tons ($1,255) in 1964, and 1 long ton ($1,460) from Republic of South Africa in 1965.

by 13 percent. This material was shipped to destinations in Canada and Mexico. No crude or ground Cornwall stone was imported in 1965.

WORLD REVIEW

World-wide production of feldspar in 1965, almost 5 percent more than in 1964, marked a new alltime high. The U.S. share of world feldspar output in 1965 was about 33 percent, compared with 32 percent in 1964. In Finland, Lohjan Kalkkitehdas Oy started construction of a new concentrator designed to yield 50,000 tons of feldspar annually. Materiales Monterrey, S.A., proposed to spend $1.6 million for a new plant in the Mexican State of Guanajuato for processing several nonmetallic minerals, including feldspar. In the Somali Republic, feldspar was listed among the minerals existing there but not yet being exploited.

The Rhodesian Department of Mines and Lands reported plans for a custom mill to grind feldspar and other ceramic raw materials for local industrial use.

Table 7.—World production of feldspar by countries [1]

(Long tons)

Country	1961	1962	1963	1964	1965 p [2]
North America:					
Canada (shipments)	9,381	8,923	7,686	r 8,169	9,670
United States (sold or used)	496,808	492,476	548,954	r 587,194	624,598
South America:					
Argentina	11,474	r 7,245	r 12,599	r 6,390	e 7,000
Brazil e	39,000	39,000	39,000	39,000	39,000
Chile	2,280	1,138	417	r 814	408
Colombia	14,800	15,250	12,300	11,426	14,600
Peru	992	287	r 217	837	926
Uruguay	877	692	282	r 883	1,227
Europe:					
Austria	3,907	4,976	2,077	1,603	1,397
Finland	13,303	14,921	12,618	10,561	11,685
France	170,470	170,194	170,764	r 193,260	e 190,000
Germany, West	265,450	269,770	r 273,610	278,355	329,968
Italy	r 93,228	r 98,367	r 100,487	r 106,905	90,803
Norway	68,895	54,100	65,000	65,300	67,900
Poland	NA	NA	26,300	e 26,300	e 26,300
Portugal	2,892	3,674	396	r 10,994	e 5,000
Spain	8,194	10,728	12,401	r 16,466	e 15,000
Sweden	55,868	53,348	44,920	r 50,785	e 50,000
U.S.S.R. e	195,000	195,000	195,000	195,000	195,000
Yugoslavia	20,215	31,578	29,413	r 33,260	e 34,400
Africa:					
Angola	-------	-------	796	493	e 500
Eritrea	2,953	425	e 490	e 9,800	-------
Ethiopia	-----	-------	-------		-------
Malagasy Republic	13	-------	(3)	r 1	(3)
Rhodesia, Southern	-------	-------	-------	-------	e 167
South Africa, Republic of	23,290	28,209	41,372	35,525	41,636
South-West Africa	89	465	2,197	1,893	2,281
United Arab Republic (Egypt)	-------	-------	-------	4,653	e 5,000
Asia:					
Ceylon	106	56	109	4	605
Hong Kong	1,206	937	1,680	1,556	1,119
India	9,706	18,918	r 20,901	19,781	23,829
Japan [4]	50,986	46,991	53,339	r 61,445	e 61,000
Korea, Republic of	r 7,520	4,651	11,392	r 13,468	e 15,000
Pakistan, West	NA	55	1,520	48	e 1,000
Philippines	14,526	15,325	6,564	7,924	12,095
Oceania: Australia	8,209	8,513	8,842	r 9,012	e 8,400
World total e	r 1,600,000	r 1,600,000	r 1,710,000	r 1,815,000	1,900,000

e Estimate. p Preliminary. r Revised. NA Not available.

[1] Feldspar is produced in China, Czechoslovakia, and Rumania, but data are not available; no estimates included in total except for Czechoslovakia.

[2] Compiled mostly from data available June 1966.

[3] Less than ½ unit.

[4] In addition, the following quantities of aplite and other feldspathic rock were produced: 1961, 132,041 tons; 1962, 168,543 tons; 1963, 211,814 tons; 1964, 258,510 tons; 1965, not available.

TECHNOLOGY

In North Carolina, the State Minerals Research Laboratory completed 3 years of research in quest of processes for recovering as salable products all the minerals—feldspar, mica, quartz, and clay—contained in waste materials, the slime and sand tailings from the Kings Mountain mill of Kings Mountain Silica, Inc., an affiliate of Kings Mountain Mica Co.[2]

A study of 21 samples of feldspar-bearing Illinois sands reported the varieties and amounts of feldspar present and the nature and amount of the accompanying iron impurity. Various processes were discussed as possibly applicable for separating feldspar from these sands and for yielding a product acceptably low in iron content.[3]

Feldspar, amounting to more than 60 tons per day, usually makes up one-third or more of the weight of batches of ceramic materials used by The Ohio Brass Co. in its Barberton, Ohio, plant for the production of porcelain insulators. A detailed account of this highly mechanized process was published, together with information about the methods by which it is controlled.[4]

[2] North Carolina State Minerals Research Laboratory. Quart. Bull. V. 6, No. 3, Aug. 1, 1964 to Jan. 1, 1965.

[3] Hunter, Ralph E. Feldspar in Illinois Sands: A Further Study. Illinois State Geol. Survey Circ. 391, 1965, 19 pp.

[4] Ceramic Age. Porcelain Insulator Production. V. 81, No. 7, July 1965, pp. 34–39.

A machine developed in England separates pea- to walnut-size lumps of mixed minerals. For example it removes waste rock from feldspar by photoelectric monitoring of a falling stream of the material. Whenever it detects a fragment that deviates too widely from a preset color standard, the device actuates a momentary air blast to deflect it from the main stream into a discard channel. One operator can look after several units, each of which can treat about 50 tons of ore a day.[5]

The Porcelain Enamel Institute, Inc., and the National Bureau of Standards, in a continuing colloboration, have devised and appraised a number of quick tests for estimating the weather resistance of porcelain enamels, in the formation of which feldspar is commonly an important component. For enameled metal panels results are obtained in minutes or hours that correlate well with those from actual weathering tests that lasted many years. A cupric sulfate procedure provides a good measure of the color fastness of pigmented panels, while an even quicker citric acid spot test rates the gloss retaining characteristics of white enamels. Tests involving prolonged real exposure showed that weather resistance of enamels is related to their acid resistance, and most acid-resistant glossy enamels retained better than 90 percent of their original gloss after 15 years.[6]

A process for coating metal surfaces with extremely fine ceramic powders, in which feldspar is a usual ingredient, was described. In this method, an adaptation of one developed for coating paper, the powders are applied dry and adhere to metals—stainless or ordinary steel, copper, brass, or aluminum—by electrostatic or molecular forces until fired. The process is advantageous for forming extraordinarily thin ceramic coatings that are highly flexible and can withstand bending through 90 degrees or more without cracking. The process also makes possible composite coatings consisting of a series of thin layers of differing compositions.[7]

Results were published of a study inquiring into the mechanism of the activation by fluorides of such silicates as feldspar and beryl for flotation with a cationic collector. It was concluded that certain fluorine compounds can produce this effect by removing silicic acid from the mineral particle surfaces thus exposing active aluminum sites to the influence of the collecting agent.[8]

Refractories with a cellular structure are formed by a patented process in which a mixture of feldspar with silicon carbide and a flux is fired on a noncellular refractory base to develop the desired texture.[9]

A patent was issued for the composition of an enamel consisting of iron furnace slag and borax mixed with up to 45 percent of an aluminosilicate material such as feldspar. The same patent covers a method by which this enamel can be applied directly to cast iron pipe without need for preliminary treatment to remove the surface oxidation.[10]

Patents were also issued for a flotation reagent mixture [11] and for a flotation process,[12] both applicable for the beneficiation of certain feldspar ores.

A fluid energy system was patented for grinding feldspar or other minerals with minimum generation of static electricity.[13] A ceramic glaze, consisting mainly of feldspar and ferric oxide and rendered semiconductive to a predetermined extent by addition of silver, was the subject of a British patent.[14]

[5] Mining Journal (London). New Electronic Machine for Separating Mineral Particles. V. 265, No. 6790, Oct. 8, 1965, p. 254.
[6] Kirby, C. K. Weathering of Porcelain Enamel Finishes. Product Eng., v. 36, No. 3, Feb. 1, 1965, pp 81–86.
[7] Metal Bulletin (London). Ceramic-Coated Metals. No. 5002, June 1, 1965, p. 17.
[8] Smith, R. W. Activation of Beryl and Feldspars by Fluorides in Cationic Collector Systems. Trans. Soc. Eng., v. 232, No. 2, June 1965, pp. 160–168.
[9] Connelly, J. H., and R. V. Harrington (assigned to Corning Glass Works, Corning, N.Y.). Foamed Cellular Body and Method of Production. U.S. Pat. 3,174,870, Mar. 23, 1965.
[10] Gottfredson, M. E., and R. O. Pabst (assigned to Pacific States Cast Iron Pipe Co., Provo, Utah). Enameling Composition and Method of Application. U.S. Pat. 3,178,323, Apr. 13, 1965.
[11] Bunge, F. H., R. F. Baarson, and H. B. Treweek (assigned to Armour & Co., Chicago, Ill.). Separating Finely-Divided Minerals. U.S. Pat. 3,179,250, Apr. 20, 1965.
[12] Neal, J. P. (assigned to The Feldspar Corp., Spruce Pine, N.C.). Froth Flotation of Micaceous Minerals. U.S. Pat. 3,214,018, Oct. 26, 1965.
[13] Mandle, R. M., and T. O. Tongue (assigned to W. R. Grace & Co., New York). Fluid Energy Mill. U.S. Pat. 3,186,648, June 1, 1965.
[14] Mrackova-Metlicka, A. British Pat. 988,296, Apr. 14, 1965.

NEPHELINE SYENITE

In 1965 domestic production of nepheline syenite was confined to exploitation of a deposit in Pulaski County, Ark., and yielded material too high in iron for ceramic purposes but suitable for use as roadstone, ballast, roofing gradules, and the like. Data pertaining to this material are included in the Stone chapter of Vol. I and in the Arkansas chapter of Vol. III of the Minerals Yearbook. A record quantity of high-grade nepheline syenite was imported from Canada in 1965 for industrial use, especially for glass making in the northeastern United States.

Canadian output of this mineral in 1964, the last year for which firm data are available, was about 290,000 tons, valued at about $3.0 million. Exports, preponderantly to the United States, accounted for 79 percent of the tonnage and 87 percent of the value of the 1964 production. Preliminary information pointed to a 1965 production of about 330,000 tons.

In 1965, glass-grade nepheline syenite, f.o.b. plant, Ontario, was quoted for sale at $10.50 per short ton, an increase of $0.50 since 1964. Canadian Chemical Processing for October 1964 cited a price of $28.50 per ton for the finest ground, high-quality nepheline syenite, bagged and in carlots.

Table 8.—U.S. imports for consumption of nepheline syenite

Year	Crude		Ground	
	Short tons	Value	Short tons	Value
1956-60 (average)	374	$7,987	170,348	$2,333,504
1961	1,167	20,224	186,297	2,026,239
1962	------	------	188,833	2,084,766
1963	272	4,731	196,567	2,109,441
1964	------	------	205,695	2,320,065
1965	111	1,537	216,860	2,442,397

APLITE

The 1965 output of ground aplite, chiefly employed in the manufacture of amber glass, was 2 percent greater in quantity and 3 percent higher in total value than that of 1964. Actual quantitative production and sales data for aplite are confidential and not available for publication.

Two companies, both operating in Virginia, were the only domestic producers of aplite in 1965. M&T Chemicals, Inc., used an electrostatic process in Hanover County, and International Minerals & Chemical Corp., Consolidated Feldspar Department, treated Nelson County aplite ore by an electromagnetic method.

Ferroalloys

By John W. Thatcher [1]

The domestic ferroalloy industry improved again in 1965 as a result of continued increase in steel production and an increased demand for ferroalloys in iron foundry products, stainless and specialty steels, aluminum products, and superalloys. Total domestic production of ferroalloys, as reported to the Bureau of Mines, increased 14 percent and shipments increased 4 percent over those of 1964. Value of shipments increased 12 percent.

More detailed information concerning the more important ferroalloys covered in this chapter may be found in the commodity chapters for individual alloying elements.

Table 1.—Government inventory of ferroalloys (stockpile grade), December 31, 1965

(Short tons)

Alloy	National (strategic) stockpile	CCC and supplemental stockpile	Total
Ferrochromium:			
High-carbon	125,477	264,449	389,926
Low-carbon	106,909	188,647	295,556
Ferrochromium-silicon	25,082	30,528	55,610
Ferrocolumbium (contained columbium)	148	------	148
Ferrotantalum-columbium (contained columbium and tantalum)	52	------	52
Ferromanganese, high-carbon	142,739	919,558	1,062,297
Ferromolybdenum (contained molybdenum)	2,013	------	2,013
Ferrotungsten	676	------	676
Ferrovanadium	1,001	------	1,001

DOMESTIC PRODUCTION

In 1965, 31 producers in 17 States made 2.8 million tons of ferroalloys in 51 plants; 8 of the plants were blast furnace; 39 were electric furnace (2 of these made some ferroalloys by a thermic process); and 4 plants used only a thermic process. Ohio led production with 788,637 short tons, followed by Pennsylvania with 696,558 tons. Production was also reported from Alabama, Florida, Idaho, Iowa, Kentucky, Montana, New Jersey, New York, Oregon, South Carolina, Tennessee, Texas, Virginia, Washington, and West Virginia.

Union Carbide Corp. announced the production of a new cerium-bearing magnesium-ferrosilicon alloy for use in making ductile iron. The new alloy contains 5 percent magnesium, 47 percent silicon, and 0.5 percent cerium. Claims were made of 30-percent higher magnesium recoveries than when using the regular 9-percent magnesium grade. Also made available was a new boron-bearing 50-percent ferrosilicon containing from 0.04 to 0.10 percent boron. Marketing of this alloy was influenced by the need for higher boron levels by a substantial portion of the malleable iron industry.

[1] Commodity specialist, Division of Minerals.

Table 2.—Ferroalloys produced and shipped from furnaces in the United States

Alloy	1964 Production: Gross weight (short tons)	1964 Production: Alloy element contained (average percent)	1964 Shipments: Gross weight (short tons)	1964 Shipments: Value (thousands)	1965 Production: Gross weight (short tons)	1965 Production: Alloy element contained (average percent)	1965 Shipments: Gross weight (short tons)	1965 Shipments: Value (thousands)
Ferromanganese [1]								
Blast furnace	617,023	77.6	601,943	$82,845	810,811	77.6	831,889	$118,717
Electric furnace [2]	312,463	78.1	340,342	52,259	337,200	78.3	308,878	48,311
Total	929,486	77.8	942,285	135,104	1,148,011	77.8	1,140,767	167,028
Silicomanganese	202,857	65.9	213,566	29,970	240,667	66.0	215,411	31,985
Ferrosilicon	554,642	52.5	576,287	86,151	595,129	53.0	588,122	97,079
Silvery iron:								
Blast furnace	70,832	10.2	73,674	4,808	50,897	10.0	53,617	4,015
Electric furnace	151,749	16.0	148,880	11,946	165,909	16.0	170,634	13,662
Total	222,581	14.2	222,554	16,754	216,806	14.6	224,251	17,677
Chromium alloys:								
Ferrochromium [3]	276,404	66.9	308,421	79,217	301,511	67.9	283,736	80,461
Other chromium alloys [4]	72,694	39.6	83,819	20,094	82,966	40.8	81,217	18,098
Total	349,098	61.2	392,240	99,311	384,477	62.1	364,953	98,559
Ferrotitanium	4,231	27.2	4,157	3,480	4,324	27.3	4,066	2,641
Ferrophosphorus	115,657	23.9	211,727	5,840	127,779	24.3	139,608	5,437
Ferrocolumbium and ferro-tantulum columbium	708	57.9	862	3,210	1,676	58.5	1,613	5,903
Ferronickel	23,187	48.5	23,441	56,330	26,246	48.3	26,277	60,284
Other [5]	61,579	29.2	67,038		64,309	29.6	57,484	
Grand total	2,464,026	58.9	2,654,157	436,150	2,809,424	60.6	2,762,552	486,593

[1] Includes briquets.
[2] Includes fused-salt electrolytic.
[3] Includes low- and high-carbon ferrochromium and chromium briquets.
[4] Includes ferrochrome-silicon, exothermic chromium additives, and other chromium alloys.
[5] Includes Alsifer, ferroboron, ferromolybdenum, ferrotungsten, ferrovanadium, simanal, spiegeleisen, zirconium-ferrosilicon, ferrosilicon-zirconium, and other miscellaneous ferroalloys.

Calumet Hecla, Inc., announced that the Alabama Metalurgical Corp. was dissloved, and the plant would be operated as the Alamet Division of the company. Also announced, was the installation of a ferrosilicon facility scheduled to be in production by yearend. Alamet produces magnesium by the reduction of dolomite with ferrosilicon.

Major plant improvements effected at the Riddle, Oreg., nickel smelter of the The Hanna Mining Co. included installation of two new transformers to increase the power supplied to the electric smelting furnaces. This plant produces ferronickel by the reduction of ore with ferrosilicon.

The Stauffer Chemical Co. launched a multi-million-dollar plant improvement and modernization program at its Mt. Pleasant, Tenn. plant with special emphasis on raw material perparation. Elemental phosphorus and ferrophosphorus are recovered from phosphate rock in this plant.

Vanadium Corporation of America launched a $5 million modernization and expansion program which included construction of an electric ferroalloy furnace with a rated capacity of over 54,700 kilovolt-amperes. This facility, scheduled for completion in late 1966 or early 1967, was designed primarily for the production of silicon alloys and metal for eventual consumption in aluminum alloy and silicone products. Important parts of the expansion program were either operative or substantially complete by yearend. A second furnace was added in the J–2 unit of the company's Vancoram, Ohio, plant for the production of silicon and chromium alloys as well as silicon metal. New furnace and material-handling facilities installed at the Graham, W. Va., plant tripled the company's capacity for the production of alloys used in making ductile iron. New facilities installed at the Keokuk, Iowa, plant of the Keokuk Electro-Metals Co. (Kemco) division tripled Kemco's capacity for producing special grades of pulverized alloys used in the heavy-media process for the beneficiation of ores ranging from iron to gold. The program also included installation of furnaces and related equipment at the Cambridge, Ohio, plant for making new vanadium alloys.

Manganese Alloys.—Eleven companies produced ferromanganese in 19 plants in 10 States. Six plants were blast furnace and 13 were electric furnace. Production and shipments of the blast furnace product increased 31 and 38 percent, respectively. Production of the electric-furnace product increased 8 percent whereas shipments decreased 9 percent. The average unit value of the ferromanganese shipped from electric furnaces was 10.0 cents per pound of contained manganese, compared with 9.8 cents in 1964.

Silicomanganese was made in 7 States by 7 companies in 12 electric furnace plants. Production in 1965 increased 19 percent and shipments increased 9 percent. The average value of shipments increased to 11.3 cents from 10.6 cents per pound of contained manganese.

Production of spiegeleisen was reported for only one company, The New Jersey Zinc Co. of Palmerton, Pa.

Ferrosilicon.—Nine companies produced ferrosilicon in 20 plants in 1965. Production and shipments increased 7 and 2 percent, respectively.

Silvery Iron.—Five companies manufactured silvery iron in five electric-furnace plants and two blast furnace plants in five States. Production decreased 3 percent while shipments remained at about the 1964 level. The unit value of the blast furnace product increased from 32 cents to 37 cents per pound of contained silicon. The unit value of the electric furnace product remained unchanged at 25 cents.

Chromium Alloys.—Six companies produced ferrochromium and other chromium alloys at 11 electric furnace installations in 6 States. Production increased 10 percent; shipments decreased 5 percent. The average unit value of the contained chromium was 21.7 cents per pound compared with 20.8 cents in 1964.

Molybdenum Alloys.—Four companies produced ferromolybdenum at four plants in two States. Molybdenum Corporation of America used both the electric furnace process and the aluminothermic method; the three remaining companies used the thermic method exclusively.

Titanium Alloys.—As in 1964, four companies produced ferrotitanium at four plants in three States. One plant used the aluminothermic process and the remaining plants used electric furnaces.

Ferrophosphorus.—Seven companies made ferrophosphorus at 10 plants in 5 States. As in previous years, the ferroalloy was a byproduct of elemental phosphorus from phosphate rock. Production increased 10 percent; shipments decreased 34 percent from those in 1964 but were still larger than 1965 production.

Ferrocolumbium and Ferrotantalum-Colombium.—Five companies reported production of ferrocolumbium at facilities located in four States. Three plants used the electric furnace and three used the aluminothermic process. Two companies reported production of ferrotantalum-columbium in 1965. Combined shipments of the two alloys doubled in 1965 while combined production more than doubled. Average unit value of $3.13 per pound of contained columbium was 2 percent lower from that of 1964.

Ferronickel.—Hanna Nickel Smelting Co., Riddle, Oreg., continued to be the only ferronickel producer.

Vanadium Alloys.—Four companies made ferrovanadium at two electric furnace plants and three aluminothermic plants in five States.

Zirconium Alloys.—Two companies reported production of zirconium alloys in 1965.

Ferroboron.—Four companies produced ferroboron in three electric furnace plants and one aluminothermic facility.

Table 3.—Producers of ferroalloys in the United States in 1965

Producer	Plant location	Product [1]	Type of furnace
The American Agricultural Chemical Co	Pierce, Fla	FeP	Electric
The Anaconda Company	Anaconda, Mont	FeMn	Do
Bethlehem Steel Co	Johnstown, Pa	FeMn	Blast
Chromium Mining and Smelting Corp	Woodstock, Tenn	FeMn, SiMn, FeSi, FeCr	Electric
Climax Molybdenum Co	Langeloth, Pa	FeMo	Aluminothermic
FMC Corp., Mineral Products Division	Pocatello, Idaho	FeP	Electric
The Hanna Furnace Corp	Buffalo, NY	Silvery iron	Blast
Hanna Nickel Smelting Co	Riddle, Oreg	FeSi, FeNi	Electric
Hooker Chemical Corp	Columbia, Tenn	FeP	Do
Interlake Steel Corp [2]	Beverly, Ohio	SiMn, FeSi, FeCr, silvery iron, Si	Do
Jackson Iron & Steel Co	Jackson, Ohio	Silvery iron	Blast
Kawecki Chemical Co.	Boyertown, Pa	FeCb	Aluminothermic
Keokuk Electro-Metals Co., Division of Vanadium Corporation of America	Keokuk, Iowa	FeSi, silvery iron	Electric
Do	Wenatchee, Wash	FeSi, Si	Do
E. J. Lavino & Co	Sheridan, Pa; Reusens, Va	FeMn	Blast
Manganese Chemicals Corp	Kingwood, W Va	FeMn	Electric
Mobil Chemical Co., Industrial Chemicals Division [3]	Nichols, Fla; Charleston, SC; Mt. Pleasant, Tenn	FeP	Do
Molybdenum Corporation of America	Washington, Pa	FeMo	Electric and aluminothermic
		FeW, FeB, FeCb	Electric
Monsanto Co	Soda Springs, Idaho; Columbia, Tenn	FeP	Do
The New Jersey Zinc Co.	Palmerton, Pa	Spln	Do
Ohio Ferro-Alloys Corp	Brilliant, Ohio	FeSi, FeCr	Do
Do	Philo, Ohio	FeMn, SiMn, FeSi, other [4]	Do
Do	Powhatan Point, Ohio	FeSi, Si	Do
Do	Tacoma, Wash	FeSi, Si	Do
Pittsburgh Metallurgical Co.	Niagara Falls, NY	SiMn, FeSi, FeCr, silvery iron	Do
Do	Calvert City, Ky	FeMn, SiMn, FeSi, FeCr, silvery iron	Do
Do	Charleston, SC	FeSi, FeCr, silvery iron	Do
Reading Chemicals	Robesonia, Pa	FeV, FeW, FeCb, NiCb, FeMo	Aluminothermic
Shieldalloy Corp	Newfield, NJ	FeV, FeTi, FeB, FeMo, FeCb, FeCbTa, other [4]	Do
Stauffer Chemical Co [5]	Mt. Pleasant, Tenn	FeP	Electric
Tennessee Valley Authority	Muscle Shoals, Ala	FeP	Do
Tenn-Tex Alloy & Chemical Corp.	Houston, Tex	FeMn, SiMn	Do
Titanium Alloy Manufacturing, Division National Lead Co	Niagara Falls, NY	FeTi, other	Do
Union Carbide Corp., Mining & Metals Division [6]	Do	FeCr, FeTi, FeW, FeV, FeB, FeCb, FeCbTa, other	Do
Do	Alloy, W. Va.	FeMn, SiMn, FeSi, FeCr, Si, other	Do
Do		FeV	Aluminothermic
Do	Marietta, Ohio	FeMn, SiMn, FeSi, FeCr	Electric
Do	Ashtabula, Ohio	FeMn, SiMn, FeSi	Do
Do	Sheffield, Ala	FeMn, FeSi	Do
Do	Portland, Oreg	FeMn, SiMn, FeSi	Do
Do	Rockwood, Tenn	FeMn, SiMn, FeSi	Do
United States Steel Corp	Birmingham, Ala, Clairto, Pa; Duquesne, Pa	FeMn	Blast
Vanadium Corporation of America	Cambridge, Ohio	FeTi, FeV, FeB, FeCb, other	Electric
Do	Vancoram, Ohio	FeSi, FeCr	Do
Do	Graham, W Va	FeMn, FeSi, FeCr, other	Do
Woodward Iron Co	Woodward, Ala	FeSi	Do

[1] FeMn, ferromanganese; Spln, spiegeleisen; SiMn, silicomanganese; FeSi, ferrosilicon; FeP, ferrophosphorus; FeCr, ferrochromium; FeMo, ferromolybdenum; FeNi, ferronickel; FeTi, ferrotitanium; FeW, ferrotungsten; FeV, ferrovanadium; FeB, ferroboron; FeCbTa, ferrocolumbium-tantalum; FeCb, ferrocolumbium; NiCb, nickel columbium; Si, silicon metal.
[2] Formerly Interlake Iron Corp.
[3] Formerly Virginia-Carolina Chemical Corp.
[4] Includes Alsifer, simanal, zirconium alloys, ferrosilicon boron, aluminum silicon alloys, and miscellaneous ferroalloys.
[5] Formerly Victor Chemical Division, Stauffer Chemical Co.
[6] Formerly Union Carbide Metals Co.

Table 4.—Consumption by major end uses, and stocks, of silicon and alloys in the United States in 1965

(Short tons)

Alloy: Type	Alloy: Silicon content (percent)	Stainless steels	Other alloy steels [1]	Carbon steels	Tool steels	Steel mill rolls	Gray and malleable castings	Aluminum base alloys	High temperature alloys	Other nonferrous alloys	Miscellaneous	Total consumption	Stocks Dec. 31, 1965
Silvery pig iron	5–13	------	214	484	------	710	96,819	------	------	1	2,028	100,256	6,434
Do	14–20	------	8,684	22,976	------	250	97,242	------	------	113	[2] 4,001	133,266	12,845
Ferrosilicon	[3] 21–55	8,602	78,509	96,747	1,095	1,403	109,276	58	282	3,153	[4] 21,376	320,501	25,577
Do	56–70	797	6,319	20,158	------	------	2,148	------	------	------	[4] 4,586	34,008	1,974
Do	71–80	11,579	16,803	6,794	332	194	12,307	------	9	35	15,142	63,195	5,735
Do	81–89	224	653	2,298	------	164	6,657	------	------	31	29	10,056	1,505
Do	90–95	20	1,053	231	------	69	381	3,287	------	56	------	5,097	551
Silicon metal	96–99	61	2,686	73	20	------	70	55,176	830	861	[5] 10,824	70,601	4,494
Ferrosilicon briquets	40–50	------	126	576	------	8	43,490	------	------	------	------	44,200	4,417
Miscellaneous silicon alloys [6]	------	347	3,734	5,337	58	137	24,014	119	68	52	4,347	38,213	3,144
Total	------	21,630	118,781	155,674	1,505	2,935	392,404	58,640	1,189	4,302	62,333	819,393	66,676

[1] Includes quantities of carbon steels because some firms failed to specify individual uses.
[2] Used mainly in high-silicon iron, and to beneficiate ores.
[3] Mainly from 40 to 55 percent silicon.
[4] Used mainly in producing ferronickel.
[5] Used mainly in producing silicones and other chemical compounds.
[6] Includes calcium-silicon, calcium-manganese-silicon, silicon-manganese-zirconium, Ferrocarbo (including briquets), Alsifer, and other miscellaneous silicon alloys.

CONSUMPTION AND USES

As reported to the Bureau of Mines, and shown in tables 5 and 6, a total of 2,411,000 tons of ferroalloys was consumed in the United States as ferroalloys and contained alloying elements, an increase of 7 percent over that used in 1964.

Manganese.—Consumption of manganese alloys (including both silicomanganese and manganese metal) increased 46,670 tons, or 3.7 percent, corresponding to an increase of 3.5 percent in steel production. Consumption of silicomanganese relative to ferromanganese continued to grow. In 1964 the ratio was 0.162:1 and in 1965 the ratio was 0.173:1.

Silicon Alloys.—Consumption of silicon alloys (including both silvery pig iron and silicon metal) increased 86,000 tons, or 12 percent. Consumption of silvery pig iron increased 17,000 tons, or 8 percent.

Titanium.—Ferrotitanium consumption increased 737 tons, or 33 percent, the largest increase occurring in use with carbon steels.

Ferrophosphorus.—Consumption of ferrophosphorus in the other uses category doubled in 1965 giving a total consumption increase of 35 percent over that of 1964.

Boron.—Consumption of ferroboron remained at about the 1964 level; however, the distribution of use shifted to some extent. For example, use in stainless and carbon steels decreased whereas use in other alloy steels and gray and malleable castings increased.

Chromium.—Consumption of chromium contained in alloys and metals increased 14,000 tons, or 6 percent, over that of 1964. The use of ferrochromium for high-temperature alloys showed the sharpest increase —39 percent over that for 1964.

Table 5.—Consumption by end uses of ferroalloys as additives in the United States in 1965

(Short tons)

Alloy	Stainless Steels	Other alloy steels [1]	Carbon steels	Tool steels	Gray and malleable iron castings	Other uses	Total
Ferromanganese [2]	13,634	249,350	795,661	4,442	32,909	16,286	1,112,282
Silicomanganese	8,359	63,334	115,941	1,020	2,133	1,494	192,281
Silicon alloys [3]	21,630	121,716	155,674	1,505	392,404	126,464	819,393
Ferrotitanium	639	883	1,193	17	------	218	2,950
Ferrophosphorus	19	4,275	8,886	----	840	15,033	29,053
Ferroboron	3	78	172	2	26	13	294
Total	44,284	439,636	1,077,527	6,986	428,312	159,508	2,156,253

[1] Includes steel mill rolls.
[2] Includes spiegeleisen, manganese metal, and briquets.
[3] Includes silicon metal and silvery iron. See table 4 for more detail.

Table 6.—Consumption by end uses of ferroalloys as alloying elements in the United States in 1965

(Short tons of contained element)

Alloy	Stainless steels	Other alloy steels [1]	Carbon steels	High speed steels	Other tool steels [1]	Gray and malleable iron castings	High temperature alloys	Other uses	Total
Ferrochromium [2]	169,196 [3]	55,828	------	1,226	2,041	4,081	7,690	3,064	243,126
Ferromolybdenum [4]	1,253	[3] 1,253	------	377	240	1,446	185	530	5,284
Ferrotungsten	([5])	[6] 383	------	324	112	------	23	11	853
Ferrovanadium [7]	31	[8] 2,787	656	265	193	35	20	55	4,042
Ferrocolumbium [9]	293	487	133	1	------	------	154	13	1,081
Ferrotantalum-columbium	8	------	------	------	------	------	2	8	18
Total	170,781	60,738	789	2,193	2,586	5,562	8,074	3,681	254,404

[1] Includes hot-work and die steels.
[2] Includes other chromium ferroalloys and chromium metal.
[3] Includes quantities believed used in producing high-speed and other tool steels and stainless steels because some firms failed to specify individual uses.
[4] Includes calcium molybdate and molybdenum silicide.
[5] Included with "Other alloy steels."
[6] Includes stainless steels, steel mill rolls, and other alloy steels.
[7] Includes other vanadium-carbon-iron-ferroalloys.
[8] Includes steel mill rolls.
[9] See columbium and tantalum chapter for more detail on end uses.

STOCKS

During 1965 total producer stocks increased 13 percent; increases in stocks of manganese ferroalloys and ferrochromium outweighed the drop in stocks of ferrophosphorus.

Total consumer stocks increased 11 percent owing principally to a substantial increase in stocks of manganese ferroalloys.

In addition to the stocks reported in table 7, the quantities of ferroalloys stored in the various U. S. Government stockpiles are shown in table 1.

Table 7.—Stocks of ferroalloys held by producers and consumers in the United States, December 31

(Short tons)

Alloy	Producer		Consumer	
	1964, gross weight	1965, gross weight	1964, gross weight	1965, gross weight
Manganese ferroalloys [1]	r 133,784	170,885	133,069	170,657
Silicon alloys [2]	r 94,450	95,602	[3] 76,235	[3] 66,676
Ferrochromium [4]	r 26,184	42,554	35,314	36,154
Ferrotitanium	896	886	666	1,402
Ferrophosphorus	r 62,021	50,192	28,916	29,051
Ferroboron	174	90	69	65
Total	r 317,509	360,209	274,269	304,005
	1964, contained element	1965, contained element	1964, contained element	1965, contained element
Ferromolybdenum [5]	r W	W	r 787	795
Ferrotungsten	r W	W	r 183	153
Ferrovanadium	r W	W	603	608
Ferrocolumbium	r 140	156	193	263
Ferrotantalum-columbium	W	W	7	5
Total	r 689	433	r 1,773	1,824

r Revised. W Withheld to avoid disclosing individual company confidential data.

[1] Includes ferromanganese, silicomanganese, spiegeleisen, manganese metal and briquets.

[2] Includes ferrosilicon, silvery iron, and miscellaneous silicon alloys. Consumers stocks also include silicon metal.

[3] For more detail see table 4.

[4] Includes other chromium ferroalloys and chromium metal.

[5] Includes calcium molybdate and molybdenum silicide.

PRICES

On January 1, the price of domestically-produced standard high-carbon ferromanganese increased to $180.00 per long ton, f.o.b. furnaces, for lump bulk material in carload lots. During the year the price decreased in four steps and finished the year at $167.50 per long ton. Prices for low- and medium-carbon ferromanganese decreased a fraction of a cent per pound of contained manganese effective on February 1. Prices were adjusted downward again on June 21. Prices for all grades of spiegeleisen increased $2.00 per long ton, f.o.b. Palmerton, Pa., on February 1 and remained at that level to yearend.

Most of the major producers announced price increases at the beginning of the year on charge chromium, blocking chromium, low-carbon ferrochromium, and ferrochromium-silicon. Increases averaged ½ cent per pound of contained chromium, f.o.b. producing point, for lump bulk in carload lots, and remained in effect throughout the year.

Ferrosilicon, 50-percent grade, was reduced in price on February 1 and held steady throughout 1965 at 12.7 cents per pound of contained silicon, bulk, carload, producer's plant. A revised, simplified schedule of prices for all silicon products was announced by the industry in June. By grouping together closely related sizes of each silicon product to sell at the same price, the number of prices for each product was reduced from an average of eight prices to two or three prices. This move is reported to be just the first in a series aimed at consolidating and simplifying the sizes and prices offered on all ferroalloys.

On June 1, the price of all three grades of ferrovanadium containing 50 to 55 percent vanadium rose from $2.50 per pound of contained vanadium, delivered, to $2.62, f.o.b., producing plant. Prices increased again in October and held till yearend. The price of carvan, the vanadium-carbon-iron alloy, was changed on June 1 from $2.17 per pound of contained vanadium, delivered, to $2.15 f.o.b. producing plant.

The increases in cost of ores and labor rates were blamed for the July increase in prices of columbium alloys. On July 6, Union Carbide Corp. raised the price of 15 to 1 grade ferrocolumbium from $3.00 to $3.24 per pound of columbium, f.o.b. Niagara Falls, N. Y., for 500-pound drum shipments. The price of 30 to 1 grade ferrocolumbium was raised from $2.92 to $3.02, base unchanged. Prices for different sizes were standardized and packaging extras were changed. On July 28, Vanadium Corporation of America raised the prices of 15 to 1 and 30 to 1 grades of columbium to $3.17 and $3.02, respectively, per pound of contained columbium, f.o.b. Cambridge, Ohio.

FOREIGN TRADE

Foreign trade in ferroalloys in 1965 continued the upward trend shown in 1963 and 1964 after the sharp drop in trade in 1962. Total tonnage of ferroalloy exports dropped 41 percent from the record high of 1964, but value increased 23 percent. Exports of ferrophosphorus in 1965 were one-half as large as in 1964, which was the principal cause of the large drop in total tonnage this year.

Ferromanganese made up the bulk of ferroalloy imports for consumption; low, medium, and high-carbon grade showed substantial increases over that of 1964. Imports for consumption of ferrochromium doubled in 1965, imports of ferrosilicomanganese increased 61 percent ,and ferrosilicon imports for consumption showed a 50 percent increase. Principal suppliers for imported ferromanganese were France, India, Republic of South Africa, West Germany, and Belgium-Luxembourg, in order of decreasing tonnage. The principal supplier of imported ferrosilicon was Canada followed by France, Norway, and Japan.

Table 8.—U.S. exports of ferroalloys

Alloy	1962 Short tons	1962 Value	1963 Short tons	1963 Value	1964 Short tons	1964 Value	1965 Short tons	1965 Value
Ferrocerium and alloys	19	$172,518	20	$182,348	19	$139,279	27	$220,715
Ferrochromium	3,075	1,182,382	2,354	772,937	10,032	2,504,405	12,002	3,021,372
Ferromanganese	4,114	629,401	678	154,973	3,903	670,073	3,273	727,407
Ferromolybdenum	95	305,126	120	379,173	873	3,328,494	1,121	4,576,800
Ferrophosphorus	14,130	594,666	41,361	1,302,337	163,166	4,938,385	79,910	2,914,388
Ferrosilicon	4,101	1,348,661	3,130	947,773	5,785	1,232,450	4,585	1,755,292
Ferrotitanium and ferro-carbon-titanium	130	95,265	211	182,828	541	391,771	(1)	(1)
Ferrotungsten	6	26,136	1	2,927	(2)	2,068	(1)	(1)
Ferrovanadium	201	745,912	183	587,690	103	308,880	220	747,399
Spiegeleisen	348	233,591	430	262,985	636	392,133	8,444	3,172,827
Ferroalloys not elsewhere classified	715	59,275	1,176	89,766	785	59,446	(1)	(1)
Total	26,934	5,392,933	49,664	4,865,737	185,843	13,967,384	109,582	17,136,200

[1] No longer separately classified, included with ferroalloys not elsewhere classified.
[2] Less than ½ unit.

Table 9.—U.S. imports for consumption of ferroalloys and ferroalloy metals

Alloy	1964 Gross weight (short tons)	1964 Content (short tons)	1964 Value	1965 Gross weight (short tons)	1965 Content (short tons)	1965 Value
Chromium metal	733	(1)	$1,108,941	1,010	(1)	$1,522,023
Ferrocerium and other cerium alloys	5	(1)	47,895	4	(1)	36,027
Ferrochrome and ferrochromium—						
Containing 3 percent or more carbon	7,470	4,555	1,257,100	5,350	3,521	854,796
Containing less than 3 percent carbon	18,652	13,141	4,525,997	49,772	33,440	12,381,308
Ferromanganese—						
Containing not over 1 percent carbon	593	534	217,873	989	884	373,386
Containing over 1 and less than 4 percent carbon	22,892	17,832	3,905,799	33,883	26,799	6,219,992
Containg not less than 4 percent carbon	189,141	143,708	21,687,448	222,467	170,435	24,892,724
Ferromolybdenum, molybdenum metal, compounds, alloys, and scrap (molybdenum content)	r 138	8	r 186,754	318	167	947,639
Ferronickel	(2)	(1)	964	32	(1)	20,697
Ferrophosphorus	80	(1)	6,990	61	(1)	5,476
Ferrosilicon	13,161	3,044	908,387	16,493	4,558	1,606,327
Ferrosilicon chromium	------	------	------	2,366	(1)	362,690
Ferrosilicomanganese (manganese content)	10,841	6,869	1,126,763	17,491	11,601	1,913,289
Ferrotitanium	28	(1)	19,481	17	(1)	11,500
Ferrotungsten	121	98	136,006	242	193	403,963
Ferrovanadium	395	(1)	840,651	26	(1)	73,183
Ferrozirconium	28	(1)	10,713	55	(1)	23,675
Manganese metal	878	(1)	328,424	1,384	(1)	559,011
Tungsten alloys (unwrought) and scrap (tungsten content)	r 62	17	25,948	3	1	1,934
Tungsten metal (lump, grains, or powder) and tungsten carbide (tungsten content)	(1)	30	126,075	(1)	22	115,048
Tungstic acid and other alloys of tungsten not specifically provided for (tungsten content)	20	14	44,888	319	187	331,580
Ferroalloys, not elsewhere classified	115	(1)	290,328	404	(1)	979,199

r Revised.
[1] Not recorded.
[2] Less than ½ unit.

Table 10.—U.S. imports for consumption of ferromanganese and ferrosilicon, by countries

Country	Ferromanganese (manganese content) excluding silicomanganese				Ferrosilicon (silicon content)			
	1964		1965		1964		1965	
	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value
North America: Canada	2,503	$377,911	5,640	$1,044,684	2,014	$654,003	2,021	$743,636
South America:								
Brazil	------	------	430	60,736	------	------	------	------
Chile	4,375	782,300	557	88,035	------	------	------	------
Peru	------	------	20	2,946	------	------	------	------
Europe:								
Belgium-Luxembourg	25,066	3,189,193	12,751	1,839,503	------	------	------	------
France	30,161	4,143,601	52,847	7,500,866	31	5,629	1,060	223,603
Germany, West	16,528	2,328,689	25,707	3,530,216	54	59,714	79	86,873
Italy	1,284	299,728	1,115	279,724	42	11,823	58	15,542
Netherlands	467	59,843	680	92,131	------	------	------	------
Norway	------	------	175	21,210	857	145,898	696	124,514
Spain	7,385	841,615	5,068	928,337	------	------	------	------
United Kingdom	------	------	8,468	1,165,594	------	------	------	------
Yugoslavia	------	------	705	95,639	------	------	------	------
Africa:								
South Africa, Republic of	14,145	1,847,480	26,667	3,688,949	------	------	87	15,210
Zambia, Southern Rhodesia, and Malawi	------	------	46	5,868	------	------	------	------
Asia:								
India	56,001	10,941,727	48,990	8,931,752	1	284	------	------
Japan	4,160	999,033	8,252	2,209,912	45	30,498	557	396,949
Outer Mongolia	------	------	------	------	1	538	------	------
Total	162,075	25,811,120	198,118	31,486,102	3,045	908,387	4,558	1,606,327

WORLD REVIEW

Belgium.—S.A. d' Applications de Chimie Industrielle (SADACI) produced ferromolybdenum at its Langerbrugge plant under an agreement with Continental Ore Corp. by converting molybdenite concentrate supplied by Duval Corp.

France.—Rationalization of the French ferroalloy industry was carried a step further with absorption of Ste' des Ferro-Alliages de l'Ardoise by Sociéte d' Ellectro-Chimie d' Electro-Metallurgie et des Acieries Electriques d'Ugine. The merger gave Ugine an effective capacity of 75,000 tons of chromium alloys a year, allowed the company to dominate the French production of low-carbon ferrochromium and refined low-carbon ferromanganese, and gave Ugine a controlling interest in Establishments Charles Bertolus, a significant producer of ferrochromium with a plant at Bellegaard, Ain.

Japan.—At the beginning of the year the Japanese ferroalloy industry proposed curbs on the production of ferrochromium predicated on reduced sales to the special steel sector, where economic pressures forced consumers to intensify their use of returned scrap.

By the end of the year the formation of a ferroalloy producers antidepression cartel was approved by the Government's Fair Trade Commission. The 21 members of the association included all the large ferroalloy producers. Their share of domestic production is put as high as 88 percent in the case of high, low, and medium-carbon ferromanganese, 100 percent of high-carbon ferrochromium, and 94 percent of low- carbon ferrochromium.

Norway.—The production of ferrosilicon was 255,000 tons in 1965, a 19-percent increase over that of 1964, while the production of other ferroalloys increased 24 percent to 290,000 tons.

Rhodesia, Southern.—Union Carbide Corp. bought the ferrochromium smelter at Que Que, which was owned by Windsor Ferroalloys (Pvt.) Ltd., a Rhodesian Company. Union Carbide Rhomet (Pvt.) Ltd., a wholly owned Rhodesian subsidiary of Union Carbide, took over operation of the smelter on May 1. Plans call for tripling the plant's capacity by installation of a 12,500-kilovolt-ampere Elkem furnace before the end of 1966. The existing 7,500-kilovolt-ampere furnace, although originally intended for the production of high carbon ferrochromium, has been producing silicochromium, but the new furnace will probably produce ferrochromium. Union Carbide Corp. owns and mines the best chromite deposits in Rhodesia, probably the richest in the world. Higher profits are expected by exporting the ferroalloy instead of the chromite ore.

Tasmania.—Construction of a second ferromanganese plant at Bell Bay was well underway in 1965. The smelter should have an output of 70,000 tons per year of ferromanganese by the end of 1966. The plant takes all of Groote Eylandt output.

TECHNOLOGY

Electric furnaces used in the production of ferroalloys have increased tenfold in size in the last 25 years—from approximately 2,500-kilovolt-ampere transformer rating to over 25,000-kilovolt-ampere rating. Although the prime motive has been to achieve greater power efficiency, additional benefits such as increased flexibility of furnace operation have appeared. As a result of higher efficiency, production costs have been lowered, and the alloy producers have been able to remain competitive in the world market. The trend toward increased furnace size is expected to continue; one well-known metallurgist predicts that a furnace of 50,000-kilovolt-ampere transformer rating will be constructed in the not-too-distant future. The new and larger furnaces will be more versatile than existing models because of new design features such as computerized controls, automated materials handling, and advanced types of replaceable hearths.[2]

The Pittsburgh Metallurgical Co. compared design and metallurgical data for four

[2] Battelle Technical Review. Ferroalloy Furnace Size. V. 14, No. 2, February 1965, p. 13.

electric furnaces ranging in shell size from 22 feet to 31 feet and in load from 8,500 kilovolt-amperes to 17,000 kilovolt-amperes. Maintaining similar operating characteristics for all four furnaces, they found that in the production of ferrosilicon improvements in electrical efficiency, reduced furnace room remelts, and ladle skullage were attained with increased furnace size.[3]

The Albany Metallurgy Research Center, Bureau of Mines, has collected and evaluated some of the scattered information relevant to an understanding of high-current metallic arcs, which are used in the production of ferroalloys. Experimental results obtained from specially designed arc-melting furnaces operated at the Albany Center were compared to results obtained from a comprehensive review of the literature. The findings from both sources were discussed in terms of physical theory, and the conclusions were applied to problems encountered in the arc-melting of metals.[4]

The increased use of vacuum degassing in steelmaking could cause a decrease in ferroalloy consumption or, at least, a change in ferroalloy composition, since vacuum degassing cuts the amount of alloying and deoxidizing metals needed to produce many kinds of steel. The degassing process removes unwanted gases and metals, minimizes inclusions, and improves composition control of the finished product. When first introduced to the steel industry, vacuum degassing was used mostly to purify specialty steels and to remove crack-causing hydrogen from steel being cast for large forgings. The trend now is toward a wider use of vacuum degassing in all kinds of steelmaking. The proponents of this process go so far as to predict that eventually the bulk of all steel will be degassed, including much of the steel for making rebar and structural shapes.[5]

The Mining and Metals Division of Union Carbide Corp. introduced a new ferrosilicon master alloy containing 5 percent magnesium that is reported to lower the cost of making ductile iron. In extensive field tests the new alloy gave a 30 percent higher magnesium recovery than did the 9-percent magnesium ferroalloy used previously. As an additional benefit, the 5-percent alloy boosted silicon pickup and gave a less violent reaction when added to the iron than occurred with the addition of the 9-percent alloy.[6]

The use of ferrosilicon as a reductant to produce magnesium, a process developed during World War II, was evaluated by the Bureau of Mines in the light of mineral processing improvements effected during the last two decades. With modern equipment and practices, and making its own ferrosilicon, a hypothetical plant costing $21 million could annually produce more than 15,000 tons of magnesium at a cost of less than 33 cents per pound. Further research might result in even greater efficiencies and lower costs.[7]

A process involving the addition of solid ferrosilicon to molten magnesium to form an iron-magnesium-silicon prealloy was patented.[8]

A patent was granted for an iron-magnesium-silicon addition alloy containing a fine suspension of calcium cyanamide.[9]

An arc-welding electrode with a coating containing from 5 to 65 parts by weight of ferrosilicon was patented.[10]

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[3] Dann, T. E., and W. H. Wise. Comparative Operating Characteristics of Large Vs. Small Ferroalloy Units. J. Metals, v. 17, No. 3, March 1965, pp. 303–305.

[4] Wood, Floyd W., and R. A. Beall. Studies of High-Current Metallic Arcs. BuMines Bull. 625, 1965, 84 pp.

[5] Howard, H. Steel Quality Aid: Vacuum Degassing. Am. Metal Market, v. 72, No. 138, July 21, 1965, p. 1.

[6] Steel. Reducing Magnesium Content In Additive Improves Recovery In Ductile Iron. V. 156, No. 23, June 7, 1965, pp. 118–120.

[7] Dean, Karl C., D. A. Elkins, and S. J. Hussey. An Economic and Technical Evaluation of Magnesium Production Methods (In Three Parts) 1. Metallothermics. BuMines Rept. of Inv. 6656, 1965, 76 pp.

[8] Ebert, Hans, and K. Frank. Process for the Manufacture of Iron-Silicon Magnesium Prealloys. U. S. Pat. 3,177,071, Apr. 6, 1965.

[9] Kaess, Franz, E. Pfuger, and L. Strassberger. Alloy Containing Magnesium, Silicon, and Calcium. U. S. Pat. 3,177,072, Apr. 6, 1965.

[10] Koibuchi, M., and T. Kataoka. Coated Arc Welding Electrode. U. S. Pat. 3,167,450, Jan. 26, 1965.

Fluorspar and Cryolite

By Ronald C. Briggs [1]

FLUORSPAR

For fluorspar 1965 was a record-setting year. Record highs were established for tons of domestic crude ore milled or washed, for tons of fluorspar (all grades) consumed, and for tons of fluorspar imported. Demand for fluorspar continued to increase with the aluminum, chemical, and steel industries providing the impetus. Shipments from domestic mines, however, did not account for a larger percentage of the total consumption. Foreign fluorspar, chiefly from Mexico, continued to dominate the market. Prices for both domestic and foreign fluorspar remained steady throughout the year.

Legislation and Government Programs.—Although Government stockpile objectives remained unchanged during 1965, transfer of material changed the inventories, accountable under the several stockpile programs. A bookkeeping transaction removed 350,000 short tons of acid-grade fluorspar from Commodity Credit Corporation (CCC) and supplemental stocks and added it to the national (strategic) stockpile as 438,000 tons of metallurgical-grade fluorspar. This reduced the excess quantity of acid-grade fluorspar and brought the metallurgical grade stocks up to the objective.

Some of the excess acid-grade fluorspar had become contaminated in storage and

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Table 1.—Salient fluorspar statistics

	1956–60 (average)	1961	1962	1963	1964	1965
United States:						
Production:						
Crude:						
Mine production short tons	716,460	615,075	623,750	586,158	620,474	772,765
Material milled or washed short tons	676,340	524,400	586,700	586,400	624,745	825,867
Beneficiated material recovered short tons	272,140	185,200	192,000	188,200	202,300	236,800
Finished (shipments) short tons	278,595	197,354	206,026	199,948	217,137	240,932
Value thousands	$12,835	$8,940	$9,166	$9,001	$9,723	$10,889
Exports short tons	1,185	338	1,308	1,202	3,702	9,385
Value thousands	$82	$30	$119	$157	$158	$315
Imports for consumption short tons	519,771	505,759	595,695	559,653	687,933	816,546
Value thousands	$12,959	$13,644	$15,596	$14,192	$16,882	$19,958
Consumption short tons	598,801	687,940	652,888	736,350	r 831,561	930,127
Stocks Dec. 31:						
Domestic mines:						
Crude do	180,884	221,961	277,876	299,197	299,109	274,011
Finished do	18,517	21,001	14,549	14,954	10,174	19,664
Consumer plants do	199,812	188,413	186,772	181,934	203,014	235,657
Importers do	50,469	75,811	75,303	68,038	65,116	25,838
World: Production do	2,010,000	2,275,000	2,370,000	2,350,000	2,730,000	3,170,000

r Revised.

Table 2.—U.S. defense materials inventories and objectives

(Short tons)

Fluorspar	Objective	Inventory by program, Dec. 31, 1965		
		National stockpile	DPA inventory	CCC and supplemental stockpile
Acid grade	540,000	[1] 463,049	[2] 19,700	[3] 323,232
Metallurgical grade	850,000	[4] 369,443		42,800

[1] Includes 10,193 tons of nonstockpile grade.
[2] Includes 2,383 tons of nonstockpile grade.
[3] Includes 4,548 tons of nonstockpile grade.
[4] Does not include 350,000 tons acid-grade fluorspar credited to metallurgical-grade fluorspar as 438,000 tons.

no longer met stockpile specifications. The General Services Administration (GSA) offered for sale on a sealed-bid basis a total of about 6,848 tons of contaminated acid-grade fluorspar during the year. About 2,300 tons were offered for a bid opening on May 7, but no acceptable bids were received. This material plus an additional quantity of about 4,548 tons was reoffered under a bid invitation opened December 17. No acceptable bids were received at the second offering.

DOMESTIC PRODUCTION

Mine production of fluorspar in 1965 increased more than 24 percent over that of 1964 and rose to the highest level since 1958. There were 17 active mining operations (including production from stockpiles) reporting, with over 95 percent of the production coming from the operations of 6 companies. The large quantity of ore produced by a few companies reflected the competitive nature of the industry. Producers working small, high-cost deposits found it increasingly difficult to compete, and the trend continued toward mining those deposits that could be worked by large-volume, low-cost mining methods. Fluorspar was mined in Colorado, Illinois, Kentucky, Montana, Nevada, and Utah in 1965. The Illinois-Kentucky district continued to dominate the domestic picture supplying nearly 90 percent of the total production. Illinois alone produced nearly 69 percent of the total.

The tonnage of ore milled or washed reached a record high, but the quantity of concentrates recovered did not increase proportionally. This higher concentration ratio resulted from processing lower-grade and more complex ores. During 1965, 13 fluorspar mills and washing plants were in operation. About 86 percent of the total beneficiated material recovered by these plants was flotation concentrates and the remainder was gravel and lump-sized fluorspar.

The Aluminum Company of America, a leading producer of acid-grade fluorspar, terminated mining operations at its mine near Rosiclare, Ill., on August 1, 1965; however, it will continue to operate the mill for several years, processing stockpiled crude ore.

Ozark-Mahoning Mining Co. started sinking a new production shaft on a property in Pope County, Ill.; it also completed development of another property in Hardin County, Ill. The Minerva Co. installed new and larger underground loading and hauling equipment at its No. 1 mine near Cave-In-Rock, Ill. The company also began operating a heavy-media preconcentrator in its mill at the same location. Operating under contract to the Minerva Co., Conn-Joiner Contractors produced a small quantity of ore by "robbing" pillars at the Old Victory Mine in Hardin County.

Kentucky Fluorspar Co. was the major purchaser of crude fluorspar from the small producers in the Illinois-Kentucky district in 1965. The purchased ore was beneficiated in its plant near Marion, Ky. This same company continued to rehabilitate and produce from the Old Nancy Hanks mine near Salem, Ky. Also in Kentucky, the Mafluor Corp., ceased operations early in 1965.

The Chemical Division of Kaiser Aluminum & Chemical Corp. completed expansion of its Gramercy, La., plant. This expansion included increasing the production capacity for aluminum fluoride by 50

Table 3.—Shipments of finished fluorspar, by States

State	1964			1965		
	Short tons	Value		Short tons	Value	
		Total	Average per ton		Total	Average per ton
Illinois	127,454	$6,451,755	$50.62	159,140	$7,861,165	$49.40
Kentucky	38,214	1,692,997	44.30	31,992	1,484,772	46.41
New Mexico	137	3,014	22.00			
Other States [1]	51,332	1,575,635	30.69	49,800	1,543,015	30.98
Total	217,137	9,723,000	44.78	240,932	10,889,000	45.20

[1] Includes Colorado, Montana, Nevada, and Utah to avoid disclosing individual company confidential data.

percent and installing a new hydrogen fluoride generator.[2]

CONSUMPTION AND USES

Domestic industries consumed a record tonnage of fluorspar in 1965. The ever-increasing demands of the aluminum, chemical, and steel industries provided the driving force which pushed the total consumption of all grades more than 11 percent above that for 1964. This gain in consumption was proportionally distributed between acid and metallurgical grades with each grade also recording an increase of about 11 percent.

Nearly 53 percent of the total quantity of fluorspar consumed was used to manufacture hydrofluoric acid. Hydrofluoric acid was the major source of fluorine for the chemical industry and a raw material in the production of synthetic cryolite and aluminum fluoride for the aluminum industry.

Fluorspar consumption by the steel industry accounted for about 38 percent of the total. It was used chiefly as a flux in the various steelmaking processes. Although the greatest percentage gain was registered in the fluorspar consumed for basic-oxygen steel, the quantity consumed per ton of steel produced by this process remained the same. It was difficult to assess the future of fluorspar consumption in basic-oxygen furnaces. Some companies claimed the quantity consumed per ton of steel produced should be more than the 1965 industry-wide average while others predicted a lowering of this ratio.

Fluoridated water is being extended to more than 2 million new users each year. Municipal water systems have now become major markets for suppliers of sodium fluoride and fluosilicic acid. Although some cities were still continuing the battle against fluoridation of their drinking water, some of the principal cities have consented to fluoridation. For example, New York City ended a 20-month delay and prepared to pour more than 2,400 tons per year of fluosilicic acid into its water supply. This action added about 8 million more people to the 50 million Americans already drinking fluoridated water.[3] Connecticut became the first State in the United States to require water fluoridation. The fluoridation bill passed affected 31 communities in the State.[4]

Plastics derived from fluorspar continued to receive considerable attention. Rapid expansion of the tetrafluoroethylene (TFE) market for chemical applications, household appliances, hydraulic and pneumatic equipment, and automotive uses was pointed out at a gathering of fluorocarbon producers. Market surveys indicated aerospace and military applications constitute 15 percent of the TFE market, while electrical and electronic applications make up an additional 35 percent; mechanical goods 15 percent; and chemical processing equipment 35 percent.[5]

[2] Chemical Engineering. CPI News Briefs. V. 72, No. 4, Feb. 15, 1965, p. 212.
[3] Chemical Week. Fluoridation: A Hard Fight. V. 97, No. 6, Aug. 7, 1965, pp. 17–18.
[4] Chemical & Engineering News. V. 43, No. 23, June 7, 1965, p. 19.
[5] Oil, Paint and Drug Reporter. TFE's Recent Gains Conference Highlight. V. 187, No. 24, June 14, 1965, p. 57.

Table 4.—Fluorspar shipped from mines in the United States, by grades and industries

Grade and industry	1964				1965			
	Quantity		Value		Quantity		Value	
	Short tons	Percent of total	Total	Average per ton	Short tons	Percent of total	Total	Average per ton
Ground and flotation concentrates:								
Hydrofluoric acid	110,236	64.8	$5,841,564	$52.99	103,495	49.3	$5,601,696	$54.13
Glass	25,471	15.0	1,080,274	42.41	30,990	14.8	1,329,331	42.90
Ceramic nd enamel	4,569	2.7	191,615	41.94	18,095	8.6	631,639	34.91
Nonferrous	2,129	1.2	92,453	43.43	3,584	1.7	156,644	43.71
Ferrous	22,268	13.1	947,855	42.57	33,163	15.8	1,436,860	43.33
Miscellaneous [1]	5,461	3.2	230,723	42.25	20,568	9.8	913,943	44.44
Total	170,134	100.0	8,384,000	49.28	209,895	100.0	10,070,000	47.98
Fluxing gravel and foundry lumps:								
Nonferrous	12	-----------	492	41.00	17	-----------	697	41.00
Ferrous	38,160	81.2	1,189,386	31.17	20,662	66.6	655,955	31.75
Miscellaneous	8,831	18.8	149,039	16.88	10,358	33.4	162,187	15.66
Total	47,003	100.0	1,339,000	28.49	31,037	100.0	819,000	26.38

[1] Includes exports.

Table 5.—Fluorspar (domestic and foreign) consumed and in stock in the United States, by grades and industries

(Short tons)

Grade and industry	1964 Consumption	1964 Stocks at consumer plants Dec. 31	1965 Consumption	1965 Stocks at consumer plants Dec. 31
Acid grade:				
Hydrofluoric acid	r 447,719	35,127	490,345	40,763
Glass	6,614	751	6,053	549
Enamel	325	51	226	50
Welding rod coatings	1,298	107	2,946	239
Special flux				
Ferroalloys	2,253	1,091	2,719	1,201
Primary aluminum				
Total	r 458,209	37,127	502,289	42,802
Ceramic grade:				
Glass	23,462	2,702	23,230	2,721
Enamel	4,746	674	4,749	603
Welding rod coatings [1]	3,003	183	3,481	77
Nonferrous	297	46	299	44
Special flux	6,034	976	6,540	1,439
Ferroalloys				
Total	37,542	4,581	38,299	4,884
Metallurgical grade:				
Glass	439	21	608	25
Enamel				
Nonferrous [2]	10,952	1,751	11,684	1,539
Special flux				
Ferroalloys	1,469	1,457	1,687	2,528
Primary magnesium				
Iron foundry	18,066	4,232	20,664	4,173
Open-hearth steel	160,770		162,200	
Basic oxygen furnace steel	95,720	153,845	139,240	179,706
Electric-furnace steel	48,394		53,456	
Total	335,810	161,306	389,539	187,971
All grades:				
Hydrofluoric acid	r 447,719	35,127	490,345	40,763
Glass	30,515	3,474	29,891	3,295
Enamel	5,071	725	4,975	653
Welding rod coatings	4,301	290	6,427	316
Nonferrous	11,249	1,797	11,983	1,583
Special flux	4,680	889	4,949	1,274
Ferroalloys	2,041	276	2,202	470
Primary aluminum	3,035	2,359	3,795	3,424
Primary magnesium				
Iron foundry	18,066	4,232	20,664	4,173
Open-hearth steel	160,770		162,200	
Basic oxygen furnace steel	95,720	153,845	139,240	179,706
Electric-furnace steel	48,394		53,456	
Total	r 831,561	203,014	930,127	235,657

r Revised.
[1] Includes metallurgical grade to avoid disclosing individual company confidential data.
[2] Includes a small amount of acid grade to avoid disclosing individual company operations.

Table 6.—Fluorspar consumption for different steelmaking processes

Process and consumption	1956–60 (average)	1961	1962	1963	1964	1965
Basic and acid open-hearth:						
Total .... thousand short tons	183	156	134	136	161	162
Per short ton of steel made .... pounds	4.2	3.8	3.2	3.3	3.3	3.4
Basic oxygen:						
Total .... thousand short tons	NA	NA	46	65	96	139
Per short ton of steel made .... pounds	NA	NA	16.8	17.6	12.6	12.6
Electric-furnace:						
Total .... thousand short tons	34	49	35	45	48	53
Per short ton of steel made .... pounds	8.6	11.9	8.2	8.4	8.2	8.3

NA Not available.

PRICES

Prices or price ranges reported in the E&MJ Metal and Mineral Markets for all grades of domestic and European fluorspar remained unchanged throughout 1965. The prices quoted were the same as those reported in Volume I of the 1964 Minerals Yearbook. Mexican prices were the same as the 1964 yearend quotations until December when all reported prices were increased by 40 cents per ton.

FOREIGN TRADE

Total fluorspar imports for consumption were the highest on record, about 19 percent above the previous high total of 1964. Mexico continued as the leading supplier providing 68 percent of the acid grade and 92 percent of the metallurgical grade imports.

Fluorspar containing more than 97 percent CaF_2 was subject to a duty of $1.875 per short ton ($2.10 per long ton) and that containing not more than 97 percent CaF_2 was dutiable at $7.50 per short ton ($8.40 per long ton).

Table 7.—Fluorspar (domestic and foreign) consumed in the United States, by States

(Short tons)

State	1964	1965
Alabama, Georgia, and North Carolina	r 11,605	10,336
Arkansas, Kansas, Louisiana, Mississippi, and Oklahoma	r 111,983	132,674
California and Hawaii [1]	32,618	39,844
Colorado and Utah	23,606	26,463
Connecticut	1,385	1,680
Delaware and New Jersey	r 102,134	77,047
Florida, Rhode Island, and Virginia	1,371	1,331
Illinois	54,972	56,697
Indiana	26,720	28,855
Iowa, Minnesota, Nebraska, and Wisconsin	5,041	4,576
Kentucky	41,535	49,122
Maryland	9,505	8,742
Massachusetts	242	254
Michigan	50,813	57,816
Missouri	3,000	3,599
New York	16,623	19,041
Ohio	76,911	83,960
Oregon and Washington	1,616	1,859
Pennsylvania	83,195	103,140
Tennessee	2,666	1,960
Texas	144,488	179,489
West Virginia	r 29,532	41,642
Total	r 831,561	930,127

r Revised. [1] 1964 only.

Table 8.—Stocks of fluorspar at mines or shipping points in the United States, by States, Dec. 31

(Short tons)

State	1964		1965	
	Crude	Finished	Crude	Finished
Illinois	281,490	6,276	250,412	15,474
Kentucky	558		W	
Other States [1]	17,061	3,898	23,599	4,190
Total	299,109	10,174	274,011	19,664

W Withheld to avoid disclosing individual company confidential data; included with "Other States."
[1] Includes Colorado, Montana, Nevada, and Utah to avoid disclosing individual company confidential data.

About 9,400 tons of fluorspar valued at $315,000 was exported in 1965. Of this total 9,241 tons went to Canada and the remaining tonnage was shipped to 4 other countries.

Table 9.—U.S. exports of fluorspar

Year	Short tons	Value
1956–60 (average)	1,185	$82,164
1961	338	30,419
1962	1,308	118,749
1963	1,202	156,898
1964	3,702	158,099
1965	9,385	315,305

WORLD REVIEW

Canada.—Fluorspar deposits in the Burin Peninsula of Newfoundland were the only significant source of supply. Production during 1964 increased about 13 percent in quantity and 16 percent in value to more than $2.29 million. The Director mine of Newfoundland Fluorspar Ltd. at St. Lawrence, Newfoundland, produced 96,000 tons of fluorspar concentrates. Some metallurgical-grade fluorspar was produced by Pacific Silica Ltd. as a byproduct of its silica operations in British Columbia.

Table 10.—U.S. imports for consumption of fluorspar, by countries and customs districts

Country and customs district	1964: Containing more than 97 percent calcium fluoride		1964: Containing not more than 97 percent calcium fluoride		1965: Containing more than 97 percent calcium fluoride		1965: Containing not more than 97 percent calcium fluoride	
	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value
Canada:								
Buffalo			9,895	$214,228				
El Paso					7	$165		
Laredo			1,064	21,464				
Michigan							9,156	$199,865
Total			10,959	235,692	7	165	9,156	199,865
Greenland: Laredo			1,195	24,108				
Guatemala: El Paso	42	$1,062						
Mexico:								
Arizona			45	901				
Buffalo			2,746	63,720			7,043	158,111
Dakota			21	433	254	6,348		
El Paso	58,955	1,426,842	59,530	1,191,042	61,610	1,539,311	87,929	1,756,753
Galveston	831	26,621			804	25,845	5,226	87,370
Kentucky	310	7,762						
Laredo	162,556	4,506,767	116,769	2,288,305	213,769	5,757,133	63,702	1,129,245
Maryland			4,604	85,753			7,389	136,122
Michigan	7,634	260,178	36,021	831,267			14,199	320,881
Mobile							5,756	95,075
New Orleans	28,678	1,032,234	41,533	873,613	43,651	1,230,329	67,157	1,319,596
Ohio			4,684	103,079			20,479	415,792
Philadelphia	12,430	364,109	13,977	297,990	14,223	350,413	17,936	385,091
St. Louis	833	18,828			545	12,375		
San Diego					134	3,634		
San Francisco					561	18,237		
Total	272,227	7,643,341	279,930	5,736,103	335,551	8,943,625	296,816	5,804,036
Colombia: Galveston	306	9,863						
France:								
Michigan					3,599	91,419		
Philadelphia	22	1,049						
Total	22	1,049			3,599	91,419		
Germany, West: Puerto Rico	299	20,505						

Table 10.—U.S. imports for consumption of fluorspar, by countries and customs districts—Continued

Country and customs district	1964: Containing more than 97 percent calcium fluoride — Short tons	1964: Containing more than 97 percent calcium fluoride — Value	1964: Containing not more than 97 percent calcium fluoride — Short tons	1964: Containing not more than 97 percent calcium fluoride — Value	1965: Containing more than 97 percent calcium fluoride — Short tons	1965: Containing more than 97 percent calcium fluoride — Value	1965: Containing not more than 97 percent calcium fluoride — Short tons	1965: Containing not more than 97 percent calcium fluoride — Value
Italy:								
Galveston					7,060	$210,491		
New Orleans	12,164	$364,248			8,946	211,493		
Philadelphia	26,303	695,988			16,369	452,141		
Total	38,467	1,060,236			32,375	874,125		
Spain:								
Michigan					11,227	377,620		
New Orleans	5,962	161,738			17,806	448,521		
Ohio	22,472	561,974			22,272	672,533		
Philadelphia	56,052	1,426,789			58,535	1,807,887		
Total	84,486	2,150,501			109,840	3,306,561		
United Kingdom:								
New York					22	1,658		
Ohio					4,761	142,842		
Puerto Rico					251	10,253		
Total					5,034	154,753		
South Africa: Republic of:								
Maryland							6,263	$86,003
Japan:								
Michigan							8,833	206,955
Philadelphia					9,072	290,648		
Total					9,072	290,648	8,833	206,955
Grand total	395,849	10,886,557	292,084	5,995,903	495,478	13,661,296	321,068	6,296,859

Table 11.—Imported fluorspar delivered to consumers in the United States, by uses

Use	1964			1965		
		Selling prices at tidewater, border, or f.o.b. mill in the United States including duty			Selling prices at tidewater, border, or f.o.b. mill in the United States including duty	
	Short tons	Total	Average per ton	Short tons	Total	Average per ton
Hydrofluoric acid	203,152	$7,075,102	$34.83	270,001	$8,778,694	$32.51
Glass, ceramic and enamel	7,219	355,221	49.21	9,016	480,043	53.24
Ferrous	104,373	2,519,001	24.13	129,193	3,449,924	26.70
Nonferrous	2,447	61,082	24.96	999	34,061	34.10
Other	56,669	1,872,751	33.05	55,268	1,867,362	33.79
Total	373,860	11,883,157	31.79	464,477	14,610,084	31.45

The Nichols Chemical Co. Ltd., a subsidiary of Allied Chemical Canada Ltd., operated a merchant hydrofluoric acid plant at Valleyfield, Quebec, using imported acid-grade fluorspar. Using Newfoundland fluorspar, the Aluminum Company of Canada, Ltd., produced hydrofluoric acid at Arvida for its own requirements in the manufacture of aluminum. Huntington Fluorspar Mines Ltd. operated a plant at Northbrook, Ontario, producing a 5-pound fluorspar briquet from imported metallurgical-grade fluorspar. The briquettes are marketed exclusively by Foseco Canada Ltd., Guelph, Ontario, for foundry use.[6]

Canada's first fluosilicic acid plant was being built by Electric Reduction Co. of Canada Ltd. (ERCO) at Port Maitland, Ontario. A ready market for its 25,000-ton-per-year capacity was expected as several Canadian authorities have started water fluoridation schemes and are buying the acid from the United States. The plant will use fluorine-containing effluent from ERCO's wet-process phosphoric acid and superphosphate plant.[7]

France.—Following the merger of Denain Anzin and Forges Nord-Est, a new company, Denain Anzin Minéraux S.A., was formed to take over the large fluorspar operation at Escaro in the Pyrénées. This was formerly Denain Anzin's "Division des Pyrénées". Production from this operation in 1964 was 96,000 tons of both acid-grade and metallurgical-grade fluorspar.[8]

The Cie. Minière et Métallurgique de l'Indochine, owners of the newest fluorspar mine in France, were absorbed by Dong-Trieu, Société Française Immodilière et Minière. This mine, La Charbonnière, in Haute Vienne, is expected to produce up to 12,000 tons of lump metallurgical-grade fluorspar per year.[9]

Germany, West.—Domestic production of fluorspar continued to decrease in 1965 because of the lack of rich and competitive deposits in the country. The low-quality ore mined had a high quartz content and was increasingly more expensive to mine and beneficiate. Imports increased greatly to fill consumption needs, and jumped to 144,400 short tons, an increase of 62 percent over 1964 fluorspar imports. Principal supplying countries were France, Spain, and mainland China.

The local price for marketable fluorspar averaged $26.31 per metric ton during the first three quarters of 1964 compared with $27.58 in 1963. Lower prices in the face of rising demand were attributed chiefly to the fact that all fluorspar mines in West Germany, except two, are owned by chemical companies. In its dual role of largest producer and consumer, the chemical industry, according to the Minister of Economics, can exert a decisive pressure on keeping prices down.[10]

[6] Bartley, C. M. Fluorspar. Dept. of Mines and Tech. Surveys, Mineral Processing Div., Mines Branch, Ottawa, Canada, 1964, 8 pp.
[7] European Chemical News (London). ERCO to Expend in Canada. V. 7, No. 158, Jan. 22, 1965, p. 16.
[8] Metal Bulletin (London). No. 5037, Oct. 8, 1965, p. 22.
[9] Mining Journal (London). Fluorspar in Strong Demand. V. 265, No. 6792, Oct. 22, 1965, p. 294.
[10] Bureau of Mines. Mineral Trade Notes. V. 61, No. 4, Oct. 1965, pp. 18–19.

Table 12.—World production of fluorspar by countries[1]

(Short tons)

Country[1]	1961	1962	1963	1964	1965[p] [2]
North America:					
Canada[e]	80,000	75,000	85,000	[r] 96,000	107,000
Mexico	[r] 440,286	553,642	530,893	[r] 708,644	801,066
United States (shipments)	197,354	206,026	199,948	217,137	240,932
South America: Argentina	[r] 11,325	[r] 13,799	[r] 10,761	[r] 10,994	[e] 11,000
Europe:					
France	214,936	[3] 154,064	[3] 160,307	[r] [3] 215,119	275,578
Germany:					
East[e]	80,000	80,000	80,000	80,000	90,000
West (marketable)	133,515	116,592	95,843	86,098	85,528
Italy	172,582	[r] 176,709	[r] 148,407	[r] 136,724	162,990
Spain (marketable)	161,954	165,356	169,094	[r] 164,995	244,795
Sewden (sales)	3,542	[r] 3,855	[r] 3,253	[e] 3,300	[e] 3,300
United Kingdom	99,868	79,525	84,878	[r] 131,175	[e] [4] 190,000
Africa:					
Morocco	869	546	7,000	7,242	3,307
Rhodesia, Southern		20	343	77	[e] 165
South Africa, Republic of	95,862	111,683	57,761	66,431	72,517
South-West Africa		240	480		
Tunisia					5,500
Asia:					
China, mainland[e]	220,000	220,000	220,000	220,000	240,000
Japan	16,326	17,120	23,037	[r] 21,078	[e] 22,000
Korea:					
North[e]	33,000	33,000	33,000	33,000	33,000
South	[r] 31,790	36,343	43,855	62,167	43,174
Mongolia	42,000	41,800	[r] 54,000	[e] 62,800	[e] 83,000
Thailand	5,241	11,806	32,221	70,039	57,132
Turkey	42	640	719	1,436	1,187
U.S.S.R.[e] [5]	230,000	265,000	300,000	330,000	385,000
Oceania: Australia			17		
World total[e]	2,275,000	[r] 2,370,000	[r] 2,350,000	[r] 2,730,000	3,170,000

[e] Estimate. [p] Preliminary. [r] Revised.
[1] Fluorspar is also produced in Bulgaria, data not available; estimate included in total.
[2] Compiled mostly from data available July 1966.
[3] Marketable.
[4] Includes fluorspar recovered from old lead and zinc mine dumps.
[5] U.S.S.R. in Europe included with U.S.S.R. in Asia, as the deposits are predominantly in Asiatic U.S.S.R.

Table 13.—International fluorspar trade in 1964

(Short tons)

Producing country	Exports	Principal destination
Argentina	747	All to South America.
Bulgaria	[1] 1,081	All to West Europe.
China, mainland	130,255	Japan 76,112, East Europe 50,596, West Europe 3,547.
France	64,623	West Europe 62,424, East Europe 2,194.
Germany:		
East	17,365	East Europe 12,787, West Europe 4,578.
West	13,604	West Europe 12,683, East Europe 621, United States 300.
Italy	51,432	United States 37,976, Japan 5,512, West Europe 3,147.
Japan	42	All to Asia.
Korea:		
North	6,281	All to Japan.
South	35,572	All to Asia.
Mexico	693,011	United States 550,407, Canada 140,717, Asia 573.
Mongolia	73,304	All to East Europe.
Morocco	9,974	West Europe 9,725, Africa 249.
South Africa, Republic of	56,564	Japan 30,865, West Europe 11,282, United States 6,326, Australia 2,943, South America 1,194, Africa 764.
Spain	151,366	United States 95,654, West Europe 27,873, Japan 27,839.
Sweden	65	All to West Europe.
Thailand	42,622	All to Asia.
United States	3,702	Canada 3,574, South America 80, Africa 10.

[1] Incomplete data.

India.—The Gujarat Mineral Development Corp. (GMDC) began building India's first fluorspar beneficiation mill and hoped to have it in operation in 1967. The Geological Survey of India completed a special program to map and evaluate fluorspar deposits of the Gujarat district and reported ore reserves totaled 11.6 million tons. Engineers for the GMDC (a State-sponsored company) completed an investigation of a mill site, water and power supplies, etc. The National Metallurgical Laboratory began pilot-plant flotation tests on samples of ores in the area.[11]

A new pilot plant to produce sodium fluoride, recovered from the fluorine-containing effluent in the wet phosphoric acid-making process, was opened at Eloor by Fertilizers & Chemicals Travancore Ltd. The company developed a process by which fluorine is recovered and treated in the pilot plant to produce sodium fluoride. The pilot plant, said to be the first of its kind, will soon be developed into a large plant with a capacity of about 15 tons of sodium fluoride per day.[12]

By the second quarter of 1966 the Indian company, Mafatlal Fine Spinning and Manufacturing Co. Ltd., hopes to have a fluorocarbon plant in trial operation. A letter of intent was granted by the Indian Goverment to the company to build a plant with a capacity of 1,200 tons per year of these versatile products.[13]

Italy.—Sarramin-Sarrabus, S.M.p.A., was loaned $400,000 to develop large deposits of fluorspar near Fluminimaggiore in southern Sardinia. The company, part of the Edison group, planned to produce between 40,000 and 60,000 tons of fluorspar and barite concentrate annually.[14]

Montecatini, Soc. Generale per l'Industria Mineraria e Chimica was milling about 360 tons of fluorite-base metal ore per day and recovering 200 tons per day of fluorspar (95.7 percent CaF_2) at its Prestavel mine near Trento. Ore was mined by overhandstoping from a steeply dipping vein cutting quartz porphyries and a series of sediments.[15]

Japan.—A new fluorochemicals plant was opened at Shimizu, about 80 miles southwest of Tokyo. Owned equally by E. I. du Pont de Nemours & Co., Inc. and Japan's Nitto Chemical Industry, the plant has an annual capacity of 2 million pounds of polytetrafluoroethylene (PTFE) and 29 million pounds of Freons. It is Japan's second PTFE facility.[16]

A Japanese trading company, Kamisho Co., concluded a contract with the China National Metals and Minerals Import and Export Corporation for an undisclosed tonnage of metallurgical-grade fluorspar. China has supplied fluorspar to Japan for a number of years, but this is the first time a private company has been able to conclude a contract. Kamisho Co. specializes in supplying the Japanese steel industry.[17]

Netherlands.—Du Pont de Nemours (Nederland) NV announced that it would begin production of fluorinated hydrocarbons in Europe at its Dordrecht site. Plants are to be built for the production of PTFE—fluorocarbon resins and some special types of Freon fluorocarbon products. Construction, under the supervision of the Du Pont engineering department, was scheduled to start as soon as the necessary building permits were granted by the Netherland authorities. The plants are due on stream in 1967.[18]

Work began on Zinc-Organon CV's plant at Budel for the production of fluorocarbons and other fluorine-based chemicals manufactured from fluorspar.[19]

Norway.—Kaiser Chemicals, a division of Kaiser Aluminum & Chemical Corp., formed a partnership with Norsk Spraengstofindustri, Norwegian producers of explosives, plastics, and sulfuric acid, to construct and operate an aluminum fluoride plant at Eugene. The plant will have an annual capacity in excess of 10,000 tons and will require an investment of about $2 million. The Norwegian company will have a 60-percent interest and Kaiser a 40-percent interest in the venture. Under the partnership arrangement, Kaiser Chemicals will provide technical assistance and

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[11] World Mining. V. 18, No. 11, October 1965, p. 82.
[12] Chemical Trade Journal & Chemical Engineer (London). Plant to Produce Sodium Fluoride. V. 157, No. 4078, Aug. 5, 1965, p. 150.
[13] European Chemical News (London). Indian Fluorocarbon Plant Gets Go-Ahead. V. 7. No. 169, Apr. 9, 1965, p. 20.
[14] Metal Bulletin (London). No. 5041, Oct. 22, 1965, p. 27.
[15] World Mining. V. 18, No. 3, March 1965, p. 83.
[16] Chemical & Engineering News. Shinto Rite Opens Plant. V. 43, No. 22, May 31, 1965, p. 30.
[17] Metal Bulletin (London). No. 5037, Oct. 8, 1965, p. 22.
[18] Chemical Age (London). Du Pont Fluorocarbons for Europe. V. 94, No. 2401, July 17, 1965, p. 81.
[19] Metal Bulletin (London). No. 5051, Nov. 26, 1965, p. 28.

supply alumina trihydrate and fluorspar, and Norsk Spraengstofindustri, merchant sulfuric acid producers, will manage the operation and supply the acid.[20]

Spain.—S.A. Azamon, a subsidiary of Imperial Chemical Industries Ltd., joined with Industrial Comas Ing. to manufacture chlorofluorohydrocarbons in Spain. A new company, ICI–Comas S.A., was formed to manufacture these chemicals. Industrial Comas Ing. had been the major producer in Spain. Production of the chemicals, which are to be sold by ICI in worldwide markets, was expanded at the existing factory in Barcelona as a preliminary to the construction of a new plant with a capacity of 5,000 tons per year. The chlorofluorohydrocarbons are used as refrigerants, aerosol propellents, and in plastic foams.[21]

South Africa, Republic of.—An expansion program was underway by General Mining & Finance Corp. Ltd. through its subsidiary Transvaal Mining & Finance at the Buffalo fluorspar mine which it acquired in 1963. The company estimated the fluorspar reserve of the Buffalo mine to be 4.8 million tons. This expansion project was designed to triple mine output to 1,800 tons per month and was scheduled for completion by October 1965. Most of the additional production will be acid grade for export to Japan.[22]

Tunisia.—The Hamman Zriba fluorspar mine, which has been closed for over 10 years, was reopened. Output is expected to reach 25,000 tons of acid-grade fluorspar and 35,000 tons of barite a year.[23]

United Kingdom.—Glebe Mines Ltd., a member of the Laporte Industries Ltd., officially opened a new fluorspar processing plant at Eyam, Derbyshire, in September. Crude fluorspar feed for the mill was obtained from the mineral deposits of the Southern Pennine orefield in north Derbyshire. The deposits consist essentially of fissure veins and bedded replacement flats. The plant, known as the Cavendish mill, is probably the largest and most advanced fluorspar mill in Europe, if not in the world. The mill flowsheet may be divided into five sections as follows: Crushing, washing, and sizing; dense media section; grinding and classification; flotation and filtration; and drying and storage. Annual capacity is 100,000 tons of fluorspar concentrate (70,000 tons of acid grade). It can also produce up to 18,000 tons per year of barite and 3,900 tons per year of lead as byproducts. This new plant will supply Laporte Acids Ltd., of Rotherham, a large-scale producer of fluorine compounds. Exports will account for more than a quarter of the sales from Glebe.[24]

TECHNOLOGY

Few changes in technology were reported regarding the mining and processing phases of the fluorspar industry. Significant equipment modifications were limited to those changes made to suit individual producer's desires or needs. In an effort to lower mining costs the trend toward greater mechanization of mines continued.

Metallurgical processes for beneficiating crude fluorspar also remained essentially unchanged. A new patent was issued regarding the use of tannic acid in a process for the froth flotation beneficiation of fluorspar ore. As described in this patent, the ore is pulped and reconditioned with tannic acid-containing quebracho or another acidulating depressant. The temperature is maintained above 70° F, and the treated pulp is conditioned with the usual soda ash and oleic acid before being subjected to froth flotation. Use of the tannic acid lowers the pulp alkalinity required in the subsequent flotation operation.[25]

The greatest technological advances affecting the fluorspar industry occurred in the field of fluorine chemistry. Fluorspar serves as a source of fluorine atoms and is the starting material for the synthesis of many fluorine chemicals. One such fluorine chemical adds water, oil, and stain resistance to fabrics treated with it. The fluorine-based finish and permanent press processes have been coapplied by licensed mills to synthetic-blend fabrics.

Based on their research work, one com-

[20] Chemical Age (London). Kaiser to Participate in Norwegian Fluorides Plant. V. 93, No. 2387, Feb. 6, 1965, p. 218.

[21] Chemical Trade Journal and Chemical Engineer (London). ICI Link in Greater Production of Chlorofluorohydrocarbons. V. 156, No. 4052, Feb. 4, 1965, p. 145.

[22] Bureau of Mines. Mineral Trade Notes. V. 62, No. 1, Jan. 1966, pp. 12–14.

[23] Metal Bulletin (London). No. 5046, Nov. 9, 1965, p. 22.

[24] Mining & Minerals Engineering (London). The Cavendish Mill. V. 1, No. 15, November 1965, pp. 579–586.

Mining Journal (London). New Plant in Derbyshire. V. 265, No. 6787, Sept. 17, 1965, p. 196.

[25] Thom, C. (assigned to The Dow Chemical Co.). Process for the Froth Flotation Beneficiation of Fluorspar Ore. U.S. Pat. 3,207,304, Dec. 1965.

pany concluded that fluorine may be close to the ideal propellant additive to boost payload capability and cost efficiency of existing, fully developed rocket systems. The study considered various means of uprating the systems. It looked at important characteristics of propellants—specific impulse, propellant density, compatibility, and safety. The report also pointed out that the additive should mix with the solvent propellant, should not separate on standing, and should pose no special cleaning problems. It was concluded that fluorine as an additive compares favorably with other uprating systems in terms of costs, schedules, and performance.[26]

A high-energy, high-density monopropellant containing liquid fluorocarbons was described in a recent patent. It consists essentially of from 20 to 40 percent by weight of magnesium, aluminum or boron metal powder, having a particle size range from about 1 micron to about 300 microns, with the remainder a liquid fluorocarbon.[27]

A new fabricating technique has made available new fluorocarbon (PTFE) products in fibrous, porous forms. Gossamer-like tissue, gauze, multilayer felt, filter paper, crepe, membranes, mattes, and many different simulated textile configurations can now be produced from this heat- and chemical-resistant material. Other advantages of fluorocarbons in these many forms include low moisture absorption, resistance to fungus, excellent dimensional stability, long flex life, high wet-strength, and a very low coefficient of friction.

This new versatility of available forms, combined with the outstanding properties of fluorocarbon plastics, are being evaluated in a wide range of applications. Some of these applications include absolute filter paper, heart-lung machine membranes, nonstick bandages, dielectric and insulating tapes, dry-lubricating packing, and cryogenic insulation. Other potential uses include demisting pads for distillation, extraction and absorption columns; high surface-area column packing; molded porous shapes for internal-combustion-engine air filters; biological and pharmaceutical filters; and nonchaffing liners for cloths and orthopedic devices.[28]

Liquid fluorocarbons are now invading the long-life enamel market. As a result of joint development between producers and users, a number of formulators are offering factory-applied external finishes containing polyvinylidene fluoride. Formulators are predicting 30-year maintenance-free life for these finishes. The properties that polyvinylidene fluoride brings to the paint industry are broad chemical resistance, high mechanical strength, good abrasion resistance, and excellent resistance to degradation by ultraviolet light. The market for long-life coated metal includes industrial plants and warehouses, mobile homes, hospitals, apartment houses, and residential homes. Areas under development include highway signs, railroad cars, ships, and agricultural and industrial equipment.[29]

Tubes made of PTFE made possible the development of heat-exchange equipment that requires little space and is free from fouling and corrosion problems. The developing company stated that these heat exchangers have the capacity of a conventional metal-tube type that is five times as large. Resistance of the fluorocarbon to chemical attack permits its use with corrosive liquids and gases.[30]

Now being offered for sale are single crystals of optical-quality magnesium fluoride for use in polarizing prisms, lenses, and windows. The crystals are said to be good polarizers especially in the ultraviolet and infrared regions of the spectrum.[31]

[26] Chemical Week. V. 97, No. 22, Nov. 27, 1965, p. 58.

[27] White, W. D., D. M. Chin, and J. L. Jones (assigned to the U.S. Navy). Monopropellants Containing Liquid Fluorocarbons. U.S. Pat. 3,164,504, Jan. 5, 1965.

[28] Materials in Design Engineering. Fluorocarbons Available in New Fibrous, Porous Configurations. V. 61, No. 5, May 1965, pp. 5–7.

[29] Chemical Engineering. Liquid Fluorocarbons Invade Long-Life Enamel Market. V. 72, No. 8, Apr. 12, 1965, p. 110.

[30] Chemical & Engineering News. Teflon Makes Strides in Heat Exchangers. V. 43, No. 22, May 31, 1965, pp. 44–45.

[31] Chemical Week. V. 96, No. 21, May 22, 1965, p. 107.

CRYOLITE

Natural cryolite from Greenland was imported into the United States in crude form and processed by the only importer, the Pennsalt Chemicals Corp., at its Natrona, Pa., flotation mill. This was the 100th anniversary of the importation of cryolite ore from Greenland by Pennsalt Chemicals Corp. Cryolite importation was begun by Pennsalt under a contract negotiated in 1865 with the Danish Government, owners of the world's largest cryolite deposit.

Synthetic cryolite was produced by Kaiser Aluminum & Chemical Corp. at Chalmette, La., and by Reynolds Metals Co. at Bauxite, Ark. Cryolite was reclaimed from scrapped pot linings by Aluminum Company of America at Point Comfort, Tex.; by Kaiser Aluminum & Chemical Corp. at Chalmette, La., and Spokane, Wash.; and by Reynolds Metals Co. at Listerhill, Ala., Longview, Wash., Corpus Christi, Tex., Troutsdale, Oreg., Massena, N.Y., and Gum Spring, Ark.

Kaiser Aluminum & Chemical Corp. announced plans to increase synthetic cryolite production capacity by 50 percent at its Chalmette, La., plant. The capacity will be raised from 20,000 to 30,000 short tons per year with the additional tonnage becoming available during the last half of 1966. Cryolite is the igneous bath material in which alumina is dissolved through the electrolytic reduction process.

PRICES

Prices of cryolite remained unchanged from previous years. The Oil, Paint and Drug Reporter quoted the following prices for cryolite in 1965: Cryolite, natural, industrial, in bags, carlots, at works, 100 pounds, $13; and in bags, less than carlots, at works, 100 pounds, $14.25.

FOREIGN TRADE

Exports of synthetic cryolite were not separately classified for statistical compilations in 1965. The import statistics shown in table 14 do not distinguish between natural and synthetic cryolite, but it is believed that virtually all of the shipments from countries other than Greenland were synthetic cryolite.

Table 14.—U.S. imports for consumption of cryolite

Year and country	Short tons	Value
1962	12,472	$933,011
1963	26,915	1,807,729
1964:		
North America: Greenland [1]	18,531	727,675
Europe:		
Germany, West	66	21,284
Italy	5,645	1,011,060
Netherlands	22	4,932
Total	24,264	1,764,951
1965:		
North America: Greenland [1]	18,026	793,147
Europe:		
France	200	34,893
Germany, West	150	51,195
Italy	5,332	1,067,716
Spain	303	61,600
Total	24,011	2,008 551

[1] Crude natural cryolite.

Gem Stones

By Benjamin Petkof [1]

Gem stone production during 1965 was estimated at $2.2 million, an increase of 50 percent over last year. Amateur collectors continued to be the principal collectors of domestic gem material.

DOMESTIC PRODUCTION

Production estimates show that 38 States produced gem material during the year. Oregon, California, Texas, Idaho, Arizona, Wyoming, and Nevada were the leading producing States. The estimated value of production was 50 percent more than in 1964.

During the year the excise tax on gem materials was removed. This appeared likely to promote increased sales of gems and gem materials.

Very well-formed augite crystals were found on the west rim of the Haleakala Crater, Island of Maui, Hawaii. Most of the crystals were single but contact and penetration twins were also found. The largest one found was eleven-sixteenth of an inch long.[2] Wavellite was identified in the King turquoise mine in the San Luis Valley, Colo.[3]

CONSUMPTION

Gem diamond consumption reached $307 million, an increase of almost 19 percent over that of 1964. Value of imported synthetic and imitation gem stones including imitation pearl was $7.1 million, an increase of 16 percent over that of 1964 and value of natural and cultured pearls was $22.2 million, an increase of 13 percent over that of 1964.

Apparent consumption (domestic production plus imports minus exports) was $248 million, an increase of 31 percent over that of 1964.

PRICES

At midyear, prices for cut and polished, unmounted gem diamond were 0.25 carat $75 to $275; 0.50 carat $200 to $725; 1 carat $400 to $1,900; and 2 carats $1,250 to $5,500.

FOREIGN TRADE

Precious and semiprecious gem stone exports were valued at $47.1 million, compared with $46.8 million in 1964. Diamond, both rough and uncut, accounted for the bulk of the exports.

Reexports of all varieties of gem stone were valued at $60.5 million, compared with $64.3 million in 1964. Diamond made up the major portion of total reexports.

India provided 73 percent of the emerald (cut but unset) imported during the

[1] Commodity specialist, Division of Minerals.
[2] Pemberton, Earl H. Augite Crystals at Haleakala Crater, Hawaii. Gems and Minerals, No. 331, April 1965, p. 42.
[3] Rock Products. Rare Wavellite Found in King Mine. V. 68, No. 4, April 1965, p. 122.

Table 1.—U.S. imports for consumption of precious and semiprecious stones, exclusive of industrial diamond

Stones	1964 Quantity	1964 Value (thousands)	1965 Quantity	1965 Value (thousands)
Diamond:				
Rough or uncut, suitable for cutting into gem stones, duty-free ---- carats--	1,547,955	$149,729	1,900,936	$175,457
Cut but unset, suitable for jewelry, dutiable--do-----	1,096,795	108,805	1,258,745	131,828
Emerald: Cut but not set, dutiable----do-----	180,069	3,218	189,828	5,397
Pearls and parts, not strung or set, dutiable:				
Natural----	NA	474	NA	592
Cultured or cultivated----	NA	19,204	NA	21,674
Other precious and semiprecious stones:				
Rough or uncut, duty-free----	NA	2,514	NA	2,728
Cut but not set, dutiable----	NA	r 7,441	NA	8,901
Imitation, except opaque, dutiable:				
Cut or faceted:				
Synthetic----number--	1,218,326	623	2,526,418	1,007
Other----	NA	5,825	NA	5,429
Imitation, opaque, including imitation pearls, dutiable-	NA	337	NA	415
Marcasites: Real and imitation, dutiable----	NA	r 2	NA	3
Total----	NA	r 298,172	NA	353,431

r Revised. NA Not available.

year. The remainder was supplied by 25 other countries. Indian emerald imports had an average value of $16.20 per carat.

Ruby and sapphire (cut but unset) were imported from 20 countries, with India and Thailand supplying over 50 percent of the total value of almost $4.8 million.

Japan supplied 97 percent of the cultured-pearl imports by value but only 8 percent of the natural pearl imports. India supplied 66 percent by value of the natural pearl imports.

Table 2.—U.S. imports for consumption of diamond (exclusive of industrial diamond), by countries

Country	1964				1965			
	Rough or uncut		Cut but unset		Rough or uncut		Cut but unset	
	Carats	Value (thousands)	Carats	Value (thousands)	Carats	Value (thousands)	Carats	Value (thousands)
Argentina							15	$18
Australia	24	$10						
Austria			584	$35			255	40
Barbados			81	11	925	$14		
Belgium-Luxembourg	77,728	9,264	583,207	60,155	74,979	7,597	679,614	73,923
Brazil	1,329	196	5	3	4,185	293	1,014	97
British Guiana	10,156	383			19,295	742	40	5
Canada	7,753	1,200	227	28	7,139	1,138	349	44
Central African Republic	102,919	5,451			144,209	8,365		
Ceylon							177	20
Congo (Léopoldville)	236	71			928	63		
Denmark							2	(1)
France	6,066	435	15,781	1,678	1,642	70	15,675	1,665
Germany, West			18,040	1,335			18,507	1,370
Ghana	858	53			2,883	146	183	16
Guinea	2,774	418			2,065	205		
Hong Kong			329	41	15	3	4	1
India			535	111			2,469	342
Iran							23	55
Ireland	3,616	464			4,114	71	47	3
Israel	49,011	3,800	426,052	36,800	56,681	3,310	472,602	42,134
Italy			84	17			13	9
Ivory Coast					188	29		
Jamaica	18	5					178	13
Japan			1,541	95	46	8	1,276	142
Korea, South			61	3				
Lebanon							28	8
Liberia	8,417	806			6,598	674		
Malaysia					67	4		
Malta and Gozo			205	16				
Netherlands	39,265	4,179	14,358	1,896	33,524	4,094	20,772	2,835
Netherlands Antilles			22	18			7	4
New Guinea					349	38		
New Zealand			74	7				
Nigeria					961	108		
Panama							2	1
Peru							55	6
Poland							158	11
Portugal			33	4				
Senegal	128	17						
Sierra Leone	72,153	2,867			44,161	2,818		
South Africa, Republic of	138,015	12,162	23,721	4,918	158,539	15,330	27,223	6,166
Switzerland	33,748	2,192	783	364	104,044	9,879	1,142	633
Trinidad and Tobago			95	13				
U.S.S.R.			5,590	503			11,289	1,410
United Kingdom	894,260	100,928	5,387	754	1,141,833	113,481	5,626	857
Venezuela	78,486	2,960			54,448	1,950		
Western Africa, n.e.c.[2]	20,995	1,868			34,973	4,903		
Western Portuguese Africa, n.e.c.[2]					2,145	124		
Total	1,547,955	149,729	1,096,795	108,805	1,900,936	175,457	1,258,745	131,828

[1] Less than ½ unit.
[2] Not elsewhere classified.

WORLD REVIEW

Angola.—The Angolan Diamond Company produced diamond in excess of 1 million carats during the year. During 1964 the company produced almost 1.15 million carats. Rubble processed in 1964 yielded 0.37 carat per cubic meter. The company intends to contract for additional prospecting teams to mark and map claims for exploitation when its present contract terminates in 1971.

Basutoland.—Two large diamonds, weighing 103 and 527 carats were found at the Letseng-la-Terae native diamond diggings in northeast Basutoland. They

Table 3.—World production of diamond, by countries
(Thousand carats)

Country	1964 Gem	1964 Industrial	1965 Gem	1965 Industrial
Africa:				
Angola	804	345	878	277
Central African Republic	221	221	268	268
Congo (Brazzaville) [1] [2] [e]	316	4,949	318	4,982
Congo (Léopoldville)	295	14,457	14	12,490
Ghana	267	2,402	225	2,023
Guinea [1]	r 21	r 51	e 21	e 51
Ivory Coast	120	80	116	77
Liberia [1]	298	272	277	263
Sierra Leone	r 585	r 878	e 658	e 804
Republic of South Africa:				
Pipe mines:				
Premier	556	1,668	e 654	e 1,963
De Beers group [3]	928	759	e 1,119	e 916
Others	18	41	e 18	e 42
Alluvial	288	192	e 188	e 126
South-West Africa	r 1,387	154	1,432	158
Tanzania	r 338	326	e 414	e 414
Total Africa	r 6,442	r 26,795	6,600	24,854
Other countries:				
Brazil [e]	175	175	175	175
British Guiana	60	49	45	68
India	2	1	4	1
U.S.S.R. [e]	240	2,760	300	3,200
Venezuela	58	58	46	45
World total [4]	r 6,977	r 29,838	7,170	28,343

e Estimated. r Revised.
[1] Exports.
[2] Probable origin, Republic of the Congo.
[3] Includes some alluvial from De Beers Properties.
[4] Does not include minor world production.

were found by native Africans, using hand methods.[4]

Bechuanaland.—Kimberlite Searches Ltd., a De Beers Consolidated Mines Ltd. subsidiary has found indications of diamond in northern Bamangwato Tribal Territory, west of Francestown.[5]

Belgium.—About 4.93 million carats of rough cuttable diamond was imported during 1964, an increase of about 11 percent over 1963 imports. Polished diamond imports reached 304,000 carats, an increase of 2 percent over 1963 imports. During the first 9 month of 1965 about 3.72 million carats of cuttable and 241,000 carats of polished diamond had been imported.

Exports of cuttable and polished diamond reached 1.02 million and 1.33 million carats, respectively, in 1964. During the first 9 months of 1965, 762,000 carats of cuttable and 1.04 million carats of polished diamond were exported. The major portion of polished diamond went to the United States, the United Kingdom, and Hong Kong.[6]

Chile.—The only producer, Compañia Minera Caren, mined about 36,400 pounds of lapis lazuli during 1964. The company has arranged to sell about 22,000 pounds of material to a New York importing firm. Deliveries are expected to extend into 1966. About 12,000 pounds of lapis lazuli, valued at $15,492, was exported to West Germany, Hong Kong, Italy, and the United States.[7]

Dahomey.—The Government issued the first license for diamond pospecting to De Beers Consolidated Mines Ltd., London. Plans include prospecting in the Dassa-Zoumé foothills and the area to the north.[8]

Indonesia.—A Netherland firm will assist the Indonesian Government in developing the Kalimantan diamond fields. Reports indicated that these deposits contain primarily gem quality diamond.[9]

[4] Bureau of Mines. Mineral Trade Notes. V. 62, No. 1, January 1966, pp. 8–9.
[5] Mining Journal (London). V. 264, No. 6763, Apr. 2, 1965, p. 251.
[6] Bureau of Mines. Mineral Trade Notes. V. 62, No. 3, March 1966, pp. 8–9.
[7] Bureau of Mines. Mineral Trade Notes. V. 61, No. 4, October 1965, p. 29.
[8] Bureau of Mines. Mineral Trade Notes. V. 62, No. 2, February 1966, p. 9.
[9] Bureau of Mines. Mineral Trade Notes. V. 61, No. 3, September 1965, p. 24.

Israel.—Imports of raw diamond material reached about \$96.7 million in 1965. Exports of polished diamond were valued at \$131.76 million.[10]

Sierra Leone.—The Parliament approved the agreement between the Sierra Leone Government and the New York firm of Leon Tempelsman & Son to establish a diamond cutting and polishing industry. The firm will have a 10-year monopoly of diamond cutting and polishing in the country. Complete details of this agreement have been published.[11]

South Africa, Republic of.—Late in 1964, the Commissioner of Patents awarded four patents to the General Electric Co. relating to the manufacture of synthetic diamond. The Transvaal and Orange Free State Chamber of Mines has requested permission to appeal the patent award.[12]

South-West Africa.—In May 1965, De Beers Consolidated Mines Ltd. announced through its subsidiary, Consolidated Diamond Mines of South-West Africa Ltd. (CDM), that a 29-percent interest in the Marine Diamond Corp. Ltd. (MDC), had been acquired. MDC recovered diamond from shallow water concessions of the South-West African coast. In addition, CDM transferred its coastal strip concession between high and low water mark to MDC.[13]

In October, Orama Holding Ltd. was formed by CDM and other MDC stockholders. Ownership of 58 percent of CDM's stock gave Orama controlling interest.

The exploration vessel "Rockeater" was purchased by De Beers to continue evaluation of offshore mineral concessions. This vessel was previously used to evaluate MDC offshore concessions for De Beers.

During 1964, MDC recovered 286,651 carats of diamond. During 1965 production of almost 219,000 carats of diamond was lower because of bad weather and accidents.[14]

TECHNOLOGY

A method was developed to grow single alumina crystals by vapor-deposition. For constant gas compositions and flow rates, the growth rate varied directly with temperature. Crystal growth rate varied up to 90 milligram per square centimeter per hour. Analysis showed impurities to be less than 30 parts per million. Substrate temperature, total pressure, and reactant gas partial pressures controlled crystal structure.[15]

A new theory has been published about the origin of the diamonds found in the glacial drift in Ohio, Indiana, Michigan, and Wisconsin. The theory proposes that the diamonds had been carried south from an ancient meteorite crater located in an area in southeastern Hudson Bay. When the meteorite impacted, the deep mantle rock breccia, containing diamonds, was brought to the surface in a central uplift as found in lunar craters. After the crater formed, it was filled with sediments which lithified. It is conjectured that these rocks slid by gravity from the crater center as it was uplifted, reexposing the diamond-bearing rocks.[16]

Volume compression measurements were made on sapphire, rutile, and spinel to a maximum pressure of 10,000 atmospheres. The data were reported as the constants of an empirical equation.[17]

Methods were developed to produce gem-quality synthetic emerald. Material was grown by hydrothermal techniques in a high-pressure bomb on seed plates cut parallel to a pyramid face. The techniques used were similar to those used for quartz crystal synthesis.[18] Gem material was crystallized in 2 minutes from beryl powder at pressures in excess of 10,000 atmospheres. Color was controlled by the quan-

[10] Mining Journal (London). V. 266, No. 6805, Jan. 21, 1966, p. 51.

[11] Bureau of Mines. Mineral Trade Notes. V. 61, No. 1, July 1965, p. 13.

[12] Bureau of Mines. Mineral Trade Notes. V. 61, No. 6, December 1965, p. 12.

[13] Bureau of Mines. Mineral Trade Notes. V. 61, No. 2, August 1965, pp. 24–26.

[14] Bureau of Mines. Mineral Trade Notes. V. 62, No. 2, February 1966, pp. 9–12.

[15] Schaffer, Philip S. Vapor-Phase Growth of Alpha Alumina Single Crystals. J. Am. Ceram. Soc., v. 48, No. 10, October 1965, pp. 508–511.

[16] Schwarcz, H. P. The Origin of Diamonds in Drift of the North Central United States—Geological Notes. J. of Geol., v. 73, No. 4, July 1965, pp. 657–663.

[17] Weir, C. E. Compressibility of Eleven Inorganic Materials. NBS J. of Res., v. 69A (Phys. and Crem.), No. 1, January–February 1965, pp. 29–31.

[18] Pough, Frederick H. The New Linde Synthetic Emerald. Jewelers' Circular-Keystone, v. 135, No. 12, August 1965, pp. 126–142.

tity of metallic oxides in the beryl powder.[19]

Ruby crystals have been grown experimentally from solution in molten lead fluoride. The solvent was chosen from a group having preferred properties. Crystals were grown under three sets of experimental conditions in a sealed platinum crucible that was in a high-temperature furnace. The results of the experiments were discussed.[20]

Structure was determined by studying etch patterns on polished diamond surfaces. The surfaces were etched at an elevated temperature with potassium nitrate. Several etch patterns were obtained. Rectilinear structures corresponded to a layered growth. Curved lines indicated growth interference. Additional conclusion concerning growth were derived based on observed patterns.[21]

Various microstructure patterns have been observed concurrently on the surfaces of diamonds obtained from the Panna mines in India. Observations indicate that these diamonds may have been subjected to solution in nature.[22]

A more efficient method to make girdles on precious and semiprecious gem stones has been described. Two rough stones are arranged to work the edges of each other's table while their axes of rotation are at right angles. While working against each other, round girdles are formed on both stones simultaneously.[23]

A method was reported to convert a used garbage disposal unit in an efficient lapping and grinding unit.[24]

Waste has been reduced in cutting cabachons from semiprecious material. A slab of material is faced with gem-defining patches. These patches are sawed off with straight line cuts. The edges are ground off to the patch. The patch is removed, and the cabachon is completed.[25]

A method was developed to produce large synthetic diamond crystals from a diamond seed. The method can be used to grow diamond in a batch or a continuous process at comparatively low temperature and pressure.[26]

A device has been designed to finish and to polish semiprecious gem stones quickly by applying a high-frequency vibration to a plastic-lined container, mixing and tumbling the charge of gem stone and abrasive completely.[27]

A method to synthesize diamond particles by using an electric discharge across a spark gap has been developed. One or both of the electrodes contain elemental carbon and are immersed in a dielectric liquid. Repeated discharges provide an elevated pressure and temperature that converts particles of carbon to diamond.[28]

An apparatus has been built to inspect a mounted or unmounted gem stone. A magnified image is projected which makes any flaw easily visible.[29]

A method was developed to join two brilliant-cut natural diamonds to form a large composite doublet stone in a marquise form.[30]

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[19] Hickman, Bill. Synthetic Emerald Process May Aid Laser, Maser R&D. Electronic News, v. 10, No. 484, Apr. 12, 1965, p. 44.

[20] White, E. A. D., and J. W. Brightwell. The Growth of Ruby Crystals From Solution in Molten Lead Fluoride. (Paper pres. at the Symp. on Inorganic Single Crystals in London, Apr. 12–13, 1965). Chem. and Ind. (London), No. 39, Sept. 25, 1965, pp. 1662–1668.

[21] Seal, Michael. Structure in Diamonds as Revealed by Etching. Am. Mineralog., v. 50, No. 1 and No. 2, January–February 1965, pp. 105–123.

[22] Patel, A. R., and M. K. Agarwal. Microstructures on Panna Diamond Surfaces. Am. Mineralog., v. 50, No. 1 and No. 2, January–February 1965, pp. 124–131.

[23] Roos, S. (assigned to Nederlandse Organisatie voor Toegepast-Natuurwetenschappelijk Onderzoek ten behoewe van Nijerheid Handel en Verkeer, The Hague, Netherlands). Method for Making Girdles. U.S. Pat. 3,202,147, Aug. 24, 1965.

[24] Redmond, Gordon. At Your Disposal. Gems and Minerals, September 1965, pp. 16–18.

[25] Drown, C. R. Method of Gem Cutting. U.S. Pat. 3,211,141, Oct. 12, 1965.

[26] Brinkman, J. A., C. J. Meecham, and H. M. Dieckamp (assigned to North American Aviation, Inc.). U.S. Pat. 3,175,885, Mar. 30, 1965.

[27] Smith, E. E. Apparatus for Agitating and Polishing Materials. U.S. Pat. 3,197,922, Aug. 3, 1965.

[28] Inoue, Kiyoshi. Method of Synthesizing Diamond Particles by Utilizing Electric Discharge. U.S. Pat. 3,207,582, Sept. 21, 1965.

[29] Robinson, D. A., L. M. Robinson, and J. Dods. Apparatus for Viewing Gems and Similar Objects. U.S. Pat. 3,225,647, Dec. 28, 1965. Australian Pat. 249,602, Feb. 13, 1964.

[30] Sirakian, C., and Fils. British Pat. 1,005,060, Sept. 22, 1965.

Gold

By J. Patrick Ryan [1]

The inauguration of the Carlin mine and a rise in gold production to the highest level since 1960 were salient features of the domestic gold-mining industry in 1965. The production gain was the second consecutive annual increase in gold output. World gold production increased for the 12th consecutive year, again establishing an alltime record.

The gain in U.S. gold production came chiefly from new production at the Carlin gold mine in Nevada and from increased output of gold-bearing copper ore at the Utah Copper mine in Utah which more than offset production losses in most other gold-producing States. As in several preceding years, the gain in world output of gold was attributed almost entirely to increased production from South African gold mines which contributed 64 percent of the estimated world gold production.

Consumption of gold in domestic arts and industries again increased reaching an alltime record, more than three times domestic mine production.

A sharp rise in the outflow of gold reduced the U.S. gold stock to $13,806 million at yearend, the lowest level since 1938. The estimated free world official gold reserve was about $43,310 million at yearend, a gain of $250 million for the year.

Legislation and Government Programs.—Two groups of bills to aid the domestic gold-mining industry through the establishment of premium prices or cost differential payments were introduced in the 89th Congress, 1st Session. The first group includes H.R. 6505, H.R. 799, H.R. 10681, H.R. 5272, and S. 1377 which were similar to H.R. 9756 and S. 2125 introduced in the 88th Congress on which Executive agencies issued unfavorable reports. Es-

[1] Commodity specialist, Division of Minerals.

Table 1.—Salient gold statistics

	1956–60 (average)	1961	1962	1963	1964	1965
United States:						
Mine production. thousand troy ounces	1,726	1,548	1,543	1,454	1,456	1,705
Value thousands	$60,408	$54,189	$53,990	$50,889	$50,971	$59,682
Ore (dry and siliceous) produced:						
Gold ore thousand short tons	2,316	2,060	2,159	2,459	2,631	3,113
Gold-sliver ore do	190	248	353	223	224	206
Silver ore do	655	565	524	556	542	752
Percentage derived from:						
Dry and siliceous ores	46	48	47	51	54	54
Base-metal ores	35	39	36	36	37	40
Placers	19	13	17	13	9	6
Refinery production thousand troy ounces	1,748	1,567	1,556	1,469	1,469	1,675
Exports [1] do	1,305	22,146	10,884	5,820	12,078	36,717
Imports, general [1] do	7,472	1,615	4,312	1,281	1,169	2,905
Stocks Dec. 31: Monetary [2] millions	$20,540	$16,947	$16,057	$15,596	$15,471	$13,806
Consumption in industry and the arts thousand troy ounces	2,041	2,775	3,576	2,920	4,801	5,276
Price: Average per troy ounce [3]	$35.00	$35.00	$35.00	$35.00	$35.00	$35.00
World: Production thousand troy ounces	39,860	39,650	42,300	44,250	46,100	47,700
Official reserves [4] millions	$39,446	$41,140	$41,470	$42,310	$43,060	$43,300

[1] Excludes coinage.
[2] Includes gold in Exchange Stabilization Fund.
[3] Price under authority of Gold Reserve Act of Jan. 31, 1934.
[4] Held by free world central banks and governments.

sentially, these bills would direct the Secretary of the Interior to compensate eligible gold producers for the difference between production costs in the fourth quarter of 1939 and costs in the fourth quarter of 1963.

The second group of proposed bills which includes S. 2562, H.R. 10924, H.R. 10925, H.R. 11667, and H.R. 11081 would provide financial assistance to eligible gold producers at an annual rate of 5 to 6 percent per year of the value of gold produced with provision for annual increases tied to the Consumer Price Index.

A bill (H.R. 6542) was introduced to establish a gold procurement and sales agency in the Department of the Interior which would buy gold from domestic producers and sell it for nonmonetary use at a price determined by the Secretary of the Interior but not to exceed $105 per ounce. This bill was referred to the Committee on Interior and Insular Affairs. Another bill (H.R. 6504) to permit free marketing of gold and pay a subsidy of $35 per fine ounce for all domestically mined gold was introduced and referred to the Committee on Banking and Currency. A resolution (S. Res. 83) introduced and referred to the Committee on Interior and Insular Affairs would establish a Senate Committee to study the gold-mining situation and recommend appropriate legislation.

A bill (H.R. 3818) to eliminate the requirement that Federal Reserve banks maintain reserves of gold against deposit liabilities became Public Law 89–3. Another bill (S. 2596), to increase the percentage depletion allowance for gold and silver from 15 to 23 percent with an increase in net income limitations from 50 to 75 percent, was introduced and referred to the Committee on Finance.

The Treasury Department amended part 54 of the Gold Regulations by placing additional restrictions on the use of gold in the arts and industry and redefining certain illegal uses. Paragraph 14 redefined "customary" use of gold to prohibit the plating of any coins, the manufacture of gold medals except special award medals, and the acquisition, holding, transportation, importation, or exportation of gold-plated coins or medals, except special awards. A supplementary amendment permitted trading in gold bars having recognized numismatic value.

The Legal and Monetary Affairs Subcommittee of the Committee on Government Operations, House of Representatives, surveyed the gold situation and published a report thereon in July. Data relating to the Nation's gold stock, price, and proposed plans for monetary reform were reviewed, but no specific recommendations were made.

With reference to the dollar-gold relationship, President Johnson stated in his Economic Report to the Congress in January 1965:

> . . . The stability of the American dollar is central not only to progress at home but to all our objectives abroad. There can be no question of our capacity and determination to maintain the gold value of the dollar at $35 an ounce. The full resources of this Nation are pledged to that end. . . .
>
> . . . Clearly, we should place beyond any doubt our ability to use our gold to make good our pledge to maintain the gold value of the dollar at $35 an ounce with every resource at our command. I am requesting the Congress, therefore, to eliminate the requirement that the Federal Reserve banks maintain a gold certificate reserve against their deposit liabilities.

Four contracts aggregating $246,890 were executed during the year for gold exploration under the Government program of financial assistance, administered by the Office of Minerals Exploration, U.S. Geological Survey. The Government share of the exploration cost was 50 percent or $123,445. The following exploration projects were active or in force in 1965:

Operator	*Location*	*Total cost*
American Mining Co	Granite County, Mont	$61,880
High Sierra Mining Co	Sierra County, Calif	25,350
Homestead Gold Exploration Corp	Plumas County, Calif	26,400
L–D Mines	Chelan County, Wash	133,260
Ivers Mining Co., Inc	Esmeralda County, Nev	46,773
Austin H. Merrill	Shasta County, Calif	41,860
Pyramid Mines, Inc	Mariposa County, Calif	42,200

Operator	*Location*	*Total cost*
Mugwump Mining Co	Sierra County, Calif	$70,440
W. S. Moore Co	Rio Grande County, Colo	81,680
Ruby Silver Mines, Inc	Jefferson County, Mont	132,800
Original Sixteen to One Mine, Inc	Sierra County, Calif	43,300
Clyde D. Painter	Idaho County, Idaho	41,830
Vitro Minerals Corp	Fergus County, Mont	93,740
Keystone Mines, Inc	Fairbanks Dist., Alaska	79,900
Dickey Exploration Co	Sierra County, Calif	50,320
Best Mines, Inc	do	80,090
Frank O. Richardson	San Juan County, Colo	57,300
Total		1,109,123

DOMESTIC PRODUCTION

A 17-percent gain in U.S. gold production resulted chiefly from sharp increases in gold output in Utah and Nevada. These gains, combined with small increases in South Dakota and New Mexico, more than offset production losses in other gold-producing States. Notwithstanding the overall gain in domestic gold output, increasing production costs in relation to the fixed price of gold continued to have an unfavorable effect on gold-mining operations. The rise in labor and supply costs was offset to some extent by improved operating techniques and by treating higher grade ore, but depletion of minable reserves forced some mines to close.

The Homestake Mining Co. reported a new high in the quantity of gold produced at its Lead, S. Dak., operations, but a decline in profits from gold mining. Value of recovered bullion increased $400,000 to $22.1 million. Ore milled dropped slightly to 2.03 million tons but average recovered grade was up slightly to $10.88 per ton. Metallurgical recovery was 95.7 percent compared with 96.24 percent in 1964. Measured ore reserves at yearend totaled 16.4 million tons averaging 0.315 ounces ($11.01) of gold per ton, compared with 16.8 million tons of the same grade at the end of 1964. Nearly 1,900 persons were employed at the mine.[2]

The 48-percent gain in Utah's gold production was largely due to a sharp rise in output and increased yield per ton of gold-bearing copper ore at the Utah Copper mine of Kennecott Copper Corp. Production at that mine was below normal in 1964 because of a 2-month shutdown due to a labor strike. An increase of more than 150 percent in Nevada's output was attributed principally to commencement of productive operations by Carlin Gold Mining Co., a subsidiary of Newmont Mining Corp., at its new Carlin mine.

During 9 months of operation at the Carlin mine, 128,500 ounces of gold was produced from 497,000 tons of ore. Average grade of ore milled was 0.28 ounce of gold per ton.[3] The estimated ore reserve was 11 million tons averaging 0.32 ounce per ton. The presently proven Carlin ore body is about 7,500 feet long, dips about 35 degrees and varies in thickness from 25 to 150 feet. The overburden stripping ratio was about 3 : 1. The Carlin mine, when operating at capacity, will rank second to Homestake in gold output.

The Montana output of gold, mostly a byproduct of base-metal operations, dropped 22 percent despite significant increases in copper, lead, and zinc production.

Gold output in Alaska continued to decline, and in 1965 it was down more than 28 percent to the lowest level since 1894. The large dredging operation of New York-Alaska Gold Dredging Corp. at Nyac shut down. United States Smelting, Refining and Mining Co., the largest producer, operated dredges at Hogatza and at Chicken Creek. During part of 1964, the company also operated a dredge at Fairbanks.[4]

Approximately 3,900 persons were employed in the gold-mining industry.

South Dakota and Utah furnished 62 percent of the total domestic gold production. Including Nevada, the three States contributed more than three-fourths of the

[2] Homestake Mining Co. 88th Annual Report. Dec. 31, 1965, pp. 7–8.

[3] Newmont Mining Corp. Annual Report. 1965, p. 9.

[4] United States Smelting, Refining and Mining Co. Annual Report. 1965, p. 12.

total output. The Homestake mine, the Nation's leading gold producer, accounted for 37 percent of the total.

The 25 leading U.S. gold producers contributing 97 percent of the total domestic output included 7 lode mines, 3 placer mines, 10 copper mines, 2 copper-lead-zinc mines and 3 lead-zinc mines.

Table 2.—Mine production of recoverable gold in the United States, by months

(Troy ounces)

Month	1964	1965
January	116,385	117,970
February	116,097	115,827
March	121,328	130,564
April	121,050	140,212
May	133,831	135,095
June	134,680	141,061
July	100,178	148,121
August	107,921	151,626
September	118,914	162,102
October	140,709	155,553
November	123,294	152,604
December	121,921	154,455
Total	1,456,308	1,705,190

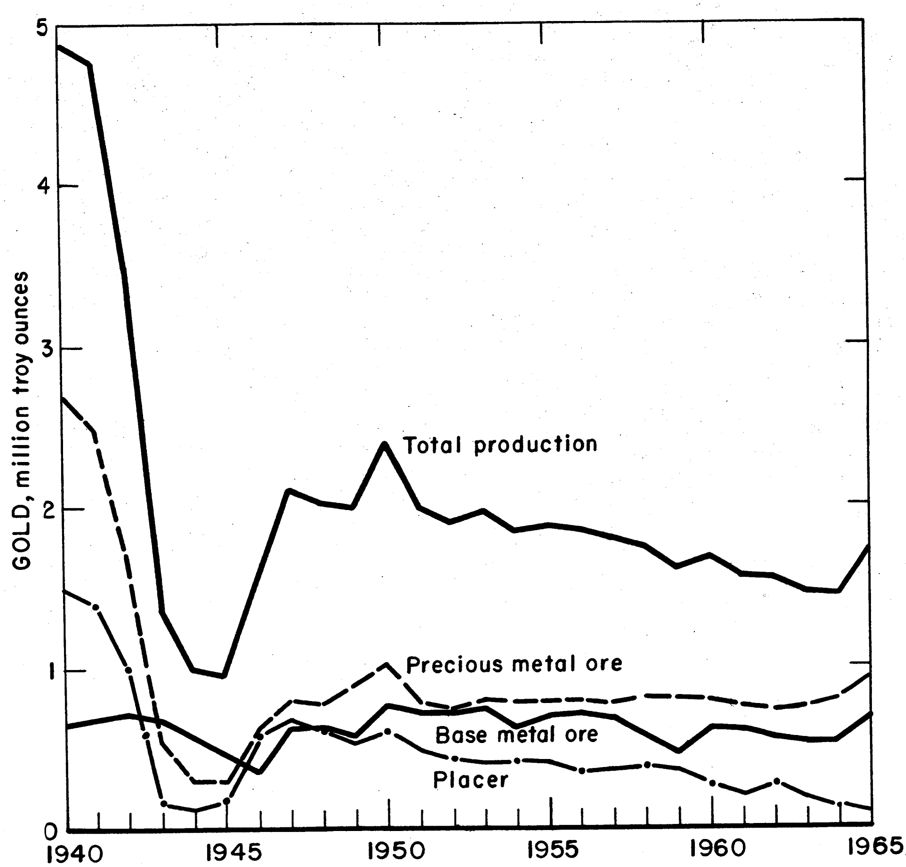

Figure 1.—Gold production in the United States.

Table 3.—Twenty-five leading gold-producing mines in the United States in 1965 in order of output

Rank	Mine	State	County	Operator	Source of gold
1	Homestake	South Dakota	Lawrence	Homestake Mining Co	Gold ore.
2	Utah Copper	Utah	Salt Lake	Kennecott Copper Corp	Copper, gold ores.
3	Carlin	Nevada	Eureka	Carlin Gold Mining Co	Gold ore.
4	Knob Hill and Gold Dollar	Washington	Terry	Knob Hill Mines, Inc	Do.
5	Getchell	Nevada	Humboldt	The Goldfield Corp	Do.
6	Yuba Unit	California	Yuba	Yuba Consolidated Gold Fields	Placer.
7	Copper Queen-Lavender Pit	Arizona	Cochise	Phelps Dodge Corp	Copper, silver ores.
8	Mayflower	Utah	Wasatch	Hecla Mining Co	Lead-zinc ore.
9	New Cornelia	Arizona	Pima	Phelps Dodge Corp	Copper, gold-silver ores.
10	Liberty Pit	Nevada	White Pine	Kennecott Copper Corp	Copper ore.
11	Idarado	Colorado	Ouray and San Miguel	Idarado Mining Co	Copper-lead-zinc ore.
12	San Manuel	Arizona	Pinal	Magma Copper Co	Copper ore.
13	Gold King	Washington	Wenatchee River	L-D Mines	Gold ore.
14	Hogatza River	Alaska	Yukon River Region	United States Smelting, Refining and Mining Co.	Placer.
15	Iron King	Arizona	Yavapai	Shattuck Denn Mining Corp	Lead-zinc ore.
16	Berkeley Pit	Montana	Summit Valley	The Anaconda Company	Copper ore.
17	Magma	Arizona	Pinal	Magma Copper Co	Copper, gold-silver ores.
18	Morenci	do	Greenlee	Phelps Dodge Corp	Do.
19	Chicken Creek	Alaska	Yukon River Region	United States Smelting, Refining and Mining Co.	Placer.
20	United States and Lark	Utah	Salt Lake	do	Lead-zinc, lead ores.
21	Chino	New Mexico	Grant	Kennecott Copper Corp	Copper ore.
22	Eagle	Colorado	Eagle	The New Jersey Zinc Co	Copper, zinc ores.
23	Kawalita Claim	Alaska	Yukon River Region	Keystone Mines, Inc	Gold ore.
24	85	New Mexico	Hidalgo	Diversified Mines, Inc	Gold-silver ore.
25	Christmas	Arizona	Gila	Inspiration Consolidated Copper Co	Copper ore.

Table 4.—Production of gold in 1963–65 in the United States, and by sources 1965

(Troy ounces)

State	1963	1964	1965 by type of production: Placers	Dry ore	Copper ore	Lead and zinc ores	Complex base metal ores	Other sources [1]	Total	Refinery production [2]
Alaska	99,573	58,416	38,686	3,548	---------	15	---------	---------	42,249	42,720
Arizona	140,030	153,676	[3] 143	491	133,830	30	15,489	583	150,566	154,000
California	86,867	[4] 71,028	58,571	3,946	3	103	65	30	[4] 62,885	61,400
Colorado	33,605	42,122	1,184	199	2,296	861	32,616	72	37,228	38,500
Idaho	5,477	5,677	31	1,413	1,600	1,456	539	39	5,078	4,500
Montana	18,520	[5] 29,115	171	2,607	15,985	3,009	92	908	22,772	25,720
Nevada	98,879	90,469	417	193,990	34,220	26	188	209	229,050	205,200
New Mexico	7,805	6,110	([3])	2,557	6,365	444	137	3	9,506	9,640
North Carolina	33	---------	---------	---------	---------	---------	---------	---------	---------	---------
Oregon	1,809	661	234	257	8	---------	---------	---------	499	320
Pennsylvania	([6])	([6])	([6])	([6])	---------	---------	---------	---------	([6])	30
South Dakota	576,726	616,913	---------	628,259	---------	---------	---------	---------	628,259	656,500
Tennessee	137	133	---------	---------	---------	---------	122	---------	122	160
Utah	285,907	287,674	---------	1,613	373,101	377	51,191	17	426,299	388,800
Washington	[6] 98,638	[6 7] 94,308	[6] 2	[6] 89,044	---------	---------	---------	---------	[6 7] 90,674	88,000
Wyoming	4	6	2	---------	1	---------	---------	---------	3	10
Total	1,454,010	1,456,308	99,441	927,924	567,409	6,321	100,439	1,861	1,705,190	1,675,500
Percent [8]	---------	---------	6	54	33	([9])	6	([9])	100	---------

[1] Gold recovered from mill and smelter cleanup, tailings, and slags.
[2] U.S. Bureau of the Mint.
[3] Production of Arizona and New Mexico combined to avoid disclosing individual company confidential data.
[4] Includes gold recovered from tungsten ore.
[5] Includes gold recovered from manganese ore.
[6] Production of Pennsylvania and Washington combined to avoid disclosing individual company confidential data.
[7] Includes gold recovered from magnetite pyrite ore.
[8] Percentage based on total, excluding 1,795 ounces obtained from other ores.
[9] Less than ½ unit.

Table 5.—Mine production of recoverable gold in the United States, 1956–65, with production of maximum year, and cumulative production from earliest record to end of 1965, by States, in troy ounces

State	Maximum production [1]		Production by years										Total production from earliest record to end of 1965
	Year	Quantity	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	
Western States:													
Alaska	1906	1,066,030	209,296	215,467	186,435	178,918	168,197	114,216	165,259	99,573	58,416	42,249	29,800,307
Arizona	1937	332,694	146,110	152,449	142,979	124,627	143,064	145,959	137,207	140,030	153,676	150,431	13,321,041
California	1852	3,932,631	193,816	170,885	185,385	145,270	123,713	97,644	106,272	86,867	71,028	62,885	106,129,343
Colorado	1900	1,391,364	97,668	87,928	79,539	61,097	61,269	67,515	48,882	33,605	42,122	37,228	40,775,923
Idaho	1871	212,850	9,210	12,301	15,896	10,479	6,135	5,718	5,845	5,477	5,677	5,078	8,322,990
Montana	1865	870,750	38,121	32,766	26,003	28,551	45,922	35,377	24,387	18,520	29,115	22,772	17,752,572
Nevada	1910	913,265	68,040	76,752	105,087	113,443	58,187	54,165	62,863	98,879	90,469	229,050	27,475,395
New Mexico	1915	70,681	3,275	3,212	3,378	3,155	5,423	6,201	7,529	7,805	6,110	9,641	2,266,765
Oregon	1940	113,402	2,738	3,381	1,423	686	835	1,054	822	1,809	661	499	5,796,486
South Dakota	1965	628,259	568,523	568,130	570,830	577,730	554,771	557,855	577,232	576,726	616,913	628,259	31,207,892
Texas	1929	1,279	----	----	----	----	----	----	----	----	----	----	8,552
Utah	1953	483,430	416,031	378,438	307,824	239,517	368,255	342,988	311,924	285,907	287,674	426,299	17,765,288
Washington	1960	129,012	70,669	89,708	113,353	118,394	129,012	117,331	93,671	98,638	94,308	90,674	3,789,420
Wyoming	1869	7,498	762	573	117	----	40	1	----	4	6	3	82,007
Total	----	----	1,824,259	1,791,990	1,738,249	1,601,867	1,664,823	1,546,024	1,541,893	1,453,840	1,456,175	1,705,068	304,493,981
West Central States:													
Missouri	1900	33	----	----	----	----	----	----	----	----	----	----	33
States east of the Mississippi:													
Alabama	1936	4,726	----	----	----	----	----	----	----	----	----	----	49,495
Georgia	1882	12,094	----	----	----	----	----	----	----	----	----	----	870,663
Indiana	----	----	----	----	----	----	----	----	----	----	----	----	NA
Maryland	1937	1,040	----	----	----	----	----	----	----	----	----	----	6,123
Michigan	1890	4,354	----	----	----	----	----	----	----	----	----	----	33,297
North Carolina	1887	10,884	882	1,373	876	965	1,826	2,094	460	33	----	----	1,173,514
Pennsylvania	1942	2,499	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	[3] 40,149
South Carolina	1941	15,508	----	----	----	----	----	----	----	----	----	----	318,801
Tennessee	1930	696	189	172	124	99	123	152	158	137	133	122	24,245
Vermont	1954	185	1,829	62	----	----	----	----	----	----	----	----	[4] 3,635
Virginia	1938	2,943	----	----	----	----	----	----	----	----	----	----	167,558
Total	----	----	2,900	1,607	1,000	1,064	1,949	2,246	618	170	133	122	2,687,480
Grand total	----	----	1,827,159	1,793,597	1,739,249	1,602,931	1,666,772	1,548,270	1,542,511	1,454,010	1,456,308	1,705,190	307,181,494

NA Not available.
[1] Except for Pennsylvania and Vermont, figures are peaks since 1880 for Central and Eastern States, and Alaska, Nevada, and Oregon.
[2] Included with Vermont 1956; with Washington 1957–65.
[3] 1908–55 only.
[4] 1905–55 only.

Table 6.—Ore, old tailings, etc., yielding gold produced in the United States, and average recoverable content, in troy ounces of gold per ton in 1965

State	Gold		Gold-silver		Silver		Copper	
	Short tons	Average ounces of gold per ton	Short tons	Average ounces of gold per ton	Short tons	Average ounces of gold per ton	Short tons	Average ounces of gold per ton
Alaska	3,194	1.111	---	---	---	---	---	---
Arizona	115	.409	142,648	0.007	4,116	0.009	83,709,159	0.002
California	7,160	.461	(1)	(1)	[1] 2,931	[1] .231	41	.073
Colorado	3,682	.039	223	.148	4,253	.012	17,269	.133
Idaho	869	.354	(3)	---	471,640	.002	84,699	.019
Montana	2,087	.649	15,080	.104	36,445	.016	14,460,309	.001
Nevada	892,766	.217	---	---	53,854	.004	10,355,163	.003
New Mexico	---	---	31,709	.079	288	.177	8,129,622	.001
South Dakota	2,031,500	.309	---	---	---	---	---	---
Tennessee	---	---	---	---	---	---	---	---
Utah	1,279	.018	15,231	.005	178,583	.008	32,167,851	.012
Wyoming	---	---	---	---	---	---	28	.036
Other States [4]	170,178	.523	1,146	.164	41	.415	13	.615
Total	3,112,830	.296	206,037	.029	752,151	.005	148,924,154	.004

State	Lead		Zinc		Lead-zinc, copper-zinc, and copper-lead-zinc		Total material	
	Short tons	Average ounces of gold per ton	Short tons	Average ounces of gold per ton	Short tons	Average ounces of gold per ton	Short tons	Average ounces of gold per ton
Alaska	39	0.385	---	---	---	---	3,233	1.102
Arizona	11,293	.003	35	0.029	419,566	0.037	84,286,932	.002
California	8,770	.012	---	---	523	.124	19,425	[2] .222
Colorado	4,932	.021	260,860	.003	726,032	.045	1,017,251	.035
Idaho	188,694	.008	96,075	---	737,454	.001	1,579,431	.003
Montana	19,670	.029	1,006,660	.002	839	.111	15,541,090	.001
Nevada	893	.029	---	---	166,721	.001	11,469,397	.020
New Mexico	1,158	.009	402,641	.001	57,375	.002	8,622,793	.001
South Dakota	---	---	---	---	---	---	2,031,500	.309
Tennessee	---	---	---	---	1,520,755	---	1,520,755	---
Utah	11,266	.033	23,555	---	463,994	.110	32,861,759	.013
Wyoming	---	---	---	---	---	---	28	.036
Other States [4]	---	---	---	---	---	---	[5] 808,094	.113
Total	246,715	.011	1,789,826	.002	4,093,259	.025	[5] 159,761,688	.010

[1] Gold-silver material combined with silver material to avoid disclosing individual company confidential data.
[2] Includes byproduct gold from tungsten ore.
[3] Less than ½ unit.
[4] Includes Oregon, Pennsylvania, and Washington.
[5] Includes magnetite-pyrite ore from Pennsylvania.

Table 7.—Gold produced in the United States from ore and old tailings, etc., in 1965, by States and methods of recovery, in terms of recoverable metal

State	Total ore, old tailings, etc., treated (thousand short tons) [1]	Ore and old tailings to mills					Crude ore, old tailings, etc. to smelters	
			Recoverable in bullion		Concentrates smelted and recoverable metal			
		Thousand short tons [1]	Amalgamation (troy ounces)	Cyanidation (troy ounces)	Concentrates (short tons)	Troy ounces	Thousand short tons	Troy ounces
Alaska	3	3	3,473	-------	25	52	(2)	38
Arizona	92,366	91,731	28	-------	2,750,506	135,681	635	14,714
California	20	13	2,296	-------	4,880	1,729	7	289
Colorado	1,021	1,006	9,720	-------	156,303	23,997	15	2,327
Idaho	1,783	1,732	256	-------	216,543	4,340	51	451
Montana	15,634	15,487	23	-------	440,187	18,687	147	3,891
Nevada	13,392	13,295	420	193,251	319,834	33,792	97	1,170
New Mexico	8,625	8,536	-------	-------	374,441	6,935	89	2,571
Oregon	1	1	27	-------	48	188	(2)	50
Pennsylvania	(3)	(3)	(3)	-------	(3)	(3)	(3)	(3)
South Dakota	2,032	2,032	429,339	198,920	---------	-------	-------	--------
Tennessee	5,528	5,528	-------	-------	304,888	122	-------	--------
Utah	32,887	32,653	-------	-------	914,727	424,223	234	2,076
Washington	[3] 1,831	[3] 1,828	[3] 14,689	-------	[3] 68,551	[3] 75,728	[3] 3	[3] 255
Wyoming	(2)	-------	-------	-------	---------	-------	(2)	1
Total	175,123	173,845	460,271	392,171	5,550,933	725,474	1,278	27,833

[1] Includes some non-gold-bearing ores not separable.
[2] Less than ½ unit.
[3] Pennsylvania and Washington combined to avoid disclosing individual company confidential data.

Table 8.—Gold produced at amalgamation and cyanidation mills in the United States and percentage of gold recoverable from all sources

Year	Bullion and precipitates recoverable (troy ounces)		Gold from all sources (percent)			
	Amalgamation	Cyanidation	Amalgamation	Cyanidation	Smelting [1]	Placers
1956–60 (average)	443,903	243,918	25.7	14.1	40.7	19.5
1961	434,134	186,086	28.0	12.0	46.9	13.1
1962	455,412	173,386	29.5	11.2	42.1	17.2
1963	437,264	218,212	30.1	15.0	42.2	12.7
1964	453,736	254,771	31.2	17.5	42.7	8.6
1965	460,271	392,171	27.0	23.0	44.2	5.8

[1] Crude ores and concentrates.

Table 9.—Gold production at placer mines in the United States, by methods of recovery

Method and year	Mines producing	Washing plants	Material treated (thousand cubic yards)	Gold recoverable: Thousand troy ounces	Value (thousands)	Average value per cubic yard
Bucketline dredging:						
1956–60 (average)	17	30	41,720	272	$9,501	$0.228
1961	19	24	33,806	177	6,192	.183
1962	20	22	25,590	242	8,456	.330
1963	17	22	18,431	161	5,651	.307
1964	13	13	14,382	103	3,604	.251
1965	9	11	13,685	83	2,889	.211
Dragline dredging:						
1956–60 (average)	14	13	317	2	61	.191
1961	16	16	[1] 608	[2] 1	43	.071
1962	13	13	532	1	47	.088
1963	11	11	266	2	70	.265
1964	19	13	195	2	68	.350
1965	10	11	[1] 632	[2] 2	57	.090
Hydraulicking:						
1956–60 (average)	37	14	176	2	84	.476
1961	19	19	104	3	107	1.029
1962	21	21	124	2	83	.669
1963	12	12	43	1	45	1.056
1964	11	11	30	(3)	10	.323
1965	6	6	4	(3)	3	.750
Nonfloating washing plants:						
1956–60 (average)	96	101	1,930	59	2,062	1.068
1961	81	81	957	19	668	.698
1962	45	45	839	16	551	.657
1963	50	67	[1] 638	[2] 14	499	.782
1964	55	49	[1] 585	[2] 14	489	.836
1965	48	64	[1] 501	[2] 11	391	.779
Underground placer, small-scale hand methods, and suction dredge:						
1956–60 (average)	86	20	76	2	83	1.087
1961	103	103	141	2	73	.518
1962	74	74	314	4	128	.408
1963	133	82	139	6	194	1.403
1964	87	56	49	6	212	4.292
1965	70	48	68	4	140	2.059
Total placers:						
1956–60 (average)	250	178	44,219	337	11,791	.267
1961	238	243	35,616	202	7,083	.199
1962	173	175	27,399	265	9,265	.338
1963	223	194	19,517	184	6,459	.331
1964	185	142	15,241	125	4,383	.287
1965	143	140	14,890	100	3,480	.234

[1] Excludes tonnage of material treated at commercial sand and gravel operations recovering byproduct gold.
[2] Includes gold recovered at commercial sand and gravel operations recovering byproduct gold.
[3] Less than ½ unit.

CONSUMPTION AND USES

Industry and Arts. Net consumption of gold by domestic manufacturers increased 10 percent to 5.3 million ounces, a new record high for the second successive year.

According to data compiled by the Office of Gold and Silver Operations, U.S. Treasury Department, about three-fourths of the total gold sold or transferred was for jewelry, artistic, and dental uses; the remainder was used chiefly for electrical and electronic components in defense and aerospace equipment and for other industrial products.

Because of its superior reflectivity and adaptability to temperature changes, nylon covered with pure gold was used in the Gemini space vehicle as a protective cover for the propulsion, radio, and guidance systems. The helmet masks and the umbilical tether used by the *Gemini IV* astronauts were gold plated. Electroplated gold coatings were applied to the external parts of vernier rocket engines in the Apollo program to provide thermal control and maintain the engines within safe operating temperatures while the spacecraft is coasting on its long trip to the lunar surface.

A gold alloy, 72Au–14Cu–4Hg–9Pt–1Zn, was developed for use as springs in electrical contacts. When cold worked and age hardened, this alloy retains good corrosion resistance, is nonmagnetic, and can be easily soldered or welded. Maximum strength, up to 175,000 pounds per square inch, is attained by cold working to about 37 percent reduction in area before age hardening at 725° to 740° F for 5 minutes.

Gold anodized aluminum sheet adaptable for many decorative home uses was made available in perforated patterns by Reynolds Metals Co.

Gold-plated contact fingers were used in the new solid-state desk-top electronic calculators. Gold provides continuous low-contact resistance during the solid-state plug-in circuit board's service life of 10 to 15 years. This type of goldplating was being used to an increasing extent in electronic accounting and other business machines.

Table 10.—Gold consumption in industry and the arts, in the United States
(Thousand troy ounces)

Year	Issued for industrial use	Returned from industrial use	Net industrial consumption
1956–60 (average)	2,781	740	2,041
1961	3,913	1,138	2,775
1962	4,486	910	3,576
1963	4,252	1,332	2,920
1964	5,887	1,086	4,801
1965	6,551	1,275	5,276

Source: U.S. Bureau of the Mint.

MONETARY STOCKS

The total U.S. gold stock dropped $1,665 million in 1965 and stood at $13,806 million at yearend, the lowest level since September 1938. The 1965 gold outflow, the largest since 1960, was closely allied to the continued balance-of-payments deficit and reflected a stepped-up rate of conversion of dollars to gold by West European countries, particularly France, which received more than half of the total outflow; $259 million represented a payment of 25 percent of the U.S. quota increase to the International Monetary Fund.

Congressional approval of the President's proposal to exclude Federal Reserve deposit liabilities from the 25-percent gold reserve requirement freed nearly $5 billion in gold to accommodate money and credit needs of the expanding economy. This action also provided reassurance to foreign governments that the United States would continue to supply gold to them at the established price of $35 per ounce.

The ratio of gold reserves to Federal Reserve note liability was 35.4 percent at yearend against 25 percent required to be held as backing for the dollar.

Gold reserves of free world central banks and governments and international banking institutions at yearend were estimated at $43,300 million, compared with $43,060 million at the end of 1964.[5] Free world central bank reserves showed little gain during the year because most of the $1.7 billion of newly mined gold apparently went into private stocks and industrial use. Strong private demand in late 1964 and early 1965 reflected the effect of the sterling crisis, President de Gaulle's call for a return to the gold standard, and the French decision to convert accumulated dollar credits into gold. Concern about the future of the international monetary system and international liquidity also were factors contributing to the strong private demand for gold.

The U.S. reserve of $13,806 million constituted about 32 percent of the total official free world gold reserves. Gold reserves of other principal free world countries, in million dollars, were as follows: France, 4,706; West Germany, 4,410; Switzerland, 3,042; Italy, 2,404; Netherlands, 1,756; Belgium, 1,558; and Canada, 1,151. The International Monetary Fund reported gold reserves of $1,869 million.

U.S. short-term liabilities to foreign interests, payable in dollars, increased $38 million to $25,444 million at yearend. These liabilities constitute a potential claim on the U.S. gold reserve. Nearly one-half of the total short-term liabilities was payable to West European countries and Canada.

[5] Federal Reserve Bulletin. V. 52, No. 4, April 1966, pp. 606–612.

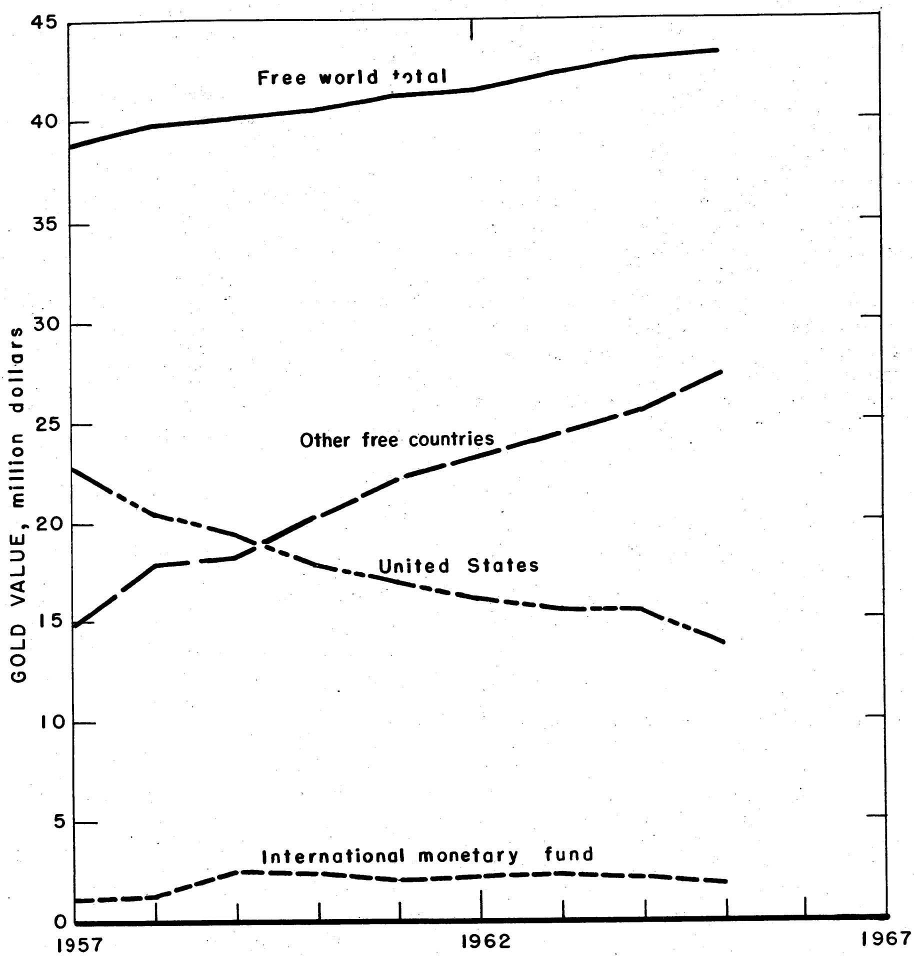

Figure 2.—Gold reserves of free world central banks and Governments.

PRICES

Under authority of the Gold Reserve Act of 1934, the Treasury Department, through the Bureau of the Mint and licensed refiners and dealers, continued to buy virtually all newly mined gold from domestic mines and gold offered by foreign banks and agencies at the official price of $35 per fine troy ounce less charges for handling, melting, and refining. Similarly, gold was sold by the Treasury and licensed dealers for industrial and artistic use at a base price of $35 per ounce.

Following the pattern of recent years, average price quotations on gold bars in markets outside of London were moderately higher than in the London market, except in the Bombay market where trading was in currencies, not readily convertible, which reflected local political conditions and monetary habits. Average prices per ounce in U.S. dollars were as follows:

Market	*Price*
Manila	$35.59
Hong Kong	39.35
Bombay	58.58
Beirut	35.29
Paris	35.38
Buenos Aires	37.55

With regard to the official price of gold, Secretary Dillon, in an address to the House Committee on Banking and Currency on February 1, stated:

. . . Gold will continue to be made freely available, at the fixed price of $35 per ounce, to meet the legitimate demands of foreign monetary authorities—a policy that is the basic foundation of the international monetary system . . .

FOREIGN TRADE

Continuing the pattern of the preceding 4 years, exports of gold continued to exceed imports by a wide margin, the excess reaching an alltime record in 1965. A substantial quantity of gold was imported from Uruguay, the first such inflow since 1958. As in the 2 preceding years, most of the gold exported went to France.

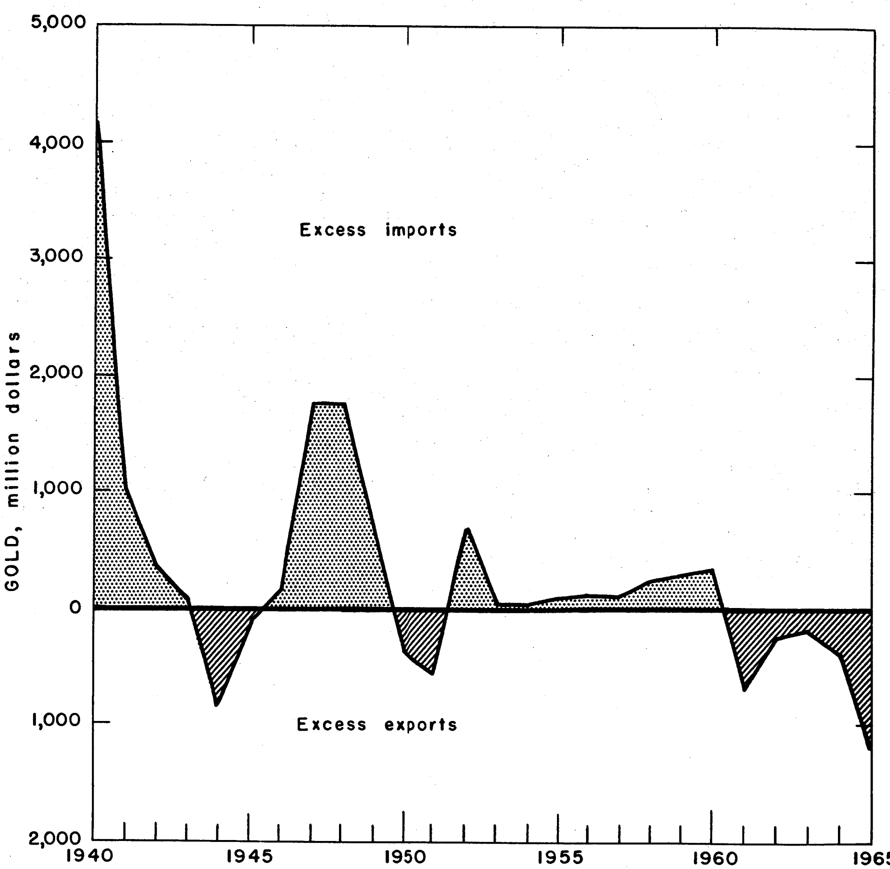

Figure 3.—Net exports or imports of gold.

Table 11.—U.S. exports of gold in 1965, by countries

Destination	Ore and base bullion		Refined bullion	
	Troy ounces	Value	Troy ounces	Value
North America: Canada	218	$7,672		
South America:				
Argentina			54	$1,885
Bolivia			1,784	62,454
Europe:				
Austria			4	138
Belgium-Luxembourg	12,062	422,170	1,166	40,810
France			36,065,069	1,262,277,395
Germany, West	424	14,799		
Italy			1,055	36,925
United Kingdom	30,479	1,066,771		
Asia:				
Burma			598,061	20,932,146
Ceylon			14	490
Japan	6,653	232,855		
Total	49,836	1,744,267	36,667,207	1,283,352,243

Table 12.—U.S. imports of gold in 1965, by countries

Country	Ore and base bullion		Refined bullion	
	Troy ounces	Value	Troy ounces	Value
North America:				
Canada	51,958	$1,815,831		
Canal Zone	42	1,470		
Costa Rica	27	945		
Cuba			9	$315
El Salvador	290	10,153		
Honduras	3,546	124,127		
Mexico	5,169	180,304		
Nicaragua	68,579	2,386,074		
Panama	9	315		
South America:				
Bolivia	105	3,675	56,906	1,996,835
Brazil	16	563		
Chile	19,131	670,004		
Colombia	609	21,315	444,372	15,553,012
Ecuador	11,511	399,095		
Peru	18,639	652,282		
Uruguay			1,714,697	60,014,369
Europe:				
Austria	199	6,977		
Belgium-Luxembourg	19,643	687,953		
Germany, West			1,825	63,711
Norway	99	3,465		
United Kingdom	6,216	218,192	34,539	1,212,131
Africa:				
Kenya	114	4,020		
South Africa, Republic of	894	31,290		
Uganda	3	105		
Asia:				
Japan	36	1,260	39,230	1,372,638
Philippines	62,184	2,169,507	321,583	11,256,411
Turkey	2,991	104,599		
Oceania: Australia	20,157	705,563		
Total	292,167	10,199,084	2,613,161	91,469,422

Table 13.—Value of gold imported into and exported from the United States

(Thousands)

Year	Imports	Exports	Year	Imports	Exports
1956–60 (average)	$266,895	$45,899	1963	$44,414	$203,784
1961	56,211	775,001	1964	40,888	422,744
1962	150,932	380,962	1965	101,669	1,285,097

WORLD REVIEW

World gold output rose 1.6 million ounces to 47.7 million ounces valued at $1,670 million. The 1965 production gain was the 12th consecutive annual increase again due largely to continued expansion of output from South African mines. Significant increases were also noted in the gold output of the United States and the U.S.S.R., but output continued to decline in Canada and Australia and was appreciably lower in Ghana, Southern Rhodesia, and Colombia.

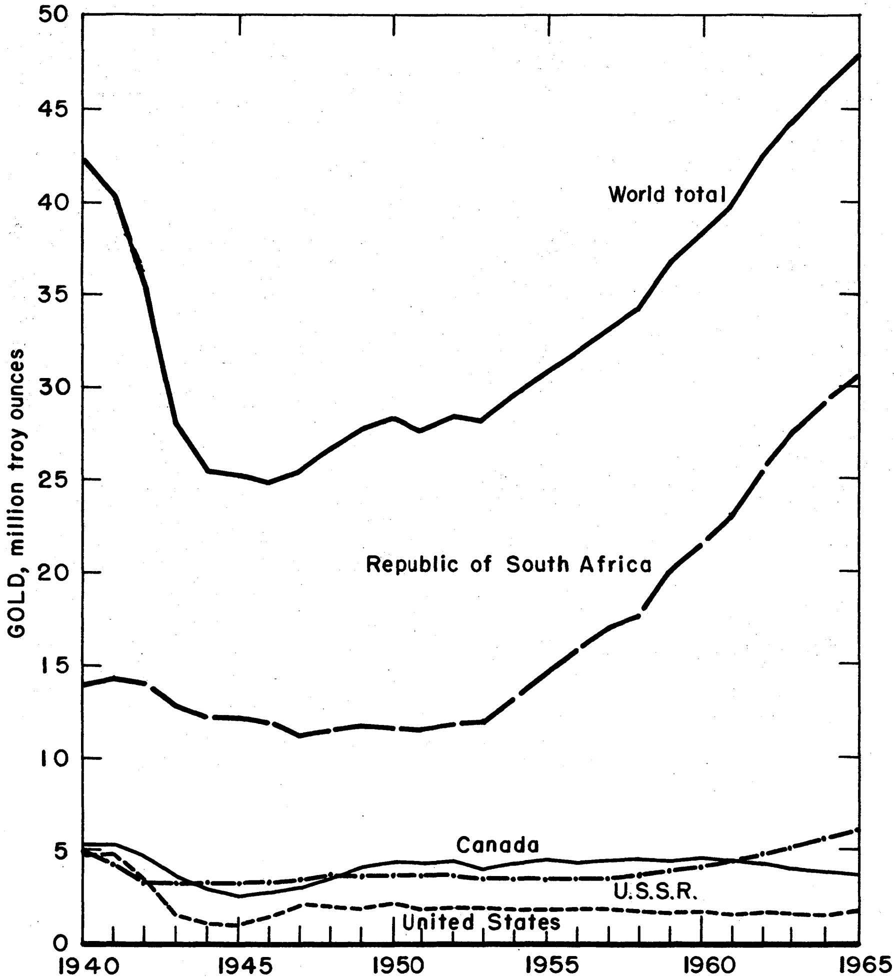

Figure 4.—World production of gold.

Table 14.—World production of gold by countries [1]

(Troy ounces)

Country [1]	1961	1962	1963	1964	1965 [p] [2]
North America:					
Canada	4,473,699	4,178,396	3,972,047	[r] 3,799,278	3,587,168
Central America and West Indies:					
Costa Rica [e]	3,000	3,000	3,000	3,000	570
Cuba [3]	----------	----------	61	----------	9
El Salvador [3]	----------	[r] 692	[r] 230	[r] 390	290
Haiti	4,341	7,149	6,778	[r] 8,090	[e] 8,000
Honduras [3]	1,685	2,132	2,474	3,319	3,546
Nicaragua	226,250	221,984	204,769	[r] 225,581	198,152
Mexico	268,684	236,758	237,948	209,976	215,796
United States [4]	1,548,270	1,542,511	1,454,010	1,456,308	1,705,190
Total	[r] 6,526,000	[r] 6,193,000	[r] 5,881,000	[r] 5,706,000	5,719,000
South America:					
Argentina	2,251	[r] 827	[r] 313	303	[e] 300
Bolivia (exports)	80,184	35,052	153,033	50,043	84,927
Brazil [5]	118,636	[r] 127,156	131,979	[r] 142,492	161,044
British Guiana	1,702	1,903	2,847	2,111	2,077
Chile	56,489	65,009	77,290	[r] 64,993	57,068
Colombia	401,060	396,827	324,514	364,991	319,362
Ecuador	15,210	20,591	21,041	[r] 17,681	11,458
French Guiana	7,941	5,273	6,993	[r] 4,823	----------
Peru	137,418	122,985	101,019	[r] 92,503	96,863
Surinam	[r] 4,019	2,604	[r] 3,548	[r] 8,258	6,269
Venezuela	30,071	28,774	26,947	33,536	23,663
Total [e]	855,000	807,000	850,000	[r] 782,000	763,000
Europe:					
Finland	20,609	15,239	20,416	22,055	18,037
France	48,676	51,088	53,627	[r] 54,303	51,441
Germany, West	2,186	1,704	[e] 2,000	[e] 2,000	[e] 2,000
Italy	720	----------	----------	----------	----------
Portugal	22,377	21,927	21,895	[r] 21,316	20,500
Spain	8,231	6,687	15,625	[r] 23,534	8,809
Sweden	[r] 86,871	[r] 128,635	[r] 121,691	[r] 117,500	[e] 118,000
U.S.S.R. [e] [6]	4,400,000	4,800,000	5,100,000	5,600,000	6,100,000
Yugoslavia	67,195	70,507	83,656	[r] 106,773	[e] 112,500
Total [e] [1]	5,000,000	5,500,000	5,800,000	6,400,000	6,900,000
Africa:					
Angola	48	77	37	7	2
Bechuanaland	261	288	142	10	----------
Cameroon	537	[r] 579	[r] 1,865	[r] 739	1,454
Central African, Republic	80	100	96	75	32
Congo, Republic of (Brazzaville)	3,376	[r] 3,729	2,958	3,567	3,718
Congo, Republic of the (Léopoldville)	233,672	203,707	214,574	[r] 188,693	66,327
Eritrea	5,529	2,315	[e] 2,300	[e] 2,300	24,236
Ethiopia	[e] 41,500	25,700	[e] 25,000	[e] 25,000	
Gabon, Republic of	15,304	16,300	35,719	42,760	37,134
Ghana	852,619	888,038	921,255	864,917	755,191
Kenya	12,299	9,327	10,193	[r] 12,480	11,420
Liberia [7]	2,088	2,184	1,960	1,824	1,701
Malagasy Republic	347	325	900	440	598
Morocco	136	----------	----------	----------	----------
Mozambique	105	91	[r] 29	40	[e] 40
Nigeria	676	384	316	244	80
Rhodesia, Southern	570,095	554,647	566,277	575,386	[e] 544,100
Rwanda	900	[r] 29	([8])	([8])	([8])
South Africa, Republic of	22,941,561	25,491,993	[r] 27,431,956	[r] 29,111,524	30,553,874
South-West Africa	----------	183	3	32	14
Sudan	[r] 1,266	[r] 932	[r] 868	877	300
Swaziland	1,325	2,214	2,092	2,078	1,619
Tanzania [9]	[r] 101,502	101,972	102,917	93,040	90,819
Uganda	[r] 419	[r] 291	[r] 48	[r] 24	36
United Arab Republic (Egypt)	931	----------	----------	----------	----------
Upper Volta	15,497	39,770	44,786	[r] 32,665	34,468
Zambia	4,192	[r] 5,326	4,960	5,033	5,196
Total	24,810,000	27,350,000	[r] 29,370,000	[r] 30,960,000	32,130,000

See footnotes at end of table.

Table 14.—World production of gold by countries [1]—Continued

(Troy ounces)

Country [1]	1961	1962	1963	1964	1965 [p] [2]
Asia:					
Burma	194	[e] 200	[e] 200	[e] 200	[e] 200
Cambodia	4,180	965	6,687	[e] 6,000	[e] 4,500
China, Mainland [e]	60,000	60,000	60,000	60,000	60,000
India	156,510	163,326	138,280	[r] 148,504	130,628
Indonesia	5,337	4,469	4,437	[e] 5,300	6,752
Japan [10]	294,534	286,593	262,142	[r] 253,300	264,408
Korea:					
North [11]	160,000	160,000	160,000	160,000	160,000
South	84,105	106,548	90,095	75,779	62,823
Malaya	12,486	6,923	9,116	7,295	3,982
Philippines	423,983	423,394	376,006	425,770	435,545
Sarawak	4,132	2,885	2,773	3,115	2,602
Taiwan	17,619	24,026	31,710	17,660	32,148
Total [e] [1] [6]	1,225,000	1,240,000	1,140,000	[r] 1,165,000	1,165,000
Oceania:					
Australia	1,076,292	1,068,837	[r] 1,023,970	[r] 965,113	877,139
Fiji	83,417	87,354	107,262	100,493	109,095
New Guinea	41,789	39,007	43,552	38,934	32,439
New Zealand	28,294	21,742	14,206	8,948	12,136
Papua	31	45	47	43	55
Total	1,229,823	1,216,985	[r] 1,189,037	1,113,531	1,030,864
World total [e]	[r] 39,650,000	42,300,000	44,250,000	46,100,000	47,700,000

[e] Estimate. [p] Preliminary. [r] Revised.

[1] Gold is also produced in Bulgaria, Czechoslovakia, and Rumania but production data are not available; estimates for these countries are included in the total. East Germany, Hungary, and Thailand probably produce a negligible amount of gold. For some countries accurate figures are not possible to obtain owing to clandestine trade in gold (as, for example, in former French West Africa).

[2] Compiled mostly from data available July 1966.

[3] Imports into the United States.

[4] Revised to indicate mine production.

[5] Mined gold only; production of alluvial gold unknown.

[6] Output from U.S.S.R. in Asia included with U.S.S.R. in Europe.

[7] Year ending August 31 of year stated.

[8] Recorded production: no estimate is included for illicit production smuggled out of Rwanda; this is believed to be confined to a few hundred ounces at the most.

[9] Including gold in lead concentrates exported amounting to 521 ounces in 1961 and none since.

[10] Refinery production for Japan is as follows: 1961, 378,922 ounces; 1962, 420,956 ounces; 1963, 432,572 ounces; 1964, 460,171 ounces; and 1965, 519,170 ounces.

[11] Estimates according to Minerais et Metaux (France), except 1965.

Australia.—Mine production of gold valued at $30.7 million declined 9 percent and was the smallest output in 15 years. Western Australia produced three-fourths of the total.

The Gold-Mining Industry Assistance Act was amended in June. After July 1, large producers were paid at the rate of three-quarters of the excess of the average production cost over $27 per ounce with a maximum subsidy of $8 per ounce. The subsidy payable to small producers whose output does not exceed 500 ounces was $6 per ounce. Net subsidy payments to gold producers was $4.1 million.

Gold production in the Kalgoorlie district was about the same as in 1964. Lake View and Star, the largest mine, treated 741,300 tons of ore yielding 160,150 ounces of gold. Metallurgical recovery was down slightly to 92.8 percent, but ore reserves dropped 6 percent to 3.4 million tons averaging 0.24 ounce per ton. Costs per ton of ore milled increased $0.11 to $5.87.

Gold Mines of Kalgoorlie Ltd. reported a significant increase in tons milled and gold recovered for the year ending March 31. Ore treated was 741,160 tons and yield was 152,487 ounces. Ore reserves dropped to 4.4 million tons averaging 0.19 ounce per ton. Operating costs declined $6.70 per ton.

Central Norseman Gold Corp. reported a small gain in gold output to 102,644 ounces from 181,784 tons treated, an average of 0.56 ounce per ton. Operating costs were down slightly to $10.33 per ton. Ore reserves rose to 675,000 tons averaging 0.52 ounce per ton.

Great Boulder Gold Mines Ltd., treated 444,000 tons of ore and recovered 99,077 ounces of gold. Operating costs were up

$0.85 to $7.54 per ton. Ore reserves declined slightly to 1.9 million averaging 0.26 ounce per ton.

North Kalgurli Ltd. treated 370,824 tons of ore and recovered 75,393 ounces of gold. Average metallurgical recovery was 91.2 percent. Operating cost remained stable at $6.61 per ton treated. Ore reserves were down slightly to 2.1 million ounces averaging 0.25 ounce per ton.

Mount Morgan Ltd., the largest gold producer in Queensland, continued to expand its output and reported a recovery of 80,030 ounces in the year ending June 30, 1965.

Canada.—Gold output dropped about 5 percent to 3.6 million ounces valued at Can$136.9 million, the fifth consecutive annual decline. Canada maintained its rank as the second largest gold-producing country in the free world. The average price per ounce paid by the mint was Can $37.73, slightly less than in 1964.

About 83 percent of the total gold output came from lode gold and placer mines; the remainder was recovered as a byproduct of base-metal ores. Lode gold mines employed an average of about 13,400 persons.

Cost aid payments were made to 44 of Canada's 54 lode gold mines under the Emergency Gold Mining Assistance Act. Eight lode gold mines closed during 1965 owing principally to depletion of ore reserves. Three mines began production. La Forma mine, the first lode gold mine in the Yukon Territory, began production at its 125-ton-per-day plant; Wasmec mines in Quebec began operation of its 1,500-ton-per-day plant; and Camflo Mattagami began regular production at the rate of 600 tons of ore per day from its gold mine in the Malartic area of Quebec. Lake Shore, once the largest gold mine in Canada, closed down after producing $271 million in gold. Other mines that closed during the year included Leitch, Canadian Malartic, Malartic Goldfields, and Bevcon. Of the total gold output, Ontario, the leading gold-producing Province, contributed 54 percent; Quebec, 25 percent; Northwest Territories, 12 percent; and British Columbia, about 3 percent.

Giant Yellowknife Mines Ltd., Canada's leading gold producer, recovered 255,000 ounces of gold valued at $9.6 million, slightly less than in 1964. Tons milled and ore grade also dropped slightly. Operating costs increased 93 cents per ton to $12.88. Developed ore reserves at yearend were estimated at 2.37 million tons averaging 0.70 ounce per ton compared with 2.31 million tons averaging 0.73 ounce per ton on the corresponding date in 1964.

Kerr-Addison Mines Ltd. reported a drop of 16 percent in tons milled and gold produced, the fifth successive annual falloff in production. Output for the year was 223,250 ounces valued at $8.4 million but recovered value of bullion per ton remained virtually unchanged at $12.92. Total operating cost per ton was $9.29 compared with $9.13 in 1964; thus the net operating profit was $3.63 per ton. The proven ore reserve at yearend was 4.8 million tons averaging 0.43 ounce per ton compared with 5.4 million tons averaging 0.43 ounce per ton in 1964.

Hollinger Consolidated Gold Mines Ltd. reported production of gold at its 56-year-old Hollinger mine and its Ross mine was valued at $10.5 million compared with $10.9 million in 1964. Operating costs dropped from $10.5 million to $9.8 million. Estimated financial aid received under the Emergency Gold Mines Assistance Act was approximately $1.4 million compared with $1.6 million in 1964.[6] About 1,228 persons were employed at the two company mines at yearend.

The Yukon Consolidated Gold Corp. Ltd. operated five dredges and combined hydraulic and mechanical operations in the Dawson area handling 2.7 million cubic yards of gravel yielding gold valued at $1.2 million, compared with about 4 million cubic yards yielding $1.4 million in gold in 1964. The sharp falloff in production was attributed largely to the shutdown of equipment caused by extremely cold weather. Average recovery per cubic yard was 39.9 cents at a cost of 42.6 cents, compared with recovery of 34.3 cents at a cost of 32.3 cents in 1964. The proved gravel reserve at yearend was 4.9 million cubic yards averaging 42.3 cents per yard. The company planned to shut down all operations at the end of 1966.[7]

Colombia.—Gold production, about two-thirds of which was from placers, dropped nearly 13 percent. International Mining

[6] Hollinger Consolidated Gold Mines Ltd. Annual Report. 1965, p. 4.

[7] The Yukon Consolidated Gold Corp. Ltd. President's Statement 1965.

Table 15.—Canada: Geographical distribution of gold production
(Troy ounces)

Province or Territory	1964	1965
Atlantic Provinces	18,555	27,429
British Columbia	138,552	118,948
Northwest Territories	397,628	436,907
Ontario	2,157,386	1,925,934
Prairie Provinces	106,175	110,464
Quebec	r 924,272	923,432
Yukon Territory	56,710	44,054
Total	r 3,799,278	3,587,168

r Revised.

Source: Dominion Bureau of Statistics.

Corp. produced nearly 109,700 ounces of gold from its placer and underground mines, 18 percent less than in 1964. The falloff in production was attributed to the lower grade of gravel worked, an unusually large amount of time lost in moving dredges to new locations, and a 6-week shutdown of one unit pending settlement of a damage claim.

Four dredges were operated in the Choco district and one in Nariño. Dredging reserves at yearend were estimated at 113 million cubic yards averaging 16.1 cents per yard compared with 108 million yards averaging 15.6 cents per yard at the end of 1964. Underground reserves increased to 185,000 tons averaging 0.79 ounce per ton from 177,000 tons averaging 0.81 ounce per ton at the and of 1964. The central bank continued buying gold at $35.60 an ounce, of which 25 percent was paid in dollars and 75 percent in pesos at the average free market rate, but the payment of a 15-peso bonus was canceled. As a result of losing the bonus, gold sales averaged $35.83 an ounce compared with $36.28 in 1964.[8]

Pato Consolidated Gold Dredging Ltd., controlled by International Mining Corp., operated seven dredges in the Nechi River in Antioquia and treated 30.5 million cubic yards of gravel averaging 14.6 cents per cubic yard, a substantial increase in both quantity and grade compared with 1964 totals. Value of gold production was $4.45 million compared with $3.69 million in 1964. The total estimated minable reserve at yearend was 337.5 million cubic yards averaging 16.1 cents per yard.[9]

Ghana.—Gold production in Ghana dropped 5 percent to the lowest level since 1956. A shortage of certain mine supplies handicapped some of the mines and was a significant factor contributing to the lower output in 1965. Ashanti Goldfields Corp. Ltd. reported a small drop in gold production from the record high of 1964 to about 467,000 ounces. Tons milled increased 5 percent to 515,600, but average grade of ore dropped slightly to 1.04 ounces per ton. Recovery was 89 percent. The Corporation accounted for about 62 percent of the country's total gold output. Ashanti's ore reserve decreased slightly to 3.29 million tons averaging about 1.0 ounce per ton. About 4,700 persons were employed.

Philippines.—Mine output of gold increased 2 percent. Benguet Consolidated, Inc., reported that it treated 1.275 million tons of ore yielding 244,300 ounces compared with 1.273 million tons yielding 236,700 ounces in 1964. Overall gold recovery was 90.7 percent as against 90.1 in 1964. Ore reserves at yearend were 2.1 million tons valued at $19.6 million, about 15 percent less than last year.

The Government subsidy on gold production continued through the year, resulting in an average price of ₱189, equivalent to $48.50 per troy ounce. Reopening of new and inactive mines was encouraged by an amendment to the Mining Act exempting these mines from all taxes except income taxes. Several gold properties in Mindinao were being explored by Benguet Consolidated and by Baguio Gold Mining Co. in Mountain Province.

Rhodesia, Southern.—Output of gold in Rhodesia dropped 5 percent from the post-World War II high in 1964.

At the Dalney mine, Falcon Mines, Ltd., treated 258,600 tons of ore in the year ending September 30 and produced 72,905 ounces of gold, a moderate decline in tonnage but an increase in total yield. The average ore grade was down moderately, but metallurgical recovery increased as a result of the installation of additional milling equipment. A further increase in gold recovery is expected following an increase in the milling rate and the adoption of cyanidation of flotation tailings. Ore reserves declined slightly to 809,600 tons averaging 0.34 ounce per ton over 77 inches.

South Africa, Republic of.—South Afri-

[8] International Mining Corp. Annual Report. 1965, pp. 4–7.
[9] Pato Consolidated Gold Dredging Ltd. 32nd Annual Report 1965.

can gold production established a record for the 14th successive year. Output rose 5 percent to 30.5 million ounces valued at $1,069 million. South Africa contributed about 73 percent of the total free world gold production.

Of the 53 operating mines that were members of the Transvaal and Orange Free State Chamber of Mines, 50 were primary gold producers and 3 were primary uranium producers. Two mines, East Champ d'Or and Rose Deep, ceased mining operations during the year. Operating costs of the industry continued to rise due largely to increased wages and higher prices of supplies and services. Total ore reserves declined 4.4 million tons to 176.0 million, but average grade increased slightly to 0.44 ounce per ton. The nonwhite labor supply was adequate but the shortage of white artisans continued to be acute. The average number of employees in the gold-mining industry was 44,100 whites and 375,330 nonwhites, a decline of 1,680 and 5,620, respectively.

Anglo-American Corporation of South Africa Ltd. reported that production from the 14 mines of its group increased 8 percent to 11.5 million ounces, nearly 38 percent of the South African gold production and 27 percent of the total free world gold output. Western Deep Levels Ltd. continued to expand production and milled 2.7 million tons of ore and recovered 1.2 million ounces of gold compared with 2.4 million tons and 800,000 ounces in 1964. The yield per ton increased to 8.51 pennyweight (0.42 ounce) from 7.06 pennyweight (0.35 ounce). The longwall system was used in mining the Carbon Leader Reef and wherever possible this system was also used on the Ventersdorp Contact Reef. Operating costs increased $0.58 per ton to $7.84 per ton.

Total payable ore reserves at yearend were nearly 5.0 million tons with an average value of 613 inch-pennyweight, equivalent to about 0.73 ounce per ton across 42 inches, a significant increase in both quantity and grade compared with the same date in 1964.

Free State Geduld Mines Ltd. increased ore production and profits substantially. About 1.8 million tons averaging 1.05 ounces per ton were milled compared with 1.7 million tons yielding 1.04 ounces per ton in 1964. The ore reserve was 4.6 million tons; average grade was 59 inch-ounces gold. Comparative data for 1964 were 4.3 million tons and 59 inch-ounces.[10]

Consolidated Gold Fields of South Africa Ltd. reported that its group of mines in the Republic of South Africa produced over 5 million ounces of gold for the first time in 1965. Most of the company's output came from four mines on the West Wits line—West Driefontein, Doornfontein, Libanon, and Venterpost. West Driefontein, the leading gold-producing mine, produced 2.8 million ounces, a new world record.[11]

Union Corp. Ltd. reported a small drop in the quantity of ore milled and gold produced in 1965 from its group of mines, a reversal of the pattern established in recent years. The production decline was attributed to the reduced scale of operations at most of the older group mines on the East Rand which was not fully offset by increased output at the newer mines in the Evander area. The Union Corp. group milled 12.98 million tons of ore yielding 3.98 million ounces. The ore reserve at yearend was 36.7 million tons averaging 0.35 ounce per ton, a decline of 2.8 million tons. Braken mines milled 1.1 million tons yielding $16.25 per ton at a working cost of $7.53 per ton. The ore reserve at yearend was 3.0 million tons averaging 0.51 ounce per ton over a 38-inch stoping width. Leslie mines treated 1.8 million tons yielding $11.93 per ton at a working cost of $5.95 per ton. The ore reserve at yearend was 4.2 million tons averaging 0.36 ounce per ton across 44 inches. At Winkelhaak mines, tons milled increased 100,000 tons to 1.6 million tons but average yield dropped $0.39 to $11.38 per ton at a working cost of $7.45 per ton. Ore reserves were 5.0 million tons averaging 0.33 ounce per ton over a 55-inch width. At St. Helena mines, tons milled dropped slightly to 2.4 million tons but average yield was up slightly to $15.92. Working costs were up $0.28 to $5.94 per ton; ore reserves totaled 9.1 million tons averaging 0.51 ounce per ton across a 59-inch stoping width. At the East Geduld mine, tons milled (1.3 million) and average yield ($8.01) continued to decline and working

[10] Anglo-American Corporation of South Africa Ltd. 49th Annual Report. 1965, pp. 14, 58, 61.

[11] Consolidated Gold Fields of South Africa Ltd. 78th Annual Report. 1965, pp. 20, 22.

Table 16.—Republic of South Africa: Salient statistics of the gold-mining industry

	1963	1964	1965 [1]
Ore milled thousand tons	73,649	79,569	80,027
Gold recovered [2] thousand troy ounces	27,432	29,137	30,102
Gold recovered ounces per ton	.358	.359	.376
Working revenue (gold)[2] thousands	$928,192	$1,022,719	$1,073,158
Working revenue per ton milled	$12.10	$12.26	$13.71
Working cost thousands	$550,166	$575,870	$610,464
Working cost per ton	$7.47	$7.69	$8.04
Working cost per ounce of gold	$20.87	$20.57	$20.69
Total working profit from gold thousands	$378,026	$413,241	$431,556
Estimated working profit per ton from gold	$5.15	$5.52	$5.97
Dividends paid thousands	$161,800	$173,547	$175,805

[1] Excludes primary uranium producers.
[2] Includes non-Chamber of Mines' properties.

Source: The Mining Journal (London).

costs ($5.84) continued to rise. The ore reserve in the Main and Kimberley Reefs was 1.3 million tons averaging 0.26 ounce across 62 inches, and 800,000 tons averaging 0.20 ounce per ton across 47 inches, respectively.[12]

U.S.S.R. — Although quantitative data are not published available information indicates that gold production continued to increase significantly. Based on the new 5-year plan published in April 1966, the outlook was for further expansion of Soviet gold output. A major new goldfield was reported to have been discovered at Muruntau in the Republic of Uzbekistan. Soviet gold sales in world markets were estimated at $310 million, a sharp drop from sales in 1964.

TECHNOLOGY

Scientists of International Business Machines Corp. have created magnetic gold-cobalt alloys with compositions ranging from 25 to 60 percent gold by a new vapor deposition technique. In the deposition technique, the metals are heated to their vaporization temperatures in separate crucibles and the vapor deposited onto a substrate which is maintained at liquid nitrogen temperature. The cold substrate keeps the atoms from rearranging into a crystalline structure. Magnetic films produced by the process can exist either in an amorphous or metastable crystalline state.[13]

A method of electroplating gold directly onto molybdenum without the usual need for preplating with other metals was developed by Bell Telephone Laboratories. The new technique offers advantages in the manufacture of semiconductor devices by yielding an adherent corrosion-resistant gold layer which will alloy readily with semiconductors and is suitable for thermocompression bonding. The new technique is based on a reaction of hydrogen peroxide with the molybdenum surface forming a thin porous oxide. During the goldplating, the noble metal penetrates the pores and then deposits onto the molybdenum. Subsequent reduction of the oxide by hydrogen at about 1,650° F causes a mechanical interlocking of the molybdenum-gold interface; additional gold can then be plated onto the surface.[14]

A new instrument for the detection and measurement of gold was developed under an Atomic Energy Commission contract by Tracerlab, a division of Laboratory for Electronics, Inc., for use by the U.S. Customs Service for determining the gold content of objects coming into the United States.

The instrument is transistorized, battery-powered, and completely portable. When gold is present in the sample being tested, a high-pitched birdlike whistle is produced, the intensity of which increases in proportion to the amount of gold present. In the instrument, the radioisotope, xenon 133 emits low-energy gamma radiation which causes the gold to give off X-rays. Filters permit only the X-rays peculiar to gold

[12] Union Corporation, Ltd. Report and Accounts for the Year Ended 31st December 1965. Pp. 26–31, 40.
[13] Journal of Metals. New Magnetic Alloys. V. 17, No. 10, October 1965, p. 1078.
[14] Chemical Engineering. Gold Can Now Be Joined Directly to Molybdenum. V. 72, No. 21, Oct. 11, 1965, p. 114.

to reach the radiation counter in the upper part of the instrument. Impulses from the counter produce the sound. As Xe^{133} has a half-life of only 5 days, efforts are being made to design a radioactive source having a much longer half-life.

A new solution analyzer that can provide automatic control of cyanide addition in gold plants was tested by Canada's Department of Mines and Technical Surveys. The new instrument measures free cyanide concentration by continuous potentiometric titration and can be assembled from relatively inexpensive, commercially available components.[15]

A simplified sensitive spectrographic method for determining trace amounts of gold in geologic materials was developed by scientists of the Geological Survey. The new technique, which is rapid and particularly useful in geochemical exploration for ore deposits, permits determining gold content in the range of 0.03 to 3 parts per million, thus bridging the gap between fire assay and neutron activation procedures. The new gold analysis method uses common laboratory chemicals to separate gold and a colorimetric reagent known as TMK to determine the amount of gold present by visual color comparison.[16]

A group of new brazing alloys for joining semiconductor devices to metallic substrates was developed. The new alloys contain from 5 to 86 percent gold and have melting points of 375° to 630° C. The alloys can also be used to braze insulating materials such as glass, Pyroceram, or alumina to semiconductor materials, metals, or each other by metalizing one surface of the insulating material.

The Committee for Research on the Properties and Uses of Gold, Inc., reported the following: Gold-germanium alloys formed by extremely rapid cooling from molten temperatures, having 27.5 to 60 atomic percent germanium, show superconductivity at temperatures ranging from 1.63° to 0.99° K; a new spray-plating process for applying mirror films of pure gold uses two aqueous solutions, which do not decompose or react to form explosive substances, to provide good adhesion at deposition rates up to 0.3 micron per minute; and a process was developed which permits gold alloy foil containing from 0.01 to 10 percent each of silicon and antimony to be rolled as thin as 0.001 inch for semiconductor devices. The technique includes melting under inert atmosphere, rapid quenching, and annealing-rolling.

The Committee also reported a method of producing boron-containing gold foil for use in P-type semiconductor devices. The technique involves mixing gold and boron powders, compacting and tempering in a protective atmosphere, followed by melting and rolling into foil.

The practice in Canadian refineries for recovering gold and other precious metals from anode slimes of electrolytic refining of copper was described.[17]

Heat treatment of an equiatomic gold-nickel alloy can produce a precipitation-hardened alloy with a yield strength of approximately 150,000 pounds per square inch. The alloy is solution treated at 900° C for 1 hour, quenched in water, and aged at 450° C to yield a roughly spherical precipitate. The alloy has potential use as a prosthetic material in dentistry and surgery.

A new gravimetric method of assaying gold-plating baths was developed that gives a more accurate determination of gold than wet chemical methods. In the new method hypophosphorus acid is the reducing agent and mercuric chloride the catalyst and collector for gold.

Recent research has shown that electron bombardment and thermal etching prior to goldplating can markedly improve the bearing life of gold film under ultrahigh vacuum. The experiments included the vapor deposition of gold onto substrates of nickel, nickel-10 percent chromium, and nickel-5 percent rhenium.

Research investigations have demonstrated that gold can be dissolved by an aerobic bacteria of the genus *Clostridium,* thus indicating the possibility of gold dissolution by decomposing vegetable matter.[18]

[15] Engineering and Mining Journal. New Analyzer Records Free Cyanide. V. 166, No. 6, June 1965, pp. 111–112.

[16] Lakin, H. W., and H. M. Nakagawa. A Spectrophotometric Method for the Determination of Traces of Gold in Geologic Materials. U.S. Geol. Survey Prof. Paper 525–C, 1965, pp. C168–C171.

[17] Habashi, Fathi. Recent Methods for the Treatment of Anodic Slimes of Copper Electrolysis. Metallurgic (Manchester, England), v. 72, No. 434, December 1965, pp. 257–263.

[18] New Scientist. Gold Succumbs to Bacteria. May 20, 1965, p. 505.

Graphite

By Donald E. Eilertsen [1]

Domestic output of natural graphite increased substantially in 1965 compared to that of 1964. Imports for consumption of natural graphite and exports of natural graphite in 1965 were the largest ever reported.

There was no change in the Government stockpile of graphite during 1965 but plans to dispose of surplus material were being made.

Table 1.—Salient graphite statistics

	1956-60 (average)	1961	1962	1963	1964	1965
United States:						
Consumption_______short tons____	37,600	35,700	44,400	47,000	54,000	47,100
Value_________thousands____	$5,126	$4,651	$5,648	$6,111	$7,026	$6,390
Imports for consumption________short tons____	40,400	29,700	39,500	52,200	47,200	58,100
Value_________thousands____	$1,837	$1,332	$1,783	$2,000	$1,944	$2,387
Exports___________short tons____	1,400	1,600	1,200	900	2,000	3,200
Value_________thousands____	$218	$257	$223	$190	$333	$419
World: Production_____short tons____	388,000	455,000	590,000	r 785,000	r 700,000	675,000

r Revised.

Table 2.—Government yearend stocks and surplus of natural graphite
(Short tons)

Type of graphite	Strategic stockpile	Supplemental stockpile	Total surplus
Malagasy crystalline flake	26,665	-----	15,865
Malagasy crystalline fines	6,013	1,908	721
Ceylon amorphous lump	4,455	1,428	383
Other than Ceylon and Malagasy, crystalline	4,809	-----	2,009
Nonstockpile-grade, crystalline	672	-----	672
Total	42,614	3,336	19,650

DOMESTIC PRODUCTION

The Southwestern Graphite Co., Burnet, Tex., continued to be the only producer of natural graphite. Its output of natural graphite was substantially larger in 1965 than in 1964.

A number of plants produced artificial graphite and the output of this material was considerable.

Union Carbide Corp. planned to construct a plant at Greenvelle, S.C., to produce its newly developed graphite filament. The new material was reported to be the strongest and stiffest material, by weight, ever produced and to have many potential uses as reinforcing material for resin-and metal-matrix composites.

Speer Carbon Co., a division of Air Reduction Co., New York, and producer

[1] Commodity specialist, Division of Minerals.

of carbon and graphite products, reportedly planned to spend $17 million on plant expansions at St. Marys, Pa., and Niagara Falls, N.Y.

Graphite Products Division, Great Lakes Carbon Corp., was reported to have started a multimillion dollar expansion and modernization program for increased output of graphite and carbon electrodes at Niagara Falls, N.Y.

Basic Carbon Corp., a new subsidiary of The Carborundum Co., Cleveland, Ohio, announced plans to build an approximately $8 million plant to manufacture graphite products at Hickman, Ky.

CONSUMPTION AND USES

Natural graphite consumption was smaller in 1965 than in 1964.

The demand for artificial graphite continued at a very high rate. Artificial graphite was used in electrodes for electrosmelting, anodes for the electrochemical industries, nuclear energy, aerospace, and in many applications similar to those which use natural graphite.

Table 3.—Consumption of natural graphite in the United States

Year	Short tons	Value (thousands)
1956–60 (average)	37,556	$5,126
1961	35,652	4,651
1962	44,383	5,648
1963	47,006	6,111
1964	54,043	7,026
1965	47,078	6,390

Table 4.—Consumption of natural graphite in the United States in 1965, by uses

Use	Crystalline flake		Ceylon amorphous		Other amorphous [1]		Total	
	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value
Batteries	W	W	-----	-----	966	$167,100	966	$167,100
Bearings	W	W	W	W	256	110,500	256	110,500
Brake linings	454	$123,400	326	$87,700	981	149,500	1,761	360,600
Carbon brushes	145	74,100	364	199,900	255	44,800	764	318,800
Crucibles, retorts, stoppers, sleeves, and nozzles	[2] 4,901	801,000	-----	-----	W	W	4,901	801,000
Foundry facings	1,175	212,500	190	48,500	11,000	1,016,200	12,365	1,277,200
Lubricants	923	245,700	140	46,400	2,674	283,800	3,737	575,900
Packings	229	114,100	W	W	481	70,500	710	184,600
Paints and Polishes	W	W	W	W	512	45,300	512	45,300
Pencils	1,008	320,100	434	147,600	492	62,000	1,934	529,700
Refractories	W	W	-----	-----	7,606	756,000	7,606	756,000
Rubber	34	16,200	130	23,700	45	15,700	209	55,600
Steelmaking	727	117,200	274	18,400	8,316	728,000	9,317	863,600
Other [3]	430	143,500	20	10,600	1,590	189,700	2,040	343,800
Total	10,026	2,167,800	1,878	582,800	35,174	3,639,100	47,078	6,389,700

W Withheld to avoid disclosing individual company confidential data, included in total.
[1] Includes graphite indicated by symbol W, unspecified graphites, and mixtures of natural and manufactured graphites.
[2] Includes some amorphous.
[3] Includes adhesives, chemical equipment and processes, electronic products, powdered-metal parts, small packages, specialties, and other uses not specified.

PRICES

Actual prices for natural graphite are negotiated between buyer and seller and cover a wide range of specifications.

Oil, Paint and Drug Reporter quoted the following prices for graphite, per pound, in bags, fiber drums, ex warehouse: Nos. 1 and 2 flake graphite containing 90 to 95 percent carbon at 29 to 32 cents; powdered crystalline graphite—containing 88 to 90 percent carbon at 20 to 23.5 cents, 90 to 92 percent carbon at 22.5 to 25.5 cents, and 95 to 96 percent carbon at 29 to 32 cents; powdered amorphous crystaline graphite containing a minimum of 97 percent carbon at 30.5 to 33 cents; and powdered amorphous graphite at 6.5 to 12 cents.

Prices quoted by E&MJ Metal and Mineral Markets for flake and crystalline graphite, f.o.b. source, bags, per short ton, were as follows: Malagasy Republic, $82 to $181; Norway $85 to $145; West Germany, $113 to $610; and Ceylon $85 to $223. Amorphous, nonflake, cryptocrystalline, graphite per short ton, f.o.b. source (80 to 85 percent carbon) was quoted as follows: Mexico (bulk) $17 to $20; South Korea (bulk), $13; and Hong Kong (bags), $21.

FOREIGN TRADE

Export of natural graphite in 1965 was the largest ever reported.

New high records of imports were established in 1965 for consumption of natural graphite, for natural amorphous graphite, and for natural amorphous graphites from Mexico, West Germany, and Norway.

A total of 84.3 percent of the imported crystalline flake graphite in 1965 was valued up to $110 per ton (5.5 cents per pound) at foreign ports.

Table 5.—U.S. exports of natural graphite, by countries

Destination	Amorphous, crystalline flake, lump, or chip and natural n.e.c. [1]			
	1964		1965	
	Short tons	Value	Short tons	Value
Argentina	13	$4,512	40	$5,132
Australia	81	14,377	32	3,489
Brazil	276	53,218	7	928
Canada	966	136,144	1,438	183,141
Colombia	12	3,688	39	5,525
France	126	19,936	155	19,015
Italy	2	516	51	6,261
Mexico	37	17,327	228	28,432
Philippines	40	11,264	44	5,634
United Kingdom	151	21,767	828	115,618
Venezuela	113	22,468	75	12,222
Other countries [2]	147	28,260	259	33,591
Total	1,964	333,477	3,196	418,988

[1] Not elsewhere classified.
[2] Includes Austria (1965), Bahamas (1965), Bolivia (1964), Chile, Costa Rica (1965), Czechoslovakia (1964), Denmark, Dominican Republic (1965), Ecuador, El Salvador (1964), West Germany, Guatemala (1965), Honduras (1964), India, Iran (1964), Israel (1965), Japan (1965), Netherlands, Netherlands Antilles (1965), Norway (1965), Pakistan, Peru, Republic of South Africa, Saudia Arabia, Spain (1965), Sweden, Switzerland (1965), Taiwan (1965), and Turkey (1965).

WORLD REVIEW

Czechoslovakia.—A plant to produce chemically refined high-purity graphite from graphite obtained from the Kolodeje na Luznici mine was reportedly put into operation at Tyn nad Vltavou. The product is used in electrical engineering, nuclear energy, and telecommunications.

India.—The occurrence and origin of graphite in the Andra (Kondamusuru), Gotivada, Kuppametta, and Rambhadrapuram localities in the Eastern Ghats area, South India, were described.[2]

Italy.—A new firm, Elettrografite Meridionale SpA, jointly owned by Union Carbide Corp.'s Italian subsidiary, Elettrografite di Forno Allione SpA and the

[2] Krishna Rao, J.S.R., and V. Malleswara Rao. Occurrence and Origin of Graphite in Parts of Eastern Ghats, South India. Econ. Geol. v. 60, No. 5, August 1965, pp. 1046–1051.

Table 6.—U.S. imports for consumption of natural and artificial graphite, by countries

Year and country	Crystalline: Flake, Short tons	Crystalline: Flake, Value	Crystalline: Lump, chip, or dust, Short tons	Crystalline: Lump, chip, or dust, Value	Amorphous: Natural, Short tons	Amorphous: Natural, Value	Artificial, Short tons	Artificial, Value	Total, Short tons	Total, Value
1956-60 (average)	4,917	$558,275	107	$26,413	35,286	$1,238,641	61	$13,864	40,371	$1,837,193
1961	4,377	428,793	55	17,138	25,246	863,457	70	22,787	29,748	1,332,175
1962	5,458	532,270	181	55,769	29,250	1,100,072	4,639	95,274	39,528	1,783,385
1963	5,489	542,374	198	61,740	46,128	1,383,440	369	12,526	52,184	2,000,080
1964:										
Ceylon	-----	-----	-----	-----	3,215	364,275	-----	-----	3,215	364,275
Germany, West	215	40,364	66	20,580	1,585	179,443	4	697	1,870	241,084
Japan	243	22,634	-----	-----	-----	-----	-----	-----	243	22,634
Korea, South	-----	-----	-----	-----	617	12,525	-----	-----	617	12,525
Malagasy	[r]4,268	408,144	-----	-----	84	7,755	-----	-----	[r]4,352	415,899
Mexico	-----	-----	-----	-----	33,709	653,515	-----	-----	33,709	653,515
Norway	13	1,402	-----	-----	2,543	203,948	-----	-----	2,556	205,350
Other countries [1]	13	4,939	-----	-----	573	19,890	52	3,694	638	28,523
Total	[r]4,752	477,483	66	20,580	42,326	1,441,351	56	4,391	[r]47,200	1,943,805
1965:										
Ceylon	28	2,625	11	1,185	2,666	275,217	-----	-----	2,705	279,027
France	29	11,645	-----	-----	-----	-----	-----	-----	29	11,645
Germany, West	509	88,498	55	17,150	1,904	233,382	5	2,641	2,473	341,671
Korea, South	12	1,800	-----	-----	1,428	38,553	-----	-----	1,440	40,353
Malagasy	5,611	538,756	-----	-----	5	414	-----	-----	5,616	539,170
Malaysia	59	11,276	-----	-----	-----	-----	-----	-----	59	11,276
Mexico	-----	-----	-----	-----	41,481	816,083	-----	-----	41,481	816,083
Norway	55	6,008	-----	-----	3,793	314,996	-----	-----	3,848	321,004
Other countries [2]	91	8,085	21	900	256	9,566	37	7,866	405	26,417
Total	6,394	668,693	87	19,235	51,533	1,688,211	42	10,507	58,056	2,386,646

[r] Revised.
[1] Crystalline flake includes Canada and France; amorphous natural includes Austria, Canada, East Germany, Hong Kong, Netherlands, United Kingdom, Cameroon, and Thailand; and artificial includes Canada and Switzerland.
[2] Crystalline flake includes Canada, Japan, and Turkey; crystalline lump, chip, and dust includes Canada; amorphous natural includes Canada, Hong Kong, and United Kingdom; and artificial includes Canada, Netherlands, Switzerland, and United Kingdom.

Italian firm of Insud-Nuove Iniziative per il Sud SpA, was formed to produce graphite products at Caserta, near Naples. The new plant, scheduled for completion late in 1967, is expected to have an initial capacity of 11,000 tons of graphite products annually for the steel, electrochemical, and nuclear power industries.[3]

Southern Rhodesia.—Plans were made to establish the graphite industry in Southern Rhodesia early in 1966. Rho-German

Table 7.—World production of natural graphite by countries [1]

(Short tons)

Country [1]	1961	1962	1963	1964	1965 [p] [2]
North America: [1] Mexico	19,846	31,992	33,065	[r] 33,441	[e] 34,000
South America:					
Argentina	[r] 869	[r] 522	[r] 306	[r] 171	[e] 180
Brazil	[r] 1,593	1,775	[r] 6,640	5,150	[e] 5,200
Europe [1]:					
Austria	89,255	98,416	109,778	112,697	94,529
Germany, West	13,349	13,134	[r] 14,110	[r] 14,793	[e] 15,000
Italy	[r] 4,485	[r] 3,327	[r] 2,053	1,443	1,353
Norway	6,300	7,222	8,400	[r] 8,350	8,500
Spain	303	-----	-----	-----	-----
U.S.S.R. [e]	55,000	60,000	60,000	60,000	60,000
Africa:					
Malagasy Republic	16,473	19,274	21,214	[r] 14,521	18,756
South Africa, Republic of	963	1,308	671	1,042	447
South-West Africa	-----	-----	-----	275	396
Asia:					
Ceylon (exports)	[r] 10,015	9,665	9,280	[r] 11,957	9,789
China [e]	45,000	45,000	45,000	45,000	45,000
Hong Kong	1,865	902	891	795	-----
India	1,830	[3]	[3]	[3]	[3]
Japan	3,836	3,812	3,305	2,700	[e] 2,800
Korea:					
North [e]	72,000	72,000	77,000	77,000	77,000
South	98,892	204,032	374,428	[r] 291,515	[e] 285,000
World total (estimate) [1]	455,000	590,000	[r] 785,000	[r] 700,000	675,000

[e] Estimate. [p] Preliminary. [r] Revised.

[1] Graphite has been produced in Czechoslovakia, but production data are not available; estimates by author of chapter included in total. U.S. figure withheld to avoid disclosing individual company confidential data, included in world total.

[2] Compiled from data available June 1966.

[3] Estimate by author of chapter included in total.

Table 8.—Ceylon: Exports of graphite by countries

(Short tons)

Destination	1964	1965
North America:		
Canada	29	-----
United States	3,430	2,290
Europe:		
Belgium	54	34
Czechoslavakia	3	105
France	543	174
Germany, West	72	83
Netherlands	-----	67
Poland	186	78
United Kingdom	2,702	2,853
Asia:		
India	1,243	1,488
Japan	2,659	1,785
Pakistan	289	211
Philippines	22	-----
Thailand	17	19
Oceania: Australia	688	537
Other countries	20	65
Total	11,957	9,789

Graphite (Pvt.), Ltd., planned to mine flake graphite ore containing 30 to 40 percent carbon in the Karoi area, to upgrade the ore to concentrate containing 85 to 90 percent carbon, and to export about 500 tons of flake graphite per month.[4]

South Africa, Republic of.—The establishment of a firm to produce graphite electrodes was announced. The firm will be a subsidiary of African Metals Corp., Ltd. (AMCOR), and will have ties with Farbwerke Hoechst A.G., and Siemens-Planiawerke A.G. of West Germany. The new plant will be built adjacent to AMCOR's Kookfontein Works in Vereeniging and is scheduled to go into operation in

[3] Oil, Paint and Drug Reporter. Graphite: A Venture for Carbide in Italy. V. 188, No. 14, Oct. 4, 1965, pp. 4, 33.

[4] Bureau of Mines. Mineral Trade Notes. V. 61, No. 5, November 1965, p. 15.

Table 9.—Malagasy Republic: Exports of graphite by countries

(Short tons)

Destination	1963	1964
North America: United States	5,306	4,960
Europe:		
Belgium-Luxembourg	95	62
Denmark	55	-----
France	3,334	2,970
Germany, West	2,362	1,825
Italy	1,246	645
Netherlands	85	61
Poland	22	-----
Spain	232	209
United Kingdom	3,729	3,523
Asia:		
India	47	103
Japan	538	1,013
Oceania: Australia	344	100
Other countries	18	22
Total	17,413	15,493

the middle of 1966 with a capacity of 5,400 tons of electrodes annually.[5]

South-West Africa.—Graphite production was resumed in 1964 after lapsing since 1955. A total of 275 tons of graphite was mined from a deposit near Aukam tin mine, 25 miles south of Kuibis Station on the Lüderitz-Keetmanshoop railway line. Production of graphite increased in 1965.

[5] South African Mining & Engineering Journal. AMCOR to Pioneer Making of Graphite Electrodes in S.A.: R5m. Project. V. 76, Pt. 1, No. 3758, Feb. 12, 1965, pp. 344, 347.

TECHNOLOGY

Some of the numerous difficulties in producing uniform-grade graphite from petroleum coke[6] and from other source materials[7] were discussed in U.S. Air Force sponsored research. Studies made on numerous coatings for graphite to protect it from oxidation at high temperatures were reported.[8] Various graphite composits were also investigated.[9]

The Atomic Energy Commission (AEC) in conjunction with the National Aeronautics and Space Administration made studies on the mechanical properties of several reactor-grade graphites and methods to predict the behavior of components made from these graphites. AEC also studied the irradiation effects on graphite that caused it to expand below about 300° C, and to shrink at higher temperatures; the corrosion of graphite by a stream of high-temperature helium contaminated with carbon dioxide, carbon monoxide, water, and hydrogen; and the usage of a new technique to measure the thermal diffusion rate of boron atoms in single crystals of graphite for motion parallel and perpendicular to the layer planes.[10]

A new group of high-strength graphite-base refractory compositions containing additives such as zirconium diboride, boron, and silicone for use in high-temperature applications were described briefly. The additives form an oxide glaze thus preventing air from attacking graphite.[11]

A new type of manufactured graphite featuring high-purity uniform-grain structure, small pore size, and many other attractions became available commercially.[12] A material consisting of layers of carbon and graphite bonded together became available for high-temperature applications.[13]

[6] Stout, C. F., M. Jones, and J. A. Biehl. Research and Development on Advanced Graphite Materials. Wright-Patterson Air Force Base, Ohio, WADD TR 61–72, v. 36, August 1964, 109 pp.; Office of Tech. Services, U.S. Dept. of Commerce, AD 607763.

[7] Union Carbide Corp. Improved Graphite Materials for High-Temperature Aerospace Use. Volume I. Research and Development for Improved Graphite Materials. Wright-Patterson Air Force Base, Ohio, ML–TDR–64–125, September 1964, 144 pp.; Office of Tech. Services, U.S. Dept. of Commerce, AD 608071.

[8] Criscione, J. M., R. A. Marcuri, E. P. Schram, A. W. Smith, and H. F. Volk. High Temperature Protective Coatings for Graphite. Wright-Patterson Air Force Base, Ohio, ML–TDR–64–173, pt. 2, October 1964, 143 pp.; Office of Tech. Services, U.S. Dept. of Commerce, AD 608092.

[9] Union Carbide Corp. Improved Graphite Materials for High-Temperature Aerospace Use. Volume II. Development of Graphite—Refractory Composits. Wright-Patterson Air Force Base, Ohio, ML–TDR–64–125, October 1964, 128 pp.; Office of Tech. Services, U.S. Dept. of Commerce, AD 609247.

[10] Atomic Energy Commission. Fundamental Nuclear Energy Research 1965. A Supplemental Report to the Annual Report to Congress. December 1965, 338 pp.

[11] Materials in Design Engineering. Graphite Refractory Resists 3,400 F. V. 61, No. 2, February 1965, pp. 106–107.

[12] Materials in Design Engineering. Graphite Has Uniform Grain Structure. V. 61, No. 4, April 1965, p. 17.

[13] Ceramic Industry. The Graphite That Withstands 5,700°F. V. 84, No. 4, April 1965, pp. 52, 144.

A new fibrous form of graphite was reported to be the strongest and stiffest material for its weight ever produced. The filament can be used as a reinforcing agent for both resin and metal-matrix composites.[14]

A number of patents on graphite were issued.[15]

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[14] Iron Age. Graphite "In" as a Reinforcement. V. 196, No. 22, Nov. 25, 1965, p. 70.

[15] Brockway, Marion Clifford (assigned to the U.S. Atomic Energy Commission). Graphite Dispersion. U.S. Pat. 3,173,973, Mar. 16, 1965.

Criss, Filmore F. (assigned to the U.S. Atomic Energy Commission). Carbide Coatings for Graphite. U.S. Pat. 3,208,870, Sept. 28, 1965.

Criss, Filmore F., and Cornel Wohlberg (assigned to the U.S. Atomic Energy Commission). Carbide Coatings on Graphite. U.S. Pat. 3,208,872, Sept. 28, 1965.

Diefendorf, Russel J. (assigned to General Electric Co., New York). Method of Forming Composite Graphite Coated Article. U.S. Pat. 3,172,744, Mar. 9, 1965.

———. (assigned to General Electric Co., New York). Method for Coating Articles With Pyrolitic Graphite. U.S. Pat. 3,206,331, Sept. 14, 1965.

Giardini, Armando A., and John E. Tydings (assigned to the U.S. Army). Method of Producing Pure Single Crystals of Graphite. U.S. Pat. 3,167,393, Jan. 26, 1965.

Gibson, David W., Kenneth B. McGhee, and Robert C. Stroup (assigned to Union Carbide Corp., New York). Graphite Cloth Laminates. U.S. Pat. 3,174,895, Mar. 23, 1965.

Jones, James Byron, and William B. Tarpley, Jr. (assigned to Aeroprojects Incorporated, West Chester, Pa.). Method of Vibratorily Extruding Graphite. U.S. Pat. 3,194,855, July 13, 1965.

Juel, Leslie H. (assigned to Great Lakes Carbon Corp., New York). Method of Controlling Orientation of Extruded Graphite Crystallites. U.S. Pat. 3,168,509, Feb. 2, 1965.

Turner, Richard F., and Ernest O. Winkler (assigned to the U.S. Atomic Energy Commission). Ceramic-Matrix-Type Fuel Element With Graphite Fabric Affixed to Exterior Surface. U.S. Pat. 3,224,944, Dec. 21, 1965.

Vinal, Albert F. (assigned to Union Carbide Corp., New York). Dry Cell Electrodes Containing Fibrous Graphite and Process of Making Same. U.S. Pat. 3,192,071, June 29, 1965.

Gypsum

By Paul L. Allsman[1]

Despite a decline in 1965 production, producers were optimistic about the immediate outlook for gypsum and gypsum products. Domestic production of crude gypsum decreased 6 percent from that of 1964, and the quantity of imported crude gypsum also decreased 6 percent. Use of both calcined and uncalcined gypsum products increased.

Table 1.—Salient gypsum statistics

(Thousand short tons and thousand dollars)

	1956–60 (average)	1961	1962	1963	1964	1965
United States:						
Active mines and plants[1]	89	98	102	103	106	114
Crude:[2]						
Mined	9,967	9,500	9,969	10,388	10,684	10,035
Value	$34,277	$34,996	$36,343	$38,138	$38,874	$37,423
Imports for consumption	4,832	4,967	5,421	5,490	6,258	5,911
Calcined:						
Produced	8,478	8,246	8,819	9,181	9,440	9,320
Value	$99,783	$118,145	$127,436	$131,668	$135,877	$133,028
Products sold (value)	$340,268	$358,811	$392,300	$414,090	$431,717	$419,668
Gypsum and gypsum products:						
Exports (value)	$1,523	$1,299	$1,302	$1,431	$1,808	$2,032
Imports for consumption (value)	$9,709	$10,306	$11,912	$12,357	$14,687	$13,328
World production	41,572	45,310	48,740	49,900	51,530	51,610

[1] Each mine, calcining plant, or combination mine and plant is counted as 1 establishment.
[2] Excludes byproduct gypsum.

DOMESTIC PRODUCTION

Crude.—Of the 75 mines operated, 57 were open pit and 18 were underground. Eighty percent of the total output came from 39 mines operated by companies having calcining equipment. By state, the leading crude gypsum producers were: California, 16 percent; Michigan, 13 percent; Iowa, 12 percent; and Texas, 10 percent. More than 49 percent of the California output was sold uncalcined for agricultural purposes.

Calcined.—Domestic or imported gypsum was calcined at 78 plants that had 227 kettles and 71 other pieces of calcining equipment. A total of 9.7 billion square feet of board products was reported in 1965 with a value of $353.2 million, as compared with 9.3 billion square feet of board products with a value of $363.9 million in 1964. Natural gas, oil, and coal were used as fuel at various plants.

Mine and Products—Plant Development.—Production began at the new gypsum products plant of The Flintkote Co. at Savannah, Ga. The plant utilizes 130,000 tons per year of crude gypsum for gypsum board and other gypsum products. Gypsum Products of America Corp., was building a $3.1 million plant at Himes, Wyo., 75 miles east of Yellowstone National Park. A $2.05 million loan was obtained from the Small Busi-

[1] Commodity specialist, Division of Minerals.

Table 2.—Crude gypsum mined in the United States, by States
(Thousand short tons and thousand dollars)

State	1964 Active mines	1964 Quantity	1964 Value	1965 Active mines	1965 Quantity	1965 Value
Arizona	6	147	$770	5	103	$540
California	9	1,893	4,539	10	1,611	3,881
Colorado	4	100	398	6	102	427
Iowa	5	1,287	5,821	5	1,254	5,554
Michigan	5	1,421	5,263	5	1,338	5,027
Nevada	3	799	2,894	4	710	2,518
New York	5	653	3,321	5	662	3,511
Oklahoma	8	694	1,899	8	761	2,343
South Dakota	1	19	76	1	7	27
Texas	7	1,131	4,049	6	1,045	3,794
Other States [1]	19	2,540	9,844	20	2,442	9,801
Total	72	10,684	38,874	75	10,035	37,423

[1] Includes the following States to avoid disclosing individual company confidential data: Louisiana, 1 mine; Arkansas, Indiana, Kansas, Montana, Ohio, Utah, Virginia, and Wyoming, 2 mines each; and New Mexico 3 mines.

Table 3.—Calcined gypsum produced in the United States, by States
(Thousand short tons and thousand dollars)

State	1964 Active plants	1964 Quantity	1964 Value	1964 Calcining equipment: Kettles	1964 Calcining equipment: Other [1]	1965 Active plants	1965 Quantity	1965 Value	1965 Calcining equipment: Kettles	1965 Calcining equipment: Other [1]
California	7	1,019	$9,662	19	14	9	820	$9,184	21	15
Georgia	W	W	W	W	W	3	431	9,250	15	----
Iowa	5	883	13,467	23	4	5	845	12,668	22	4
Louisiana	3	218	3,897	6	1	W	W	W	W	W
Michigan	4	403	6,300	11	1	4	408	6,315	10	1
New York	7	1,100	16,669	24	5	7	1,041	15,359	23	5
Texas	7	913	12,886	29	3	7	837	10,743	27	3
Other States [2]	39	4,904	72,996	120	44	43	4,938	69,509	109	43
Total	72	9,440	135,877	232	72	78	9,320	133,028	227	71

W Withheld to avoid disclosing individual company confidential data; included with "Other States".
[1] Includes rotary and beehive kilns, grinding-calcining units, Holo-Flites, and Hydrocal cylinders.
[2] Comprises States and number of plants as follows: Arizona, 1; Arkansas, 1; Colorado, 2; Connecticut, 1; Delaware, 1; Florida, 3; Georgia, (1964), 2; Illinois, 1; Indiana, 3; Kansas, 2; Louisiana, 3; Maryland, 2; Massachusetts, 1; Montana, 1; Nevada, 3; New Hampshire, 1; New Jersey, 3; New Mexico, 2; Ohio, 3; Oklahoma, 2; Pennsylvania, 1; Utah, 2; Virginia, 2; Washington, 1; Wyoming, 1.

ness Administration. The new plant will turn out wallboard up to 54 inches wide, and pulverized gypsum for agricultural use.

Kaiser Gypsum Co. was adding a multi-million-dollar gypsum products plant at Delanco, N.J. to its string of plants. Sunshine Mining Co. was readying a large open-pit gypsum mining operation at Raynesford, Mont. The deposit, discovered in August 1965, is estimated to contain 3 million tons of 98-percent-pure gypsum.

National Gypsum Co. unveiled its new $1 million testing facilities and research center at Tonawanda, N.Y.

Ideal Cement Co. closed its gypsum mine at Hanover, Mont. because of unsafe conditions. Blue Diamond Co., a division of The Flintkote Co., completed manufacturing and warehousing facilities at a new plant in Fremont, Calif. Crude gypsum is shipped from the Blue Diamond, Nev. mines.

CONSUMPTION AND USES

Production from the rapidly expanding gypsum companies equaled and sometimes exceeded the demand of its housing market, and as a result, earnings declined. Still the industry showed an eagerness to add capacity, and the general feeling was that building would boom again in the coming year. The number of private non-farm housing starts was 1.46 million units in 1965, a decline of 4 percent from the 1964 figure. Wallboard consumption increased 7 percent over that of 1964.

Because the average home continues to grow in size, because of increasing demands for gypsum walls and ceilings, because of the strengthening of building codes in the area of fire protection and sound control, and consequently the greater use of multiple gypsum wallboard assemblies, the gypsum industry is confident and optimistic about its long-range potential. Growth in output of gypsum products is expected to continue at the present rate if the high level of construction activity continues.

Table 4.—Gypsum products (made from domestic, imported and byproduct gypsum) sold or used in the United States, by uses

(Thousand short tons and thousand dollars)

Use	1964		1965	
	Quantity	Value	Quantity	Value
Uncalcined:				
Portland-cement retarder	3,034	$12,997	3,152	$14,765
Agricultural gypsum	1,475	5,518	1,362	4,820
Other uses [1]	53	623	66	776
Total	4,562	19,138	4,580	20,361
Calcined:				
Industrial:				
Plate-glass and terra-cotta plasters	50	788	56	861
Pottery plasters	53	1,218	54	1,236
Dental and orthopedic plasters	14	541	18	698
Industrial molding, art, and casting plasters	99	2,165	111	2,370
Other industrial uses [2]	76	2,796	80	3,116
Total	292	7,508	319	8,281
Building:				
Plasters:				
Base-coat	972	18,667	828	15,930
Sanded and premixed perlite	455	11,515	436	10,981
To mixing plants	(3)	3	W	W
Gaging and molding	121	2,703	113	2,552
Prepared finishes	9	817	10	815
Roof deck	352	5,438	363	5,708
Other [4]	22	1,108	28	1,037
Keene's cement	34	936	27	761
Total	1,965	41,187	1,805	37,784
Prefabricated products [5]	[6] 8,642	363,884	[6] 8,998	353,242
Total	—	405,071	—	391,026
Grand total, value	—	431,717	—	419,668

W Withheld to avoid disclosing individual company confidential data; included with "Other".
[1] Includes uncalcined gypsum for use as filler and rock dust, in brewer's fixe, in color manufacture, and for unspecified uses.
[2] Includes dead-burned filler, granite polishing, and miscellaneous uses.
[3] Less than ½ unit.
[4] Includes joint filler, patching, painter's, insulating, and unclassified building plasters.
[5] Excludes tile.
[6] Includes weight of paper, metal, or other materials.

New products and product research improved the outlook for uses of gypsum in 1965. Screw fasteners especially designed for use in gypsum wallboard construction have now been developed by almost all major screw manufacturers. A new fire-rated gypsum wallboard in 54-inch widths has been announced by several manufacturers.

A new sprayable drywall contact adhesive has greatly reduced costs and time required to laminate gypsum wallboard.[2]

A new waterproofed gypsum wallboard, heavily impregnated with special waterproofing compounds and tested under extreme moisture conditions, was made available in either regular gypsum core or Type X gypsum core.[3]

[2] Gypsum Drywall Industry Newsmagazine. Taping, Inc. V. 8, No. 1, February–March 1965, pp. 24–25.
[3] Gypsum Drywall Industry Newsmagazine. Not a Damp Thing in the House. V. 8, No. 5, August–September 1965, p. 31.

Table 5.—Prefabricated products sold or used in the United States, by products

Product	1964 Thousand square feet	1964 Thousand short tons [1]	1964 Value (thousands)	1965 Thousand square feet	1965 Thousand short tons [1]	1965 Value (thousands)
Lath:						
3/8 inch	1,393,022	1,038	$38,744	1,237,983	916	$31,985
1/2 inch	95,581	96	3,513	123,578	121	4,485
Other [2]	6,008	8	306	6,234	8	285
Total	1,494,611	1,142	42,563	1,367,795	1,045	36,755
Wallboard:						
1/4 inch	133,077	76	4,073	144,158	82	3,540
3/8 inch	1,767,135	1,341	63,811	1,781,836	1,339	59,825
1/2 inch	4,988,816	4,983	206,783	5,444,859	5,352	206,100
5/8 inch	639,618	806	36,454	693,356	873	36,522
1 inch [3]	13,564	29	1,086	18,864	32	1,284
Total	7,542,210	7,235	312,207	8,083,073	7,678	307,271
Sheathing	197,453	208	6,790	213,402	216	6,834
Laminated board	[4] 6,691	6	323	[4] 7,126	7	317
Formboard	48,462	51	2,001	50,056	52	2,065
Grand total [5]	9,289,427	8,642	363,884	9,721,452	8,998	353,242

[1] Includes weight of paper, metal, or other materials.
[2] Includes a small amount of 1/4-inch, 5/8-inch, and 1-inch lath.
[3] Includes a small amount of 5/16-inch, 3/4-inch, 1 5/8-inch, and 3 3/4-inch wallboard.
[4] Area of component board and not of finished products.
[5] Excludes tile, for which figures are withheld to avoid disclosing individual company confidential data.

Improved specifications for gypsum plastering were approved by the American Standards Association. Work was sponsored by the American Institute of Architects and the American Society for Testing Materials.[4]

A Bureau of Mines publication describing the organization, technology, and outlook for the gypsum industry was released in 1965.[5]

PRICES

Prices (base rates) for truckload lots of gypsum products in 20 U.S. cities are published monthly in Engineering News-Record. Neat plaster averaged $31.32 per ton and ranged from $24 in Baltimore to $46.50 in Seattle. Gauging plaster sold for an average of $37.09 per ton and ranged from $25.65 at Cincinnati to $49 at Seattle. One-half inch gypsum board averaged $60.51 per thousand square feet and ranged from $43 at Detroit to $75.50 at Seattle. Quotations for 3/8-inch board averaged $51.18 and ranged from $35.75 at Detroit to $64.50 at Seattle. Three-eighths-inch gypsum lath averaged $41.28 and ranged from $27.25 in the Detroit market to $56.75 at Seattle. Tongue and groove sheathing averaged $55.79 and ranged from $38.40 in the Detroit area to $74 at St. Louis.

Gypsum wallboard and cement producers were engaged in rough-and-tumble price competition for their products in 1965. Producers were hopeful of stabilizing prices and possibly obtaining higher prices in 1966.

FOREIGN TRADE

Imports of crude gypsum decreased 6 percent compared with those of 1964. Imported gypsum was 37 percent of the total crude gypsum supply. Canada provided 81 percent of the total crude imports; Mexico provided 15 percent; and Jamaica provided 3 percent.

[4] Plastering Industries. Plastering Specs Now Approved. V. 55, No. 2, March 1965, p. 29.
[5] Barton, Wm. R. Gypsum. Ch. in Mineral Facts and Problems. BuMines Bull. 630, 1965, 11 pp.

WORLD REVIEW

NORTH AMERICA

Canada.—Gypsum production decreased 1 percent in 1965 because of a slackening demand from the United States. Western Gypsum Products Ltd. opened a new mine at Silver Plains, Manitoba. The $500,000 operation replaces the firm's Amaranth mine in Northern Manitoba. The firm also added 10,000 square feet to its plant at Clarkson, Ontario. United Gypsum Corp. Ltd., a subsidiary of Alscope Consolidated Ltd., planned to open its new gypsum mine at Canal Flats, British Columbia, in 1966. Two hundred thousand dollars will be spent on an open pit.

SOUTH AMERICA

Argentina.—Large quantities of gypsum are available to supply local requirements and also to provide an exportable surplus. Exports have multiplied in the last few years.

Chile.—Cia. Industrial "El Volcan" is the leading producer of gypsum in Chile, reporting about 70 percent of crude gypsum production.

Table 6.—U.S. exports of gypsum and gypsum products

Year	Crude, crushed, or calcined: Short tons (thousands)	Crude, crushed, or calcined: Value (thousands)	Other manufactures n.e.c., value (thousands)	Total value (thousands)
1956–60 [1] (average)	21	$745	$778	$1,523
1961	20	731	568	1,299
1962	20	736	566	1,302
1963	17	669	762	1,431
1964	21	829	979	1,808
1965	28	1,112	920	2,032

[1] Effective Jan. 1, 1958, plasterboard, wallboard, and tile not separately classified included with "other manufactures, n.e.c." 1955: 8,686,854 square feet, $412,397; 1956: 7,026,932 square feet, $363,648; 1957: 8,866,572 square feet, $519,668.

Table 7.—U.S. imports for consumption of gypsum and gypsum products [1]

Year	Crude (including anhydrite): Short tons	Crude (including anhydrite): Value (thousands)	Ground or calcined: Short tons	Ground or calcined: Value (thousands)	Alabaster manufactures, [2] value (thousands)	Other manufactures n.e.s., value (thousands)	Total value (thousands)
1956–60 (average)	4,832,090	$8,620	997	$40	$703	$346	$9,709
1961	4,967,061	9,043	1,127	51	836	376	10,306
1962	5,420,876	10,490	1,780	55	1,025	342	11,912
1963	5,490,298	10,887	226	62	1,031	377	12,357
1964	6,257,702	13,305	1,364	53	945	384	14,687
1965	5,911,258	11,848	1,366	65	1,055	360	13,328

[1] In addition, Keene's cement was imported as follows; 1956–60 (average) none; 1961, none; 1962, 2,760 short tons ($2,073); 1963–65 none.
[2] Includes imports of jet manufactures, which are believed to be negligible.

Table 8.—U.S. imports for consumption of crude gypsum (including anhydrite), by countries

(Thousand short tons and thousand dollars)

Country	1964 Quantity	1964 Value	1965 Quantity	1965 Value
North America:				
Canada	4,891	$10,187	4,779	$9,501
Dominican Republic	111	360	69	221
Jamaica	156	584	186	619
Mexico	1,074	2,125	877	1,506
Total	6,232	13,256	5,911	11,847
South America: Colombia	18	28	----	----
Europe	(1)	(1)	(1)	1
Oceania: Australia	8	21	----	----
Grand total	6,258	13,305	5,911	11,848

[1] Less than ½ unit.

EUROPE

Sweden.—Anhydrite is to be the charge-stock for a new 175,000-ton-per-year sulfuric acid plant to be built by a subsidiary of Bolidens Gruvaktiebolag at Halsingborg. Total capacity of sulfuric acid by Bolidens Gruv will be 700,000 tons per year by 1967.

United Kingdom.—Marchon Products Ltd. has developed a new continuous SO_3 sulfonation process for their new plant at Whitehaven. The plant produces high-grade alkyl sulfonates and sulfonates for detergents. Imperial Chemical Industries Ltd. announced a 3 million pound expansion of its plaster and plasterboard plants at Severnside and at Billingham.

AFRICA

Zambia.—A gypsum mine went into production at Lochinvar, 120 miles southwest of Lusaka. Production is expected to be about 10,000 tons per year, and a processing plant is nearly completed. The development is by the Anglo-American group.

ASIA

India.—There are an estimated 966 million tons of gypsum reserves in India. More than 98 percent of the reserves are located in four districts of Rajasthan. The principal consumer is the Government-owned fertilizer plant at Sindri, Bihar.

Japan.—Nearly all of the gypsum produced goes to cement plants, About 10 percent of the gypsum consumed is imported, and a small quantity of uncalcined gypsum is exported to Singapore. A gypsum board plant utilizing byproduct gypsum was planned by Toyo Gas Chemical Industry Ltd.

Pakistan.—Greater exploitation of West Pakistan's large gypsum deposits in the Daudkhel area is expected, and a gypsum board plant has been set up at Lahore.

Thailand.—Renewed activity in Thailand gypsum was noted. A deposit, 300 kilometers north of Bangkok, contains 10 million tons of high-grade gypsum and currently produces about 40,000 tons per year for use in two local cement plants. Another deposit, 700 kilometers south of Bangkok, is being drilled and sampled.

Table 9.—World production of gypsum by countries [1]

(Thousand short tons)

Country [1]	1961	1962	1963	1964	1965 p [2]
North America:					
Canada [3]	5,060	r 5,398	r 6,082	6,361	6,211
Cuba e	21	21	24	NA	NA
Dominican Republic	451	484	39	r 121	99
Guatemala	13	e 11	16	e 17	e 17
Jamaica	250	252	256	r 215	215
Mexico	857	876	1,210	r 1,284	1,192
Nicaragua	----	4	3	6	6
Trinidad	r 3	4	r 3	r 3	2
United States	9,500	9,969	10,388	10,684	10,035
Total e	r 16,155	r 17,019	r 18,021	r 18,691	17,777
South America:					
Argentina	r 212	237	r 216	r 166	e 220
Brazil	172	119	132	r 93	e 165
Chile	88	e 127	116	r 131	118
Colombia	83	91	112	r 118	123
Paraguay	----	----	----	1	2
Peru	70	67	58	72	102
Venezuela	e 66	e 69	71	e 72	e 83
Total e	r 691	710	r 705	r 653	813
Europe:					
Austria [3]	750	754	644	626	681
Bulgaria	149	129	110	e 121	121
Czechoslovakia	390	411	333	387	410
France [3]	4,227	4,406	4,639	5,415	e 5,401
Germany:					
East [4]	284	302	284	r 295	298
West (Marketable)	1,315	1,227	1,168	r 1,329	1,362
Greece	99	104	e 105	er 88	e 110
Ireland	184	194	r 225	251	e 241

Table 9.—World Production of gypsum by countries [1]—Cont.
(Thousand short tons)

Country[1]	1961	1962	1963	1964	1965 [p] [2]
Europe: Cont.					
Italy	2,293	[r] 2,377	[r] 2,633	[er] 2,646	2,646
Luxembourg	8	9	7	[r] 8	6
Poland	516	605	645	[er] 645	[e] 661
Portugal	79	80	66	[r] 72	[e] 72
Spain	2,822	3,287	4,258	[r] 3,147	[e] 3,147
Switzerland [e]	110	110	110	110	110
U.S.S.R.	4,912	4,824	4,673	[r] 4,633	[e] 4,740
United Kingdom [3]	4,179	4,479	4,567	[r] 5,056	4,911
Yugoslavia	107	[e] 110	156	170	154
Total [e]	22,510	[r] 23,520	[r] 24,730	[r] 25,110	25,180
Africa:					
Algeria [e]	195	195	195	195	195
Angola	[r] 13	18	16	[er] 15	[e] 15
Ethiopia	----	----	----	[e] 4	[e] 3
Kenya	22	30	23	31	37
Libya	----	----	----	[5]	2
Morocco [e]	28	28	33	33	33
Niger	----	----	----	----	2
South Africa, Republic of	191	212	207	265	335
Sudan	6	8	5	5	5
Tanzania	1	2	2	3	5
Tunisia	18	18	20	[e] 20	[e] 20
United Arab Republic (Egypt)	510	515	[r] 500	[r] 372	513
Total [e]	[r] 984	1,026	[r] 1,001	[r] 943	1,165
Asia:					
Burma	1	2	1	[er] 1	[e] 1
China, mainland [e]	450	450	550	650	650
Cyprus	115	115	110	[r] 50	[e] 67
India	953	1,239	[r] 1,313	970	1,265
Iran [e6]	[r] 440	1,100	1,100	1,300	1,700
Iraq [e]	550	550	550	550	550
Israel [e7]	88	[r] 82	115	121	121
Japan	799	882	863	[r] 828	[e] 827
Jordan	8	10	[e] 10	----	----
Mongolia [e]	11	[r] 11	17	22	22
Pakistan	[r] 113	201	218	215	162
Philippines	9	16	34	[r] 45	30
Saudi Arabia	----	[e] 12	[e] 40	[er] 33	25
Taiwan	14	18	29	19	31
Syrian Arab Republic	9	17	[r] 17	[r] 22	[e] 17
Thailand	13	23	26	46	12
Turkey	66	154	198	[e] 220	[e] 243
Total [e]	[r] 3,639	[r] 4,882	[r] 5,191	[r] 5,092	5,723
Oceania: Australia	683	707	770	[r] 881	[e] 948
World total [e]	[r] 44,660	[r] 47,870	[r] 50,420	[r] 51,370	51,610

[e] Estimate. [p] Preliminary. [r] Revised. NA Not available.
[1] Gypsum is also produced in Rumania, but production data are not available; an estimate is included in the total. Production in Ecuador and Korea is negligible.
[2] Compiled mostly from data available June 1966.
[3] Includes anhydrite.
[4] Crude production estimates based on calcined figures.
[5] Less than ½ unit.
[6] Year ended March 20 of year following that stated.
[7] Year ended March 31 of year following that stated.

TECHNOLOGY

Much research effort was devoted to the mechanization of and development of more efficient mining methods in gypsum and anhydrite mines. A program of mechanization, standardization, centralization, and engineering control was applied to the largest underground noncoal mine in England, at Billingham-on-Tees, County Durham. Mechanization to off-track mining has raised output to 21 long tons per shift for underground production men.[6]

Increased operating efficiencies were obtained by the employment of various types of loading equipment and the development of improved face-loading techniques and

[6] Chadwick, B. T. How Standardization Cuts Mining Costs at English Anhydrite Mines. World Min. V. 18, No. 12, November 1965, pp. 38–42.

efficiencies, to keep pace with advances made in face drilling and blasting. Euclid L-20 loaders loading into Shawnee-Poole trailers, which deliver ore to an underground crusher, achieved outputs of 1,100 tons per shift from one loader and three trailers at the Sandwith mine in England.[7]

A new gypsum deposit discovered in 1964 by the Indiana Geological Survey in La Porte County was extensively sampled and described. The deposits are from 350 to 500 feet deep, are close to water transportation and the Chicago market, and are of commercial thickness.[8] The producing gypsum deposits near Shoals, Ind., were further explored and the known extent of the deposits expanded. Precipitation of the evaporites and the carbonate replacement were studied. Commercial-grade gypsum exists at depths of 350 to 500 feet and averages 75 to 95 percent gypsum.[9]

Studies were reported on the setting characteristics of gypsum plasters, on the addition of water and other additives to plaster powders, and on controlling the rate at which the paste loses its water.[10] Systematic studies of one type of mechanical plastering were reported. This entails transport of undercoat mixes by pumping and application by spraying. Studies included comparisons of quality of sprayed plaster, examination of the machines and equipment used for mechancial plastering, properties of materials and mixes, and productivity.[11]

A method of making color designs in gypsum sheets was patented.[12]

A method of using byproduct gypsum, which results from phosphoric acid manufacturing, for making paper-lined gypsum products was patented.[13] Another process, which enables making the removal of phosphoric acid from gypsum byproducts waste more easier, has been patented by a chemical company.[14]

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[7] Mining and Minerals Engineering (London). Loading Underground at Sandwith. V. 1, No. 5, January 1965, pp. 170–174.

[8] Rooney, L. F. Gypsum Deposits in Northern Indiana. Trans. Soc. of Min. Eng., v. 232, No. 3, September 1965, pp. 268–273.

[9] French, R. R. Geology of Gypsum and Anhydrite in Southwestern Indiana. Soc. of Min. Eng., preprint No. 65H, February 1965, 14 pp.

[10] Dargie, K. G. Controlling the Water Loss Rate of Plastering Pastes. Chem. and Ind. (London), No. 42, Oct. 16, 1965, pp. 1740–1742.

[11] Ryder, J. F., and E. Kempster. Mechanical Plastering-Studies by the Building Research Station. Chem. and Ind. (London), No. 42, Oct. 16, 1965, pp. 1748–1751.

[12] Murray, A. E. Method of Making Color Designs in Gypsum Sheets. U.S. Pat. 3,206,527, Sept. 14, 1965.

[13] Gates, W. E., Whippany, and R. L. Harris. (assigned to Allied Chemical Corp., New York). Process for Producing Paper-lined Byproduct Gypsum Products. U.S. Pat. 3,181,985, May 4, 1965.

[14] Assigned to Dorr-Oliver Inc., Stamford, Conn. Surfactant Improves Phosphoric Yields. U.S. Pat. 3,192,014, Aug. 28, 1965.

Iodine

By William C. Miller [1]

Crude iodine consumption in the United States established a new record high. Recovery of iodine from natural brines in Michigan increased, whereas the recovery from oil-well brines in California decreased. Resublimed iodine and organic compounds accounted for 50 percent of the crude iodine consumed.

Chemical and petroleum companies expressed considerable interest in developing oilfield brines as potential sources of iodine. Bureau of Mines data showed several locations where iodine in oilfield brines fall within the range of economic recovery.

An important development in the use of iodine was a new series of lubricants having iodine complexes as their key ingredient. These lubricants were developed to increase the machinability and uses of space-age materials.

Legislation and Government Programs. The Commodity Credit Corporation, in exchange for agricultural commodities, completed contracts in December for the delivery within the next 2 years of 1,694,000 pounds of Japanese crude iodine and 2,002,000 pounds of Chilean crude iodine to fulfill the current stockpile objective for iodine.

The Government strategic stockpile contained 2,956,713 pounds of iodine and the supplemental stockpile 1,333,512 for a total of 4,290,225 pounds at the end of 1965. Total Government stocks were 3,709,775 pounds below the miximum stockpile of 8 million pounds.

DOMESTIC PRODUCTION

Production of crude iodine increased 18 percent in quantity and in value compared with that of 1964. The quantity of iodine recovered from natural brines in Michigan increased 36 percent and from oil well brines in California decreased 16 percent. The Dow Chemical Co. plants at Seal Beach, Calif., and Midland, Mich. produced the entire domestic production of crude iodine.

West Chemical Products Inc., Long Island City, N.Y., increased its investment in the iodine industry by acquiring the Interstate Chemical Co. of Kansas City, Mo. Ethylene diamine dihydriodide, U.S.P. and feed grades of potassium iodide, sodium iodide, calcium iodate, hydriodic acid, and tincture of iodine were produced by Interstate.

Chemical and petroleum companies started investigations to determine whether additional domestic sources of iodine are available from certain oilfield brines. The large volume of laboratory data obtained by the Bureau of Mines on the concentration and distribution of iodine in oilfield brines was one of the major sources of information. These data showed several locations where the iodine concentrations appear to be sufficiently concentrated to permit economic recovery at present market prices.

CONSUMPTION AND USES

The consumption of crude iodine increased 12 percent over the 1964 consumption, thus establishing a new record high for the third consecutive year. A large increase in the consumption of crude iodine for sanitizers, disinfectants, and intermedi-

[1] Commodity specialist, Division of Minerals.

ates resulted in a 26-percent increase in the consumption of iodine organic compounds compared with that of 1964. The substitution of resublimed iodine for crude iodine in the preparation of several compounds and the augmentation of pharmaceuticals, catalysts in intermediate manufacture, and analytical reagents accounted for the 24-percent increase over the 1964 consumption of resublimed iodine.

Most of the new products placed on the market were disinfecting agents. A powdered product that released iodine entirely as colorless hypoiodous acid (HIO) was marketed for disinfecting swimming pools. Claims were made that a new iodicide cleaning compound had more sustained killing action against disease-producing organisms by an improved control of speed at which the natural iodine base of the iodine was released. A compound was introduced that could be used as a bactericide or as a disinfectant.

Table 1.—Crude iodine consumed in the United States

Product	1964			1965		
	Number of plants	Crude iodine consumed		Number of plants	Crude iodine consumed	
		Thousand pounds	Percent of total		Thousand pounds	Percent of total
Resublimed iodine	8	160	5	8	198	6
Potassium iodide	12	1,285	41	10	1,300	37
Sodium iodide	4	W	W	4	W	W
Other inorganic compounds	18	946	30	20	1,083	31
Organic compounds	25	737	24	25	925	26
Total	[1] 43	3,128	100	[1] 44	3,506	100

W Withheld to avoid disclosing individual company confidential data; included with "Other organic compounds."
[1] Nonadditive total because some plants produce more than 1 product.

Iodine oil additives, in the form of organic complexes, were used in metal-working lubricants. The lubricants allowed tough space-age alloys to be machined and permitted titanium and stainless steel to be used for bearings.

Stream pollution from machine-tool coolants was reduced by a coolant control process that used an iodine vaporizer. Iodine vapors injected below the water surface of the coolant pits eliminated the use of additives that were difficult to filter out before coolant dumping. The process permitted repeated usage of less costly coolants and improved their performance, safety, and cleanliness on the production line.

STOCKS

Stocks held by firms that convert crude iodine into resublimed iodine and iodine compounds declined in 1965, continuing a trend that began in 1964. Yearend stocks were 765,957 compared with 1,112,517 on December 31, 1964.

PRICES

An increase, effective February 1, in the price of crude iodine from $1.18 to $1.27 per pound was announced by The Dow Chemical Co. The increase applied to all shipments. In May, the price was reduced to its previous value. Prices for resublimed iodine and iodine compounds were not affected by the increase on crude iodine and remained firm. The prices for iodine and iodine compounds reported in the Oil, Paint and Drug Reporter remained the same as those in 1964.

FOREIGN TRADE

Exports of iodine, iodide, and iodates in 1964 amounted to 147,000 pounds valued at $343,000. Reexports of these items amounted to 8,000 pounds valued at

$9,000. Beginning January 1, 1965, the exports and reexports of these items were no longer separately classified.

Imports of crude iodine for consumption increased in quantity and value compared with that of 1964. Resublimed imports from Japan totaled 2,000 pounds valued at $2,783, a decrease of 33 percent in quantity and 35 percent in value compared with that of 1964.

Table 2.—U.S. imports for consumption of crude iodine, by countries
(Thousand pounds and thousand dollars)

Country	1956–60 (average)		1961		1962		1963		1964		1965	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Canada	----	----	----	----	----	----	----	----	29	$31	----	----
Chile	1,443	$1,272	1,964	$1,822	2,229	$2,054	2,462	$2,093	1,759	1,492	2,111	$1,689
Japan	419	485	1,053	1,030	797	787	874	865	804	846	736	787
Total	1,862	1,757	3,017	2,852	3,026	2,841	3,336	2,958	2,592	2,369	2,847	2,476

WORLD REVIEW

Chile.—Crude iodine production of 4,764,000 pounds in 1964 increased slightly above the 1963 level of 4,753,000 pounds. Of the total output, Anglo-Lautaro Nitrate Corp. produced 4,350,000 pounds or 91 percent; Empresa Salitrera Victoria, 337,000 pounds or 7 percent; Cía Salitrera Iquique: Oficina Alemania 46,000 pounds or 1 percent; and Cía Salitrera P. Perfetti: Oficina Flor de Chile, 31,000 pounds or 1 percent. The industry operated below capacity because of competition from Japanese exports into a limited market.[2] A 45-day strike at the Victoria mines was estimated to have cost the company about 42,000 pounds of crude iodine production.

Exports rose 6 percent to 4,211,000 pounds compared with 3,990,000 pounds in 1963. The United States was the leading importer with 1,836,000 pounds or 44 percent. Exports to the United Kingdom, France, West Germany, and Netherlands amounted to significant quantities. The U.S.S.R., Czechoslovakia, and mainland China imported 341,713 pounds or 8 percent of the Chilean exports.

Indonesia.—Production of crude iodine in 1964 amounted to about 8,900 pounds.

TECHNOLOGY

Substitutes were found for silver iodide used in seeding clouds for weather control. New seeding agents of magnesia and alumina were less costly than silver iodide.[3]

A process was patented for the production of free iodine from lithium iodide. Elemental oxygen and steam were reacted with lithium iodide in a molten state.[4]

Iodine was removed as a polyhalide anion from an aqueous solution by an anion exchange resin in a patented process for the recovery of elemental iodine.[5]

Radioactive iodine (I^{125}) was used by Goodyear Tire and Rubber Co. to reduce the time and expense of tire testing. Finished tire treads absorbed the radioactive iodine from isotopes enbedded in tire treads. The tests which were reduced from thousands of miles duration to 50 miles gave the same tread-wear data.[6]

The first relative rate studies of iodine isocyanate, an electrophilic reagent, were reported. Investigations were conducted of relative rates of addition of the reagent to various unsaturated compounds. A comparison of these rates with those of two other electrophiles were made. Results showed that the relative activity of this electrophilic reagent was similar to other electrophiles.[7]

[2] Bureau of Mines. Mineral Trade Notes. V. 61, No. 4, October 1965, pp. 24, 25.

[3] Mining Journal (London). Seeding Agents. V. 264, No. 6756, Feb. 12, 1965, p. 118.

[4] Du Bois, Jennings B., Jr. (assigned to Shell Oil Co., New York). Production of Iodine From Molten Lithium Iodide. U.S. Pat. 3,169,830, Feb. 16, 1965.

[5] Houy, James J. (assigned to The Dow Chemical Co., Midland, Mich.). Recovery of Elemental Iodine With a Fluidized Ion Exchange Bed. U.S. Pat. 3,177,050, Apr. 6, 1965.

[6] Iron Age. Radioactive Isotopes Shorten Tire Road Tests. V. 196, No. 5, July 22, 1965, p. 31.

[7] Gebelein, C. G., and D. Swern. Relative Electrophilicity of Iodine Isocyanate, Dibromocarbene, and Bromine. Chem. and Ind. (London), No. 33, Aug. 14, 1965, pp. 1462–1463.

Studies were conducted to determine new X-ray diffraction and optical data on silver iodide. Crystal structures and stability fields of six polymorphs of silver iodide were investigated. Techniques and instrumentation used in the studies were described. Stability fields of some silver iodide polymorphs as a function of pressure and temperature were described. Changes were described in the atomic arrangements and the nature of bonding.[8]

Iodine was the key ingredient in a new series of lubricants discovered by scientists at the General Electric Research & Development Center, Schenectady, N.Y. These lubricants were designed for hard-to-lubricate metals. The iodine in the lubricant reacted instantaneously with the fresh surfaces of the metals as soon as the protective oxide films were removed by abrasion during a sliding process. A thin film, only a few atoms thick, was formed which contained a lamellar di-iodide with a crystal structure similar to that of graphite. Investigations showed that the new iodine complexes were readily soluble in other lubricants and that they protected the di-iodide film from decomposition by water in the atmosphere. The new lubricants were applied to the rubbing surfaces in pure form or added to conventional lubricants and metal-working lubricants.[9]

A method was patented for the removal of elemental iodine from an aqueous solution. Tetrahydronapthalene-swollen resin beads were used to recover the iodine from the solution.[10]

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[8] Bassett, William A., and Taro Takahashi. Silver Iodide Polymorphs. Amer. Min., v. 50, No. 10, October 1965, pp. 1576—1594.

[9] Steel. Iodine Lubricant: First Aid for Exotic Metal Miseries. V. 157, No. 21, Nov. 22, 1965, p. 43.

[10] Asher, Delman R. (assigned to The Dow Chemical Co., Midland, Mich.). Recovery of Iodine From Aqueous Solutions. U.S. Pat. 3,219,409, Nov. 23, 1965.

Iron Ore

By F. E. Brantley [1]

Developments involving the iron ore deposits of Western Australia, the continued resurgence of taconite on the Mesabi range, and construction of pelletizing facilities dominated the iron ore news.

Large international consortiums moved to exploit the massive iron ore bodies of Western Australia. Long-term contracts having a total value in excess of $2 billion were obtained from Japanese interests, and construction was begun on the necessary installations, which included railroads, ports, plants, and towns.

Taconite plant construction and startup of new pelletizing facilities helped raise the economy of the Lake Superior iron-mining district to a high level. Commitment of more than $500 million to taconite projects during the year, in addition to prior investments, insured the continuance of this area as the Nation's major iron ore source.

Competition between exporting nations showed signs of increasing rapidly in the near future, with lower unit prices in some areas of the world resulting. Many of the producers in older mining regions were either closing mines or turning to modernized methods in efforts to remain competitive. Exploration for new iron ore deposits continued throughout the world, and several discoveries were announced.

[1] Commodity specialist, Division of Minerals.

Table 1.—Salient iron ore statistics

(Thousand long tons and thousand dollars)

	1956–60 (average)	1961	1962	1963	1964	1965
United States:						
Iron ore (usable;[1] less than 5 percent Mn):						
Production [2]	84,159	71,329	71,829	73,599	84,836	87,842
Shipments [3]	81,903	72,379	69,969	73,564	84,300	84,474
Value [3]	$684,682	$650,500	$618,242	$678,181	$802,331	$804,490
Average value at mines per ton	$8.36	$8.99	$8.84	$9.22	$9.52	$9.52
Exports	4,465	4,958	5,898	6,812	6,963	7,085
Value	$44,595	$54,230	$62,847	$76,340	$79,670	$80,418
Imports for consumption	32,360	25,805	33,409	33,263	42,408	45,103
Value	$280,305	$250,226	$324,573	$323,158	$421,288	$443,788
Consumption	109,632	99,254	99,562	112,535	132,328	131,888
Stocks Dec. 31:						
At mines	7,794	10,335	11,614	11,099	[3] 10,241	[3] 12,667
At consuming plants	53,735	58,869	59,553	54,971	54,189	53,799
At U.S. docks	5,942	6,100	6,429	5,347	3,741	2,494
Manganiferous iron ore (5 to 35 percent Mn):						
Shipments	571	201	302	485	213	333
World: Production	431,961	494,604	499,645	514,086	569,336	606,359

[1] Direct shipping ore, washed ore, concentrates, agglomerates, and byproduct pyrites cinder and agglomerate.
[2] Includes byproduct ore.
[3] Excludes byproduct ore.

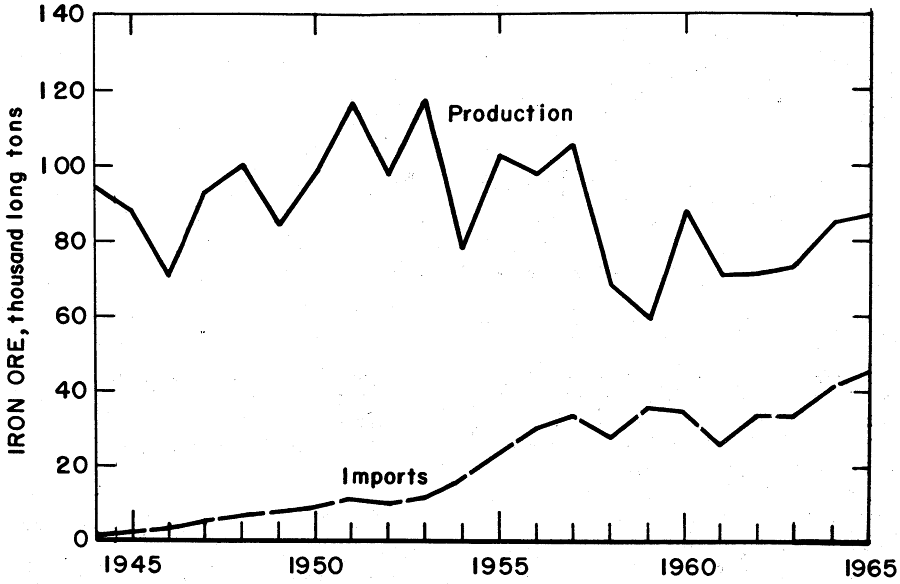

Figure 1.—United States iron ore production and imports for consumption.

Table 2.—Employment at iron ore mines and beneficiating plants, quantity and tenor of ore produced and average output per man in 1964, by districts and States

District and State	Employment: Average number of men employed	Employment: Average number of days	Employment: Total man-shifts (thousands)	Employment: Hours (thousands)	Production[1]: Crude ore (thousands long tons)	Usable ore: Thousand long tons	Usable ore: Iron contained[2]: Thousand long tons	Usable ore: Iron contained[2]: Percent (natural)	Average per man-shift, Long tons: Crude ore	Average per man-shift, Long tons: Usable ore
Lake Superior:										
Michigan	3,742	274	1,024	8,173	22,653	13,677	7,923	58	22	13
Minnesota	9,624	270	2,594	20,692	110,472	49,227	27,708	56	43	19
Wisconsin	160	249	40	319	376	376	210	56	9	9
Total	13,526	270	3,658	29,184	133,501	63,280	35,841	56	36	17
Southeastern States:										
Alabama } Georgia }	913	240	219	1,884					32	12
Alabama					5,508	2,192	767	35		
Georgia					1,393	354	163	46		
Total	913	240	219	1,884	6,901	2,546	930	37	32	12
Northeastern States:										
New Jersey	325	215	70	557						
New York	1,148	271	311	2,492						
Pennsylvania	1,374	287	394	3,244						
New Jersey, New York, Pennsylvania }					12,678	5,214	3,337	64	16	7
Total	2,847	272	775	6,293	12,678	5,214	3,337	64	16	7
Western States:										
Arizona	12	83	1	11	W	W	W	W	W	W
Arkansas	18	222	4	29	W	W	W	W	W	W
California	849	246	209	1,673	W	W	W	W	W	W
Missouri	993	282	280	2,249	1,797	1,110	710	64	6	4
Nevada	143	294	42	350	1,121	911	556	61	27	22
New Mexico	11	182	2	18	W	W	W	W	W	W
Texas	246	252	62	499	W	W	W	W	W	W
Utah	401	224	90	723	2,237	2,052	1,088	53	25	23
Wyoming	702	248	174	1,389	4,191	2,061	1,030	50	24	12
Undistributed	---	---	---	---	11,581	6,798	3,740	55	42	24
Total	3,375	256	864	6,941	20,927	12,932	7,124	55	24	15
Grand total	20,661	267	5,516	44,302	174,007	83,972	47,232	56	32	15

W Withheld to avoid disclosing individual company confidential data; included with "Undistributed."
[1] Includes manganese bearing ore in the Lake Superior district. [2] Average iron content of all types of ore shipped.

EMPLOYMENT

The expansion of mining and beneficiation activities in Minnesota and Michigan resulted in a noticeable upturn in employment. The average number of men employed in the Lake Superior district in 1964 increased 10 percent over that of 1963 to 13,526.

The Western States, led by Missouri, California, and Wyoming, showed an increase of more than 40 percent, although total employment in this area was less than one-third that of Minnesota.

Noticeable increases in average amount of crude ore and contained iron per ton produced per man-hour occurred in the Western States, due to the large-scale developments brought into full production.

The practice of mining companies maintaining a stable labor force by keeping men employed all year, even if not producing iron ore, prevents a true measure of productivity. The increased year-round production from the large-scale low-grade iron ore operations has helped, however, to bring the figures more into line.

DOMESTIC PRODUCTION

Production of crude ore from domestic iron mines increased in 1965 by 2.5 percent over that of 1964. Magnetite and brown ore showed almost equal gains, while hematite decreased by 2.5 million tons. There was an increase of 22 operating mines in the Lake Superior district and 8 in the Southeastern States, while those in the Northeastern and Western States decreased by 1 and 4 respectively.

Usable iron ore production increased over 1964 output by 3 million tons, with the average iron content rising 1 percent to a 57 percent average.

The surge of activity by the taconite industry in Minnesota, following passage of the Taconite Amendment in November 1964, continued throughout 1965. Construction started during the year on the National Steel Pellet Co. plant near Keewatin, the Butler Pellet Co. project near Nashwauk, and the United States Steel Corp. Minntac plant near Mountain Iron.

Plant expansions were announced by Erie Mining Co. near Hoyt Lakes and Reserve Mining Co. near Silver Bay. Jones & Laughlin Steel Corp. started engineering work on a new taconite project near Biwabik. The Eveleth Taconite Co. shipped the first pellets from its new plant in December.

The total capacity for pellet production from plants in Minnesota on completion of announced plans was estimated to be at least 31 million tons per year, compared with a total planned capacity of 49.5 million for the United States.

In Michigan the Cleveland-Cliffs Iron Co. began construction to increase the pellet capacity at its Empire mine near Palmer by 1.8 million tons per year. The company's Pioneer plant at Eagle Mills began operation in June, with a capacity of 1.2 million tons of pellets per year. This was the first pelletizing plant in the United States to produce pellets from ore mined underground.

The Kaiser Steel Corp. placed its Eagle Mountain pellet plant in operation during September, with a production capacity of 2 million tons per year.

United States Steel Corp. Atlantic City taconite pellet plant in Wyoming completed its second full year of production.

Construction started on the Pilot Knob Pellet Co. underground mine and pelletizing plant at Pilot Knob, Mo. Planned capacity was 750,000 tons of pellets annually.

Total U.S. operating pellet plant capacity at yearend was given as 33.5 million tons per year by the American Iron Ore Association. An additional 16 million tons annual capacity was given as under construction and 3.8 million tons considered for construction.

The last active iron ore mine in New Jersey, the Scrub Oaks, owned by Alan Wood Steel Co., closed during the year.

Table 3.—Crude iron ore mined in the United States, by districts, States, and varieties

(Thousand long tons and exclusive of ore containing 5 percent or more manganese)

District and State	1964					1965				
	Number of mines	Hematite	Brown ore	Magnetite	Total [1]	Number of mines	Hematite	Brown ore	Magnetite	Total [1]
Lake Superior:										
Michigan	16	22,653	--------	W	22,653	21	W	--------	W	23,904
Minnesota	57	54,085	779	55,216	110,080	74	55,710	3,024	55,193	113,927
Wisconsin	1	376	--------	--------	376	1	56	--------	--------	56
Total	74	77,114	779	55,216	133,109	96	W	3,024	W	137,887
Southeastern States:										
Alabama	22	1,403	4,105	--------	5,508	24	759	3,344	--------	4,103
Georgia	11	--------	1,393	--------	1,393	17	--------	1,697	--------	1,697
Total	33	1,403	5,498	--------	6,901	41	759	5,041	--------	5,800
Northeastern States: New Jersey, New York, Pennsylvania	8	--------	--------	12,678	12,678	7	--------	--------	12,206	12,206
Western States:										
Arizona	3	W	--------	W	W	3	W	--------	W	W
Arkansas	1	--------	W	--------	W	--------	--------	--------	--------	--------
California	4	W	--------	W	W	4	W	--------	W	W
Colorado	5	--------	35	W	35	3	--------	W	W	W
Idaho	1	3	--------	--------	3	3	W	--------	W	W
Mississippi	--------	--------	--------	--------	--------	1	--------	W	--------	W
Missouri	5	--------	W	1,797	1,797	3	--------	92	2,739	2,831
Montana	1	--------	--------	15	15	1	--------	--------	9	9
Nevada	6	W	--------	1,121	1,121	5	W	--------	W	1,301
New Mexico	2	--------	--------	W	W	1	--------	--------	17	17
Texas	4	--------	W	--------	W	5	--------	W	--------	W
Utah	7	2,237	--------	W	2,237	6	W	--------	W	2,303
Wyoming	4	W	--------	4,191	4,191	4	W	--------	W	4,535
Undistributed	--------	--------	--------	11,528	11,528	--------	W	1,792	W	11,052
Total	43	2,240	35	18,652	20,927	39	W	1,884	W	22,048
Grand total	158	80,757	6,312	86,546	173,615	183	78,242	9,949	89,750	177,941

[1] In some instances data do not add to totals due to rounding.

W Withheld to avoid disclosing individual company confidential data; included with "Undistributed."

Table 4.—Crude iron ore mined in the United States, by districts, States, and mining methods

(Thousand long tons and exclusive of ore containing 5 percent or more manganese)

District and State	1964			1965		
	Open pit	Underground	Total[1]	Open pit	Underground	Total[1]
Lake Superior:						
Michigan	16,534	6,119	22,653	17,342	6,562	23,904
Minnesota	108,663	1,417	110,080	112,664	1,263	113,927
Wisconsin	-------	376	376	-------	56	56
Total	125,197	7,912	133,109	130,006	7,881	137,887
Southeastern States:						
Alabama	4,237	1,271	5,508	3,444	659	4,103
Georgia	1,393	-------	1,393	1,697	-------	1,697
Total	5,630	1,271	6,901	5,141	659	5,800
Northeastern States: New Jersey, New York, Pennsylvania	12,678	W	12,678	W	W	12,206
Western States:						
Arizona	W	-------	W	W	-------	W
Arkansas	W	-------	W	-------	-------	-------
California	W	W	W	W	-------	W
Colorado	35	-------	35	115	-------	115
Idaho	3	-------	3	W	-------	W
Mississippi	-------	-------	-------	W	-------	W
Missouri	W	1,797	1,797	299	2,532	2,831
Montana	15	-------	15	9	-------	9
Nevada	1,121	W	1,121	W	W	1,301
New Mexico	W	-------	W	17	-------	17
Texas	W	-------	W	W	-------	W
Utah	2,237	-------	2,237	2,303	-------	2,303
Wyoming	4,191	W	4,191	3,720	815	4,535
Undistributed	11,528	-------	11,528	W	W	10,937
Total	19,130	1,797	20,927	W	W	22,048
Grand total	162,635	10,980	173,615	160,355	17,586	177,941

W Withheld to avoid disclosing individual company confidential data; included with "Undistributed."
[1] In some instances data do not add to totals due to rounding.

Table 5.—Crude iron ore shipped from mines in the United States, by districts, States, and disposition

(Thousand long tons and exclusive of ore containing 5 percent or more manganese)

District and State	1964			1965		
	Direct to consumers	To beneficiation plants	Total [1]	Direct to consumers	To beneficiation plants	Total [1]
Lake Superior:						
Michigan	5,753	17,982	23,735	4,969	19,311	24,280
Minnesota	10,441	99,582	110,023	11,579	102,054	113,633
Wisconsin	524	-------	524	141	-------	141
Total	16,718	117,564	134,282	16,689	121,365	138,054
Southeastern States:						
Alabama	275	5,166	5,441	122	3,937	4,059
Georgia	-------	1,393	1,393	-------	1,697	1,697
Total	275	6,559	6,834	122	5,634	5,756
Northeastern States: New Jersey, New York, Pennsylvania	-------	12,549	12,549	-------	12,282	12,282
Western States:						
Arizona	W	W	W	W	-------	W
Arkansas	-------	W	W	-------	-------	-------
California	W	W	W	W	W	W
Colorado	35	-------	35	114	-------	114
Idaho	4	-------	4	9	-------	9
Mississippi	-------	-------	-------	-------	W	W
Missouri	-------	1,920	1,920	-------	2,843	2,843
Montana	15	-------	15	9	-------	9
Nevada	W	1,121	1,121	W	W	1,301
New Mexico	W	W	W	-------	18	18
Texas	-------	W	W	-------	W	W
Utah	2,406	W	2,406	1,612	727	2,339
Wyoming	W	4,185	4,185	51	4,425	4,476
Undistributed	W	11,423	11,423	796	11,422	10,917
Total	2,459	7,227	9,686	2,591	19,435	22,026
Grand total	19,452	155,322	174,774	19,402	158,716	178,118

W Withheld to avoid disclosing individual company confidential data; included with "Undistributed."
[1] In some instances data do not add to totals due to rounding.

Table 6.—Usable iron ore produced in the United States, by districts, States, and varieties

(Thousand long tons and exclusive of ore containing 5 percent or more manganese)

District and State	1964				1965			
	Hematite	Brown ore	Magnetite	Total [1]	Hematite	Brown ore	Magnetite	Total [1]
Lake Superior:								
Michigan	13,677	------	W	13,677	W	------	W	14,322
Minnesota	30,330	425	18,299	49,054	32,527	629	18,989	52,054
Wisconsin	376	------	------	376	56	------	------	56
Total	44,383	425	18,299	63,107	W	629	W	66,432
Southeastern States:								
Alabama	1,165	1,027	------	2,192	634	906	------	1,540
Georgia	------	354	------	354	------	424	------	424
Total	1,165	1,381	------	2,546	634	1,330	------	1,964
Northeastern States: New Jersey, New York, Pennsylvania	------	------	5,214	5,214	------	------	5,173	5,173
Western States:								
Arizona	W	------	W	W	W	------	------	W
Arkansas	------	W	------	W	------	------	------	------
California	W	------	W	W	W	------	W	W
Colorado	------	W	35	35	------	W	W	115
Idaho	3	------	------	3	W	------	W	W
Mississippi	------	------	------	------	------	W	------	W
Missouri	W	W	1,110	1,110	------	W	W	1,869
Montana	------	------	15	15	------	------	9	9
Nevada	W	------	911	911	W	------	W	W
New Mexico	------	------	W	W	------	------	10	10
Texas	------	W	------	W	------	W	------	W
Utah	2,052	------	W	2,052	------	------	2,147	2,147
Wyoming	W	------	2,061	2,061	W	------	W	2,147
Undistributed	W	W	6,750	6,750	W	705	W	7,171
Total	W	W	10,882	12,937	W	705	W	13,468
Total all States	47,603	1,806	34,395	83,804	47,043	2,664	37,330	87,037
Byproduct ore [2]	------	------	------	1,032	------	------	------	805
Grand total	47,603	1,806	34,395	84,836	47,043	2,664	37,330	87,842

W Withheld to avoid disclosing individual company confidential data; included with "Undistributed."
[1] In some instances data do not add to totals due to rounding.
[2] Cinder and sinter obtained from treating pyrites. Ore treated in Arizona, Colorado, Delaware, Pennsylvania, Tennessee, Texas (1964), and Virginia.

Table 7.—Usable iron ore produced in the United States, by districts, States, and types of products

(Thousand long tons and exclusive of ore containing 5 percent or more manganese)

District and State	1964				1965			
	Direct shipping ore	Ag-glom-erates	Concen-trates	Iron content (natural percent)	Direct ship-ping ore	Ag-glom-erates	Concen-trates	Iron content (natural percent)
Lake Superior:								
Michigan	5,489	6,683	1,505	58	5,181	7,684	1,457	58
Minnesota	10,442	18,481	20,131	56	11,631	19,053	21,370	57
Wisconsin	376	------	------	56	56	------	------	55
Total	16,307	25,164	21,636	56	16,868	26,737	22,827	57
Southeastern States:								
Alabama	341	------	1,851	35	166	------	1,374	41
Georgia	------	------	354	46	------	------	424	45
Total	341	------	2,205	37	166	------	1,798	42
Northeastern States: New Jersey, New York, Pennsylvania	------	4,408	806	64	------	4,308	865	64
Western States:								
Arizona	W	------	W	W	W	------	------	W
Arkansas	------	------	W	W	------	------	------	------
California	W	------	W	W	W	W	W	W
Colorado	35	------	------	60	115	------	------	64
Idaho	3	------	------	33	W	------	------	W
Mississippi	------	------	------	------	------	------	W	W
Missouri	------	811	299	64	------	1,575	294	66
Montana	15	------	------	45	9	------	------	44
Nevada	911	------	W	61	W	------	W	W
New Mexico	W	------	W	W	------	------	10	60
Texas	------	W	W	W	------	W	W	W
Utah	2,052	------	W	53	1,597	------	550	53
Wyoming	2,061	W	------	50	111	1,443	593	54
Undistributed	W	331	6,419	56	815	552	5,804	55
Total	5,077	1,142	6,718	55	2,647	3,570	7,251	57
Total all States	21,725	30,714	31,365	56	19,681	34,615	32,741	57
Byproduct ore [1]	------	1,032	------	69	------	805	------	67
Grand total	21,725	31,746	31,365	57	19,681	35,420	32,741	57

W Withheld to avoid disclosing individual company confidential data; included with "Undistributed."
[1] Cinder and sinter obtained from treating pyrites.

Table 8.—Shipments of usable iron ore from mines in the United States in 1965

(Thousand long tons and thousand dollars; exclusive of ore containing 5 percent or more manganese)

District and State	Gross weight of ore shipped				Iron content of ore shipped				
	Direct shipping ore	Agglomerates	Concentrates	Total quantity[1]	Direct shipping ore	Agglomerates	Concentrates	Total quantity[1]	Total value[1]
Lake Superior:									
Michigan	4,969	7,554	1,004	13,527	2,602	4,721	546	7,869	$145,482
Minnesota	11,579	19,039	20,255	50,873	5,989	11,665	11,112	28,766	459,290
Wisconsin	141	------	------	141	79	------	------	79	W
Total	16,689	26,593	21,259	64,541	8,670	16,386	11,658	36,714	W
Southeastern States:									
Alabama	122	------	1,373	1,495	41	------	571	612	8,241
Georgia	------	------	424	424	------	------	187	187	2,170
Total	122	------	1,797	1,919	41	------	758	799	10,411
Northeastern States:									
New Jersey, New York, Pennsylvania	------	4,311	447	4,758	------	2,760	275	3,035	68,338
Western States:									
Arizona	8	------	------	8	5	------	------	5	51
Arkansas	------	------	W	W	------	------	W	W	W
California	W	W	W	W	W	W	W	W	W
Colorado	114	------	------	114	83	------	------	83	787
Idaho	9	------	------	9	4	------	------	4	84
Mississippi	------	------	W	W	------	------	W	W	W
Missouri	------	1,507	277	1,784	------	1,025	148	1,173	24,607
Montana	9	------	------	9	4	------	------	4	71
Nevada	W	------	W	1,141	W	------	W	703	5,330
New Mexico	------	------	W	W	------	------	W	W	W
Oregon	W	------	------	W	W	------	------	W	W
Texas	------	W	W	W	------	W	W	W	W
Utah	1,613	------	526	2,139	835	------	306	1,141	14,229
Wyoming	51	1,443	593	2,087	30	857	300	1,187	25,198
Undistributed	787	531	5,786	5,965	471	311	3,399	3,478	W
Total	2,591	3,481	7,182	13,256	1,432	2,193	4,153	7,778	W
Total all States	19,402	34,385	30,685	84,474	10,143	21,339	16,844	48,326	804,490
Byproduct ore[2]	------	857	------	857	------	582	------	582	10,524
Grand total	19,402	35,242	30,685	85,331	10,143	21,921	16,844	48,908	815,014

W Withheld to avoid disclosing individual company confidential data; included with "Undistributed."
[1] In some instances data do not add to totals due to rounding.
[2] Cinder and sinter obtained from treating pyrites. Ore treated in Arizona, Colorado, Delaware, Pennsylvania, Tennessee, and Virginia.

Table 9.—Iron ore produced in the Lake Superior district, by ranges

(Thousand long tons and exclusive after 1905 of ore containing 5 percent or more manganese)

Year	Marquette	Menominee	Gogebic	Vermillion	Mesabi	Cuyuna	Total
1854–1960	309,436	267,747	311,938	[1] 95,400	2,291,242	[2] 65,089	3,340,852
1961	3,205	4,097	2,190	[3] 1,421	41,199	1,095	53,207
1962	4,563	3,460	2,318	[3] 1,521	43,039	655	55,556
1963	5,706	3,729	1,314	[3] 1,298	43,570	515	56,132
1964	7,898	4,551	1,603	[3] 1,285	47,256	513	63,106
1965	8,973	4,595	810	[3] 1,407	50,280	367	66,432
Total	339,781	288,179	320,173	102,332	2,516,586	68,234	3,635,285

[1] Production for 1957 and 1959 included with Mesabi range.
[2] Includes production from Spring Valley district in 1959.
[3] Includes production from Spring Valley district not in the true Lake Superior district.

Table 10.—Average analyses of total tonnages (bill-of-lading weights) of all grades of iron ore from all ranges of Lake Superior District

Year	Thousand long tons	Content, percent [1]					
		Iron	Phosphorus	Silica	Manganese	Alumina	Moisture
1956–60 (average)	64,752	52.98	0.087	9.15	0.62	(2)	9.05
1961 r	55,403	55.28	.079	8.62	.56	1.21	7.12
1962 r	55,010	55.69	.076	8.46	.51	1.21	6.96
1963 r	57,591	56.45	.073	8.22	.52	1.07	6.20
1964 r	64,222	56.81	.072	8.12	.45	1.05	6.06
1965	64,689	56.93	.067	8.14	.47	0.97	6.05

r Revised.
[1] Iron on natural basis; phosphorus, silica, manganese, and alumina on dried basis.
[2] Alumina analyses not available prior to 1961.

Source: American Iron Ore Association.

Table 11.—Beneficiated iron ore shipped from mines in the United States [1]
(Thousand long tons and exclusive of ore containing 5 percent or more manganese)

Year	Beneficiated	Total	Proportion of beneficiated to total (percent)
1956–60 (average)	37,726	81,903	46.9
1961	46,125	72,379	63.7
1962	46,942	69,969	67.1
1963	57,277	73,564	77.7
1964	64,329	84,300	76.3
1965	65,070	84,474	77.0

[1] Excludes byproduct ore.

CONSUMPTION AND USES

The change adopted in 1963 for reporting iron ore consumption has been continued. Concentrate used for agglomerate production at mine sites is not reported as iron ore consumption. Its consumption is reported when the agglomerate produced is shipped to the furnace site and consumed. Concentrate and fines used for agglomerate production (mainly sinter) at blast furnaces and steel mills are reported as iron ore consumed. This method of reporting gives a valid balance between consumption and iron ore production plus imports less exports, considering losses and ore lost in transit.

Iron ore consumed in making agglomerate at steel mills included foreign and domestic direct-shipping ores, fines generated in shipping, and foreign and domestic iron ore concentrate. Other materials such as limestone, flue dust, mill scale, and coke breeze used in making agglomerates are excluded from iron ore consumption.

The use of nodules in blast furnaces and steel furnaces has decreased to a point where it comprised less than one half of 1 percent of the total agglomerates used in 1965.

Miscellaneous use data shown in table 12 included iron ore used in the manufacture of paint and coatings, cement, and ferrites; in high-density concrete as aggregate; in ferroalloy furnaces; and magnetite used in heavy-media coal and ore processing plants.

Table 12.—Consumption of iron ore and agglomerates in the United States in 1965

(Long tons and exclusive of ore containing 5 percent or more manganese)

State	Iron ore [1]		Agglomerates [2]		Miscellaneous [3]	Total
	Blast furnaces	Steel furnaces	Blast furnaces	Steel furnaces		
Alabama, Kentucky, Texas	7,778,057	342,563	3,864,198	W	116,733	12,101,551
California, Colorado, Utah	3,321,282	518,135	4,196,141	W	79,413	8,114,971
Maryland and West Virginia	3,376,914	647,494	7,382,355	-------	(4)	11,406,763
Illinois and Indiana	14,683,842	1,668,416	11,085,631	W	102,413	27,540,302
Michigan and Minnesota	5,803,040	138,208	4,772,880	W	(4)	10,714,128
New York, Ohio, Pennsylvania	34,534,480	2,670,378	23,756,963	W	55,912	61,017,733
Other States	---------	---------	----------	887,443	105,517	992,960
Total	69,497,615	5,985,194	55,058,168	887,443	459,988	131,888,408

W Withheld to avoid disclosing individual company confidential data; included with "Other States."
[1] Includes 25 million tons of pellets and nodules produced at mines.
[2] Does not include agglomerate produced at mine site.
[3] Includes iron ore used in making paint and cement, also ore consumed in ferroalloy furnaces.
[4] Included with Illinois and Indiana

Table 13.—Iron ore consumed in agglomerating plants and agglomerate produced in 1965, by States

(Long tons)

State	Iron ore [1] consumed	Agglomerate produced
Alabama, Kentucky, Texas	3,042,313	3,984,507
California, Colorado, Utah	2,523,563	2,894,851
Maryland and West Virginia	5,838,874	6,045,839
Illinois and Indiana	9,728,947	11,051,747
Michigan and Minnesota	2,157,081	2,848,880
New York, Ohio, Pennsylvania	16,626,776	18,156,616
Total	39,917,554	44,982,440

[1] Does not include material used in agglomerate produced at mine site.

Table 14.—Production of agglomerates [1] in the United States in 1965, by types

(Long tons)

Type	Agglomerate produced
Sinter [2]	47,774,991
Pellets	31,642,455
Nodules	-----------
Total	79,417,446

[1] Production at mines and consuming plants.
[2] Includes 16,652,000 tons of self-fluxing sinter.

STOCKS

Iron ore stocks at mines, U.S. docks, and consuming plants, including byproduct ore, totaled 69.2 million tons on December 31, 1965; 54 million tons was at consuming plants. According to the American Iron Ore Association 2.5 million tons was at U.S. docks. The docks incentory had declined each year from a high of 6.4 million tons in 1962. Mine stocks were above average.

Table 15.—Stocks of usable iron ore at mines [1] December 31, by districts

(Thousand long tons)

District	1964	1965
Lake Superior	6,829	8,718
Southeastern States	179	225
Northeastern States	2,475	2,889
Western States	758	835
Total	10,241	12,667

[1] Excluding byproduct ore.

PRICES

Base prices for Lake Superior 51.5 percent iron ores remained unchanged during 1965. The quoted prices at rail of vessel, lower lake ports, per long ton, were as follows: Mesabi nonBessemer, $10.55; Mesabi Bessemer, $10.70; Old Range non-Bessemer, $10.80; and Old Range Bessemer, $10.95. Corresponding base long ton unit values were $0.20485, $0.20777, $0.20971, and $0.21262, respectively. Lake Superior pellets were quoted at $0.252 per long ton unit; open-hearth lump, Marquette, at $12.60 per long ton; and open-hearth lump, Vermillion, at $13.15 per long ton.

Published prices of selected foreign ores were as follows: Venezuela, Cerro Bolivar, f.o.b. Puerto Ordaz (58 percent iron), $7.84 per metric ton; Brazil, f.o.b. shipping point, Itabira hematite, lump (68.5 percent iron), $10.40 per long ton, fines (64 percent iron), $6.10; Sweden, f.o.b. shipping point, Kiruna D (59 percent iron), 43.5 kronor ($8.43) per metric ton, Kiruna B (67 percent iron), 47.0 kronor ($9.11), per metric ton, pellets (68 percent iron), $0.2059 per metric ton unit; Goa, f.o.b. shipping point, lump (62 percent iron), $8.49 per metric ton, lump, 56 percent iron), $5.05 per metric ton.

The average value of domestic usable ore per long ton f.o.b. mines, excluding byproduct ore, remained the same as for 1964, $9.52, compared with $9.22 in 1963. These values were compiled from producers' statements and approximate the commercial selling price less the cost of mine-to-market transportation.

Table 16.—Average value per long ton of iron ore shipped from mines in the United States in 1965

District	Direct-shipping ore			Concentrates			Agglomerates
	Hematite	Brown ore	Magnetite	Hematite	Brown ore	Magnetite	
Lake Superior	$7.13	W	---------	$7.83	W	---------	$12.08
Southeastern	W	---------	---------	W	$5.34	---------	---------
Northeastern	---------	---------	---------	---------	---------	$14.02	14.40
Western	5.53	$5.77	$6.63	6.89	11.29	7.68	14.04
Total	6.98	5.29	6.63	7.75	6.77	8.14	12.57

W Withheld to avoid disclosing individual company confidential data.

TRANSPORTATION

Higher capacity ore carriers, with ports to accommodate them, unit trains, and accelerated ore-handling facilities at transfer points were some of the transportation highlights for 1965. These helped point up the necessity of moving iron ore from source to user at minimum unit cost as a more pronounced international buyers' market began to take shape.

The third of three king-size carriers designed for shipping ore to Japan, the 80,000-ton *Marshall Clark* was launched. The other two, the *Inayama* and the *Shigeo Nagano* moved record loads of Swaziland iron ore from Lourenco Marques by top loading at sea to give maximum ore cargoes of from 77,000 to 78,000 tons. The *Sigtina*, completed in 1965, unloaded 62,150 tons of iron ore from Labrador at the Newport News, Va., docks. A record shipment of 55,756 tons of Venezuelan ore was moved by the *Ore Transport* to Morrisville, Pa., for United States Steel's Fairless plant.

The *Fritz Thyssen*, largest freighter built in West Germany since World War II, was launched at Hamburg. The 55,000-ton vessel was designed to transport iron ore from Sweden, South America, and Africa. A carrier of 91,000 deadweight-ton capacity was under construction in Japan for San Juan Carriers, an affiliate of Cyprus Mines Corp.

New or improved port facilities were planned in several countries. Construction was started on a 2.25-million-ton-capacity handling and storage facility at Great Northern's Allovez ore docks in Superior, Wis. When it is completed, unit trains of pellets will be received for storage or for direct lake vessel transfer. Facilities for handling and loading pellets were under construction at the ports of Los Angeles and Long Beach. New ore-loading facilities were installed at the Wabush Mines Dock at Pointe-Noire, Ontario. Included were two conveyor loaders having a loading rate of 8,000 tons per hour.

Australian Government and mining company officials talked of shipping ore to Great Britain, West Germany, and northern Italy as subsidiary markets when Japanese trade was establishd. Surveys of several port sites in Great Britain were made by the National Ports Council to evaluate possible schemes to accommodate ore carriers up to 100,000 tons capacity.

Patterns of world iron ore trade and developments affecting seaborne ore traffic were discussed in a special iron ore publication.[2]

Shipments of iron ore from U.S. Upper Great Lakes ports totaled 62,564,516 long tons according to the American Iron Ore Association. A total of 145 ore carriers operated on the lakes compared with 141 in 1964. The first carrier shipment of ore from a Lake Superior district port was cleared April 7 and the final shipment for the 1965 transportation season was December 14. The St. Marys River channel at the Soo Locks was dredged to 28 feet at low water. This allowed a record clearance through the Soo by the ore carrier *William A. Reiss* with 26.5 feet registered draft.

Iron ore moved on the St. Lawrence Seaway including the Welland Canal during the 1965 season amounted to 17.2 million tons, or 28.6 percent of the total Seaway traffic. The Welland Canal Section recorded upbound ore as 12.2 million tons and downbound ore 3.9 million tons. Shipment of 300,000 tons of iron ore pellets during January from Quebec through the Port of Sept-Iles principally to Bethlehem Steel Co. Sparrows Point plant in Maryland indicated the possibility of future all year shipping of this commodity.

A favorable feasibility report on a proposal to link Lake Erie with the Ohio River by constructing a 120-mile canal was given by a survey team of the U.S. Army Corps of Engineers. Cost was estimated at $1.025 billion.

Unit iron ore trains of 100 to 110 cars operated throughout the year, even under adverse weather conditions. Experimental all-rail unit trains of pelletized ore from Michigan to Pennsylvania were tried. The Chicago and North Western Railway Co., added 24-inch steel plates around the tops of 600 ore cars to increase capacity for pellet transportation. Other innovations in the operation of unit trains were discussed in an article by the Director of Research for the Pennsylvania Railroad.[3]

The pipeline as a method of transporting iron ore received considerable attention. A paper describing pilot plant investigations in this field was presented in Canada.[4]

Anaconda Iron Ore Ltd. successfully tested a method of pumping iron concen-

[2] Mills, R. H. Shipping of Iron Ore. Metal Bull. (London). Iron Ore Special Issue, March 1965, pp. 11–36.

[3] Chitz, J. J. Unit Trains for the Future. Skillings' Min. Rev., v. 54, No. 25, June 19, 1965, pp. 1, 6–7, 18–19, 28–29.

[4] Kostuik, S. P. Hydraulic Hoisting and the Pilot Plant Investigation of the Pipeline Transport of Crushed Magnetite. Canadian Min. and Met. Bull. (Montreal), v. 59, No. 645, January 1966, pp. 25–38.

trate and planned construction of a pipeline from Nakina, Ontario, to Nama Bay, site of a planned pellet plant.

The Tasmanian development plans of Pickands Mather & Co. and Japanese interests in the Savage River area provided for a 65-mile pipeline to transport concentrate to a pelletizing plant. Pilot studies of the pipeline were made at Hibbing, Minn.

Rotterdam interests investigated the use of a pipeline to move ore from deposits at Minas Gerais, Brazil, to Rio de Janeiro. Estimated cost in pumping 4 million tons of material per year through a 240 mile line was given as about $2 per ton.

Published rail and lake freight rates on ore remained unchanged during the year. A short-term lowered rate was given on unit-train shipments by one railroad prior to opening of lake traffic.

Tariff definitions as applied to heat-treated ores were changed near the end of the year to allow without question entry of such treated iron ores duty-free.

FOREIGN TRADE

U.S. exports were approximately the same as for 1964, with essentially all iron ore consigned either to Canada or to Japan. Imported iron ore was valued at $444 million, an increase of about 6 percent over 1964 imports. The increase was due primarily to shipments from Venezuela and Brazil. Canadian imports failed to gain over previous years for the first time since 1961.

Table 17.—U.S. exports of iron ore, by countries

(Thousand long tons and thousand dollars)

Destination	Quantity	Value	Quantity	Value	Quantity	Value
	1956–60 (average)		1961		1962	
Canada	3,689	$36,604	3,889	$42,269	4,781	$51,377
Germany, West	(1)	1	172	1,993	64	340
Japan	771	7,752	883	9,655	981	10,213
South Africa, Republic of	3	142	4	179	5	164
United Kingdom	--------	--------	6	70	64	714
Other countries	2	96	4	64	3	39
Total	4,465	44,595	4,958	54,230	5,898	62,847
	1963		1964		1965	
Canada	4,987	58,054	4,834	58,586	4,560	54,399
Germany, West	72	423	73	432	92	553
Japan	1,682	17,087	2,021	20,247	2,431	25,425
South Africa, Republic of	3	155	1	44	--------	--------
United Kingdom	65	605	18	260	--------	--------
Other countries	3	16	16	101	2	41
Total	6,812	76,340	6,963	79,670	7,085	80,418

[1] Less than ½ unit.

Table 18.—U.S. imports for consumption of iron ore,[1] by countries

(Thousand long tons and thousand dollars)

Country	1956-60 (average)		1961		1962		1963		1964		1965	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
North America:												
Canada	11,720	$108,084	9,683	$99,164	16,825	$169,765	18,891	$199,416	24,854	$274,548	23,756	$264,360
Mexico	169	560	123	421	145	546	1	5	22	129	10	43
Other	107	1,282	--------	--------	--------	--------	--------	--------	([2])	([2])	--------	--------
Total	11,996	109,926	9,806	99,585	16,970	170,311	18,892	199,421	24,876	274,677	23,766	264,403
South America:												
Brazil	1,229	15,365	889	9,613	1,299	14,080	781	7,731	1,055	11,660	2,279	23,380
Chile	3,019	23,166	2,604	21,913	3,400	28,907	2,679	25,332	2,712	24,220	2,660	23,253
Peru	2,176	20,447	1,209	11,752	573	6,196	290	2,406	580	6,646	957	10,350
Venezuela	12,365	95,025	10,478	99,118	10,328	96,981	9,231	76,937	9,954	79,207	12,273	97,925
Other	([2])	4	--------	--------	--------	--------	--------	--------	8	79	84	774
Total	18,789	154,007	15,180	142,396	15,600	146,164	12,981	112,406	14,309	121,812	18,253	155,682
Europe:												
Sweden	404	5,282	78	1,156	32	566	37	742	93	1,109	57	1,108
Other	7	112	3	157	1	24	([2])	13	10	477	11	518
Total	411	5,394	81	1,313	33	590	37	755	103	1,586	68	1,626
Africa:												
Algeria	2	17	--------	--------	--------	--------	--------	--------	20	235	51	356
Liberia	1,016	9,401	715	6,728	757	6,478	1,310	9,944	2,873	20,297	2,813	19,978
Mauritania	--------	--------	--------	--------	--------	--------	--------	--------	133	1,618	94	1,128
Nigeria	--------	--------	--------	--------	--------	--------	--------	--------	72	666	12	171
Other	103	731	23	203	--------	--------	21	264	19	222	45	439
Total	1,121	10,149	738	6,931	757	6,478	1,331	10,208	3,117	23,038	3,015	22,072
Asia:												
Philippines	30	605	--------	--------	49	1,018	22	367	--------	--------	--------	--------
Other	13	224	([2])	1	([2])	12	([2])	1	2	166	1	3
Total	43	829	([2])	1	49	1,030	22	368	2	166	1	3
Oceania: Australia	--------	--------	--------	--------	--------	--------	--------	--------	1	9	([2])	2
Grand total	32,360	280,305	25,805	250,226	33,409	324,573	33,263	323,158	42,408	421,288	45,103	443,788

[1] In addition pyrites cinder (byproduct iron ore) was imported as follows: 1956-60 (average) Canada 3,469 long tons ($12,015), Italy 683 tons ($4,962); 1961—3,504 tons ($17,822); 1962—4,248 tons ($26,345) all from Canada; 1963—Canada 3,489 tons ($46,057) West Germany, 22 tons ($2,294); 1964, 8,635 tons ($49,266); 1965, 1,563 tons ($18,580) all from Canada.
[2] Less than ½ unit.

Table 19.—U.S. imports for consumption of iron ore, by customs districts

Customs district	1964		1965	
	Long tons	Value	Long tons	Value
Buffalo	2,578,887	$29,218,104	2,381,735	$30,063,584
Chicago	4,659,345	47,793,095	4,863,194	51,749,297
Duluth and Superior	228	1,351	5,911	13,024
Florida	----------	----------	43,925	320,214
Galveston	689,301	8,923,344	792,979	10,010,079
Indiana	----------	----------	7,438	106,289
Laredo	21,604	128,823	10,072	42,597
Los Angeles	----------	----------	102	1,866
Maryland	8,991,885	81,124,132	10,281,834	91,826,604
Michigan	2,763,367	37,329,044	2,804,679	36,753,029
Mobile	3,010,260	24,506,883	3,867,983	32,101,266
New Orleans	607,121	5,470,234	532,018	5,126,391
New York	(1)	(1)	191	3,771
Ohio	5,947,880	64,015,475	5,590,587	59,755,321
Philadelphia	r 12,583,076	r 117,325,727	13,453,500	121,648,235
St. Lawrence	26,471	426,547	3,713	61,550
South Carolina	15	1,603	----------	----------
Vermont	411	38,813	----------	----------
Virginia	528,001	4,982,008	463,333	4,201,495
Washington	236	2,463	----------	----------
Wisconsin	4	300	224	3,359
Total	42,408,092	421,287,946	45,103,418	443,787,971

r Revised.
[1] Revised to none, included in Philadelphia.

WORLD REVIEW

A high level of activity continued in most of the world's iron ore areas, and resulting overall increase in production capacity indicated a growth rate higher than the demands of the iron and steel industry. Availability of high-grade natural ores increased. The price structure of lower grades of ores weakened, while the market increased for pelletized ore of maximum iron content and steps were taken to satisfy future pellet requirements. Ocean transportation costs were being reduced through introduction of high-tonnage carriers and rapid ore-transfer systems. This, combined with the increasing capacity of pellet plants, continued to force the phasing out of many small marginal low-grade iron mines.

NORTH AMERICA

Canada.—*Alberta.*—The Alberta Research Council had a $1.5 million research facility underway near Edmonton in which the Peace River Mining & Smelting Ltd. expected to lease space for research studies. The company planned to develop an acid-leach process to produce high-purity iron powder. Peace River has reserves of approximately 250 million tons of oölitic ore averaging about 33 percent iron.

British Columbia.—Westfrob Mines Ltd., a subsidiary of Falconbridge Nickel Mines Ltd., had under development an iron ore mine on Moresby Island, Queen Charlotte Islands. A 10,000-ton-per-day concentrator, harbor facilities, and a town were included in the development plans. Bulk ore carriers of 50,000 tons were to be provided for on completion of harbor improvements. A contract to supply Mitsubishi Shoji Kaisha Ltd. of Japan with 900,000 tons of pellet and sinter feed per year beginning in late 1966 was obtained. Jedway Iron Ore Ltd., also operating on adjoining property at the southern end of the Queen Charlotte Islands, was shipping ore to Japan from the port of Harriet Harbor at a rate of about 350,000 tons per year.

Orecan Mines Ltd. began operations at its Kelsey Bay property on Vancouver Island. Daily production of about 500 tons of 62 percent iron concentrate was scheduled. A contract was obtained for sale of 1 million tons of the concentrate to be shipped to Japan at a minimum rate of 150,000 tons annually. The Vancouver Island magnetite deposits were the subject of a paper based on field studies.[5]

[5] Eastwood, G. E. P. Replacement Magnetite on Vancouver Island, British Columbia. Econ. Geol., v. 60, No. 1, January–February 1965, pp. 124–148.

Table 20.—World production of iron ore, iron ore concentrates, and iron ore agglomerates by countries

(Thousand long tons)

Country	1961	1962	1963	1964	1965 p[1]
North America:					
Canada	18,178	24,428	26,914	r 34,219	35,527
Cuba e	2	1	1	1	1
Guatemala e	5	5	6	7	8
Mexico (60 percent Fe equivalent)	1,127	1,790	2,291	r 2,284	2,503
United States [2]	71,329	71,829	73,599	84,836	87,842
Total	90,641	98,053	102,811	r 121,347	125,881
South America:					
Argentina	137	r 121	r 98	94	111
Brazil	10,059	10,567	11,042	r 16,694	r 17,220
Chile	6,879	7,964	8,373	9,697	11,229
Colombia	665	669	684	699	695
Peru	8,559	5,855	6,470	6,501	e 7,200
Uruguay	----------	----------	1	2	e 2
Venezuela	14,335	13,057	11,562	15,403	17,125
Total	40,674	r 38,233	r 38,230	r 49,089	53,582
Europe:					
Albania	352	418	r 255	e 345	e 365
Austria	3,635	3,692	3,675	3,507	3,480
Belgium	113	80	94	60	90
Bulgaria	411	625	645	705	e 2,500
Czechoslovakia	3,242	3,422	3,357	2,801	2,969
Finland [3]	276	299	360	r 466	669
France	65,554	65,254	56,978	r 59,976	58,585
Germany:					
East	1,617	1,616	1,635	r 1,608	1,624
West	18,568	16,380	12,694	11,340	10,676
Greece	287	209	35	59	295
Hungary	595	671	721	763	750
Italy	1,216	1,133	r 1,008	900	773
Luxembourg	7,340	6,404	6,880	6,575	6,215
Norway	1,647	1,919	1,935	2,019	2,385
Poland	2,348	2,398	2,568	2,638	2,816
Portugal	r 245	r 258	r 259	r 212	181
Rumania	1,710	1,711	2,250	r 1,901	2,440
Spain	5,967	5,670	5,111	r 5,026	5,597
Sweden	23,220	r 22,170	r 23,264	r 26,239	29,019
Switzerland	e 85	e 102	94	89	111
U.S.S.R.[4] [5]	115,776	r 126,088	r 135,331	r 143,553	150,584
United Kingdom	16,518	15,277	14,912	r 16,326	15,414
Yugoslavia	2,150	2,155	2,261	2,271	2,464
Total [4]	r 272,872	r 277,951	r 276,322	r 289,469	300,002
Africa:					
Algeria	2,822	2,209	1,945	2,696	3,083
Angola	799	740	628	r 885	802
Guinea, Republic of	533	689	652	755	591
Liberia	3,200	3,550	[6] 6,453	10,291	15,707
Mauritania	295	984	r 1,652	r 5,000	5,905
Morocco	1,439	1,131	1,019	874	936
Rhodesia, Southern	382	609	645	811	e 1,340
Sierra Leone	1,668	1,843	1,882	1,962	2,110
South Africa, Republic of	3,898	4,263	4,390	4,754	5,724
South-West Africa	----------	----------	15	9	32
Sudan	5	20	----------	([7])	34
Swaziland	----------	----------	----------	59	1,004
Tunisia	836	749	851	924	1,099
United Arab Republic (Egypt)	415	454	r 481	440	429
Total	16,292	17,061	r 20,613	r 29,460	38,796
Asia:					
Burma	e 16	9	r 4	----------	5
China, mainland e [8]	34,400	29,500	34,400	36,400	38,400
Hong Kong	117	111	112	114	132
India	12,076	13,151	r 14,758	r 15,069	16,634
Goa	6,381	5,354	4,921	5,571	6,388
Iran [9]	41	10	r 21	----------	59
Japan [10]	2,826	2,546	2,387	r 2,517	2,467

See footnotes at end of table.

Table 20.—World production of iron ore, iron ore concentrates, and iron ore agglomerates by countries—Continued

(Thousand long tons)

Country	1961	1962	1963	1964	1965 p 1
Asia—Continued					
Korea:					
North	3,494	3,287	3,799	4,724	e 5,800
South	r 481	464	493	674	723
Malaysia	6,734	6,508	7,264	6,465	6,873
Pakistan [11]	4	----------	(7)	5	23
Philippines	1,153	1,365	1,363	1,345	1,415
Taiwan [12]	13	6	5	7	14
Thailand	55	44	16	r 188	738
Turkey	746	800	735	961	1,506
Total e 4	r 68,500	63,200	r 70,300	r 74,000	81,177
Oceania:					
Australia	5,342	4,843	5,515	r 5,669	6,643
Fiji	10	6	1	----------	3
New Caledonia	273	298	294	302	275
Total	5,625	5,147	5,810	r 5,971	6,921
World total e	r 494,604	r 499,645	r 514,086	r 569,336	606,359

e Estimate. p Preliminary. r Revised.
1 Compiled mostly from data available July 1966.
2 Includes byproduct ore.
3 Iron concentrates and pellets.
4 U.S.S.R. in Asia included with U.S.S.R. in Europe.
5 Data represents iron concentrates of approximately 60 percent iron.
6 Exports.
7 Less than ½ unit.
8 Roughly equivalent of 50 percent iron.
9 Year ending March 20 of year following that stated.
10 Includes iron sand production as follows: 1961, 1,685,137; 1962, 1,419,744; 1963, 1,274,748; 1964, 1,402,814; and 1965, 1,353,099.
11 Obtained principally during exploration activities.
12 Principally magnetite sands with limonite.

Table 21.—World trade of iron ore, iron-ore concentrates, and iron-ore agglomerates in 1964

(Thousand long tons)

Exports by countries of origin	Fe (percent) [a]	Production	Exports	Exports by countries of destination: North America: Canada	North America: United States	South America: Argentina	Europe: Austria	Europe: Belgium-Luxembourg	Europe: Czechoslovakia	Europe: France	Europe: Germany, East	Europe: Germany, West	Europe: Hungary	Europe: Italy	Europe: Netherlands	Europe: Poland	Europe: Rumania	Europe: United Kingdom	Europe: Other Europe	Asia: Japan	Other countries
North America:																					
Canada	55	34,219	30,474	----	24,793	----	----	273	----	25	----	[e]506	----	31	----	----	----	3,162	----	1,677	7
Dominican Republic	--	----	6	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	6	--
Mexico	60	2,284	21	----	----	----	----	21	----	----	----	----	----	----	----	----	----	----	----	----	--
United States	57	[1]84,836	6,963	4,834	----	----	----	----	----	----	----	73	----	----	15	----	----	18	----	2,021	2
South America:																					
Brazil	68	16,694	9,576	373	1,034	611	252	489	354	372	----	3,440	----	1,028	260	177	94	523	77	492	--
Chile	64	9,697	8,969	----	2,706	263	----	----	----	----	----	628	----	22	43	----	----	----	----	5,307	--
Colombia	45	699	NA	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	--
Peru	63	6,501	5,123	----	474	162	----	113	----	237	----	[e]1,265	----	90	----	----	----	52	----	2,730	--
Venezuela	62	15,403	14,658	----	9,959	----	----	32	----	----	----	2,083	----	823	83	----	----	1,678	----	----	--
Europe:																					
Austria	32	3,507	(2)	----	----	----	----	----	----	----	----	(2)	----	----	----	----	----	----	----	----	--
Belgium-Luxembourg	30	6,635	222	----	----	----	----	----	----	204	----	[3]18	----	----	----	----	----	----	----	----	(2)
Bulgaria	62	705	11	----	----	----	----	----	----	----	----	----	----	----	----	----	11	----	----	----	--
Finland	65	466	312	----	----	----	----	29	20	----	----	151	----	----	----	108	----	----	4	----	--
France	30	59,976	21,742	----	----	----	----	15,204	----	----	----	6,309	----	----	----	----	----	227	----	----	2
Germany, West	27	11,430	285	----	----	----	266	2	----	11	----	----	----	(2)	4	----	----	(2)	2	----	--
Greece	50	59	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	--
Italy	51	900	6	----	----	----	----	----	----	[3]6	----	----	----	----	----	----	----	----	----	----	--
Norway	64	2,019	1,528	----	----	----	----	----	2	----	----	[3]809	----	----	----	111	----	[e]606	----	----	--
Poland	34	2,638	19	----	----	----	----	----	----	----	----	----	----	----	----	----	----	18	----	----	1
Portugal	50	212	36	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	36
Spain	50	5,026	2,414	----	----	----	----	52	----	145	1	976	----	45	559	----	----	567	66	----	3
Sweden	61	26,239	23,959	----	37	----	56	5,529	138	482	28	9,596	11	279	687	655	----	5,806	653	----	2
Switzerland	40	89	63	----	----	----	----	----	----	----	----	62	----	----	1	----	----	----	----	----	--
U.S.S.R.	60	[4]143,553	22,243	----	----	----	[3]426	----	7,517	----	2,524	[3]461	2,302	----	----	[3]7,132	1,641	----	----	----	240
United Kingdom	28	16,326	NA	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	--
Yugoslavia	43	2,271	198	----	----	----	----	----	----	----	----	----	198	----	----	----	----	----	----	----	--

Other East Europe	--	7,418	NA	----	-----	------	----	-----	---	----	----	-----	----	----	----	----	----	-----	----	-----	--
Africa:																					
Algeria	54	2,696	2,784	----	20	------	----	6	96	62	----	283	----	840	15	19	----	1,064	379	-----	--
Angola	65	885	1,110	----	-----	------	----	-----	14	23	----	946	----	23	25	----	----	-----	----	79	--
Guinea, Republic of	50	755	690	----	-----	------	[3]56	-----	---	----	----	-----	----	----	----	[3]390	----	[3]150	----	-----	94
Liberia	65	10,291	12,069	----	3,044	------	----	763	---	852	----	[3]4,227	----	658	[e]825	----	----	1,657	43	-----	--
Mauritania	65	5,000	4,888	----	[3]133	------	----	-----	---	[3]981	----	1,222	----	733	[3]168	[3]14	----	1,369	----	[3]52	216
Morocco	58	874	978	----	-----	------	----	23	105	129	----	418	----	----	----	----	----	205	98	-----	--
Rhodesia, Southern	58	811	282	----	-----	------	----	-----	---	----	----	-----	----	----	----	----	----	-----	----	282	--
Sierra Leone	64	1,962	1,980	----	-----	------	----	-----	---	16	20	667	----	----	662	----	----	615	----	-----	--
South Africa, Republic of	62	4,754	1,068	----	-----	------	----	-----	---	----	----	3	----	1	8	----	----	-----	----	1,052	4
Tunisia	54	924	818	----	-----	------	----	-----	---	10	----	37	----	223	----	48	----	300	158	-----	42
United Arab Republic (Egypt)	50	440	------	----	-----	------	----	-----	---	----	----	-----	----	----	----	----	----	-----	----	-----	--
Asia:																					
China, mainland	50	[e]36,400	[3]52	----	-----	------	----	-----	---	----	----	-----	----	----	----	----	----	-----	----	[3]51	[3]1
Hong Kong	56	[e]114	130	----	-----	------	----	-----	---	----	----	-----	----	----	----	----	----	-----	----	130	--
India, including Goa	60	20,640	10,316	----	-----	------	----	77	771	40	41	[3]935	12	335	38	249	492	(2)	433	6,893	--
Japan	56	2,517	------	----	-----	------	----	-----	---	----	----	-----	----	----	----	----	----	-----	----	-----	--
Korea:																					
North	37	4,724	[3]346	----	-----	------	----	-----	---	----	----	-----	----	----	----	----	----	-----	----	[3]346	--
South	50	674	479	----	-----	------	----	-----	---	----	----	-----	----	----	----	----	----	-----	----	479	--
Malaysia	56	6,465	6,317	----	-----	------	----	-----	---	----	----	-----	----	----	----	----	----	-----	----	6,264	53
Philippines	58	1,345	1,491	----	-----	------	----	-----	---	----	----	-----	----	----	----	----	----	-----	----	1,491	--
Turkey	56	961	------	----	-----	------	----	-----	---	----	----	-----	----	----	----	----	----	-----	----	-----	--
Other Asia	--	200	NA	----	-----	------	----	-----	---	----	----	-----	----	----	----	----	----	-----	----	-----	--
Oceania:																					
Australia	65	5,669	------	----	-----	------	----	-----	---	----	----	-----	----	----	----	----	----	-----	----	-----	--
New Caledonia	55	302	288	----	-----	------	----	-----	---	----	----	-----	----	----	----	----	----	-----	----	-----	288
Other countries	--	171	(5)	----	-----	------	----	-----	---	----	----	-----	----	----	----	----	----	-----	----	-----	--
Total	--	[6]569,336	194,914	5,207	42,200	1,036	1,056	22,613	9,017	3,595	2,614	35,115	2,523	5,131	3,393	8,903	2,238	18,017	1,913	29,352	991

[e] Estimate. NA Not available.
[1] Includes byproduct ore.
[2] Less than ½ unit.
[3] From import detail of customs returns of the respective country.
[4] U.S.S.R. in Asia included with U.S.S.R. in Europe.
[5] Incomplete data.
[6] Data do not add to totals shown because of rounding where estimated figures are included in the detail.

Newfoundland — Quebec. — Wabush Mines, an internationally owned mining and concentrating venture 200 miles north of the Gulf of St. Lawrence, was formally dedicated on June 22. The operation was rated at 5.3 million tons of concentrate per year, most of which was used by an associate company, Arnaud Pellets. This company, a 4.9-million-ton-per-year pellet plant at Pointe-Noire, Quebec, was officially dedicated on July 10. Concentrate production went to the 10 iron and steel companies owning the $250 million development, managed by Pickands Mather & Co., and pellet production to 8 of the companies.

The Iron Ore Company of Canada planned expansion of its treatment facilities at Carol Lake, and recorded the first production from its Carol East mine, which supplied 735,000 tons of ore during the year. The company conducted pilot plant tests at its Knob Lake research laboratory incorporating flotation which indicated the north end ore to be suitable for production of pellets grading 64.5 to 65 percent iron. The Bechtel Corp. was awarded a contract for preliminary estimates on a plant, possibly to be located at Schefferville or Sept-Iles.[6]

Mt. Wright Iron Mines Co. Ltd., planned to develop its Quebec properties and produce iron ore pellets at a 4 million ton-per-year rate by 1969. Development costs were estimated at about $80 million.

Northwest Territories. — Hudson Bay Mining and Smelting Co. Ltd. entered into an agreement with Baffinland Iron Mines Ltd. to participate in an investigation of the possibilities of developing the latter's high-grade iron deposits on Baffin Island. There were four major deposits involved. Drilling indicated the presence of over 100 million tons of ore in one of these averaging 68 percent iron and less than 1 percent silica, and an additional 20 million tons of ore grading 64 percent. About one-third of the reserves are magnetite and the rest hematite.

Ontario.—A new iron ore discovery in the Nipissing district, 35 miles northeast of North Bay was noted. Iron City Mines had a drilling program underway on the property.

The Steel Company of Canada Ltd. (Stelco) planned to develop iron ore claims and build a pelletizing plant in northwestern Ontario on property leased from Iron Bay Mines Ltd. Annual output of 1.5 million tons of pellets was expected on completion in 1968.

The Jones & Laughlin Steel Corp. completed the first full year of iron ore production at its Adams mine, Kirkland Lake. Official opening was March 10. Pellets produced from magnetic taconite were being shipped at a rate of 1 million tons per year. Descriptions of the project were presented giving details of operations.[7]

Algoma Steel Corp. Ltd. signed an option agreement with Can-Fer Mines Ltd. for iron ore properties near Nakina in northern Ontario. A cash payment by Algoma plus annual royalties were involved.

Dominion Foundries & Steel Ltd. (DOFASCO) and Cliffs of Canada Ltd. planned to open an iron ore property and construct a 1-million-ton-per-year pellet plant in the Temagami area north of North Bay.

Saskatchewan.—Choiceland Iron Mines Ltd. negotiated for tenders to sink a shaft on its orebody 52 miles east of Prince Albert. A pilot hole was completed in August to the ore zone which is at a depth of 2,000 to 3,000 feet. The Saskatchewan Government previously offered financial assistance on the project under specified conditions.

Mexico.—Four Mexican steel companies were reported to have been granted a concession to develop the iron ore deposits of the Peña Colorado region in Colima. The deposits have been estimated to contain 300 million tons of good grade ore. The proposed extraction rate was given as 600,000 tons yearly.

Studies conducted by the Banco Nacional de Comercio Exterior showed proved reserves of iron ore in Mexico to be 570 million tons averaging 57 percent iron.

Surveys for iron ore were continued by the Government in several areas. Part of the cost was to be contributed by the United Nations Special Fund.

[6] Skillings, David N., Jr. Iron Ore Co. of Canada Operations in the Quebec-Labrador Regions. Skillings' Min. Rev., v. 54, No. 27, July 3, 1965, pp. 1, 4–5, 12–13.

[7] Guimond, Roger. The Adams Mine. Mining in Canada (Winnipeg), v. 38, No. 4, April 1965, pp. 12–43.

Mamen, C. From Taconite to Pellets at the Adams Mine. Canadian Min. J. (Quebec), v. 86, No. 5, May 1965, pp. 65–71.

SOUTH AMERICA

Bolivia.—The new liberal mining code reduced to three the number of State reserves; one included the iron ore deposits near Mutún. Under an agreement made by the United Nations Special Fund to survey the deposits and examine possibilities of exporting the ore by way of the Paraguay River, a feasibility study was completed. A minimum investment of $136 million was reported as necessary to mine and market the ore. The deposits have been variously estimated at from 3,000 to 40,000 millions tons, with average iron content between 53 to 58 percent. The Bolivian Ministry of Mines considered the total tonnage of ore may exceed 40,000 million tons.

At yearend the Government was seeking tenders on a long term worldwide basis to develop and exploit the deposits, which are close to the border of Brazil in the Department of Santa Cruz. This area has been considered largely inaccessible.

Brazil.—The Brazilian mining code was modified to allow more active participation by foreign capital in mining ventures. A new mining company, Minerações Brasileiras Reunidas S.A. (MBR) was formed by a merger of Cia. Auxiliarde Emprêsas de Mineração (CAEMI) and the St. John del Rey Mining Co. The new company was to be controlled by the Antunes group (CAEMI) with 51 percent of the stock; 49 percent was to be held by St. John (Hanna). MBR planned a substantial expansion to raise production and to construct a pellet plant. A new ocean-loading terminal constructed by CAEMI in Septiba Bay was planned with facilities for handling 100,000-ton ships. In Minas Gerais, a State-controlled company, Metais Minas Gerais S.A. (Metamig), was given control of the Ferrobelan Iron Ore Co., owned by the city of Belo Horizonte. Reserves of the latter company were to be exploited.

Cia. Vale do Rio Doce (CVRD) had under construction a new port, Tuberão in Espirito State. A new loader and a stacker, both rated at 6,000 tons per hour were being installed. The company's capacity of 10 million tons per year was expected to double on completion of the facilities. MBR was to collaborate with CVRD in shipping iron ore through the port, which was planned for a dockside depth of 53 feet.

Cia. Siderúrgica Belgo-Mineira S.A. and its subsidiary S.A. Mineração da Trinidade (SAMITRI) planned production increases of 1 million tons per year, to reach 8 million tons in 1969. The Alegria and Piracicaha complexes were to be prospected intensely.

CVRD and CAEMI, and MBR were reported to be prepared to construct pellet plants. Nine of Japan's major steel firms had contracts for Brazilian iron ore, with 1 million tons scheduled to be shipped in 1966.

The nature and origin of the iron ores of Minas Gerais were described by a member of the Federal Geological Survey.[8]

Chile.—A change in rail rates for iron ore transported more than 50 kilometers was made in a move by the Government to bring into production additional mines in the Atacama and Coquimbo Provinces.

Bethlehem-Chile Iron Mines Co. (a subsidiary of Bethlehem Steel Corp.) began operation of a 300-ton-per-hour magnetic separation plant at its El Tofo mine in Coquimbo Province. Feed from waste dumps containing about 30 percent iron was upgraded in the plant to a final 65 percent concentrate for export. The last phase of a $8.75 million program to increase efficiency of both the El Romeral and El Tofo operations neared completion.

Cía. Minera Santa Fe had a fifth iron ore beneficiation plant under construction at Desvio Norte using either dump or crude ore as feed. Geological work on the company's El Laco deposit was reported to have blocked out over 300 millions tons of iron ore with 64 to 69 percent iron content.

Exploration for iron ore occurred in several areas. Work completed on the Chañar-Boqueron deposit north of Vallenar showed an estimated 70 million tons of high-grade ore. An iron ore body previously discovered by aerial surveys in the Atacama desert about 420 miles north of Santiago was undergoing exploratory drilling. Aerial magnetometer surveys were completed in Chile under the United Nations Special Fund.

Peru.—The Marcona Mining Co. exported about 1 million tons more iron

[8] Dorr, John Van N. II, Nature and Origin of the High-Grade Hematite Ores of Minas Gerais, Brazil. Econ. Geol., v. 60, No. 1, January–February 1965, 46 pp.

ore in 1965 than in 1964, reaching 6.7 million long tons. An expansion program was underway to raise capacity of the pellet plant at San Nicolas Bay to 1.25 million tons annually, and add a new 2-million-ton-per-year facility. This company received the 1965 annual award of the Institute of International Education for distinguished service in international education.

Northern Peru Mining Co. (a subsidiary of American Smelting and Refining Company) signed an option to purchase the Berenguela mine containing manganiferous iron near Santa Lucia.

Venezuela.—Production of iron ore exceeded that for 1964 by 11 percent. Exports were mainly to the United States with West Germany and the United Kingdom taking about 10 percent each.

Proposals for development of the Government-owned San Isidro iron ore deposits were requested of companies in several countries for study by the Minister of Mines and Hydrocarbons. The Government inspected direct-reduction process experimental plants in the U.S.A. and Canada, and the Minister announced that pipe line construction was planned to move natural gas from the eastern fields to the Guayana area to supply the iron ore and other industries.

The El Pao iron deposit was described and a derivation hypothesis of the ore presented.[9]

EUROPE

European Coal and Steel Community.—A report by the High Authority of ECSC indicated investments for 1964 in the iron mines were less than one-half the average amounts spent in the years 1956 to 1962. This was not considered sufficient to make up for the capacity closed because of imported ore competition. Some expansion was expected in the Lorraine region, with the others to continue to reduce capacity. Mine closures lowered potential production from 97.9 million tons in 1963 to 92.3 millions tons in 1964.

The Lorraine region was expected to account for 73 percent of ECSC capacity by 1968. Reserves of iron ore in the Lorraine region of France were estimated at 6 billion tons with iron content more than 28 percent.[10]

Fifteen ECSC companies considered establishing facilities at Rotterdam for the unloading, storage and treatment of imported iron ore. Imports of ore to the Community amounted to 47.7 million tons in 1964.

Germany, West.—Output of iron ore in West Germany dropped steadily the past few years. Decrease was attributed to high production costs, low-grade local ore, and imported cheaper and higher grade ore. Underground iron ore miners requested Federal Government aid in the face of closing mines, output of which declined from 18.6 million tons in 1960 to 10.7 million tons in 1965. Since 1960 West German companies have closed about 30 mines. West German imports of iron ore for 1964 were over 35 million tons.

Norway.—A new iron ore pellet-hardening plant was opened south of the Arctic Circle at Mo-I-Rana (A/S Rana Gruber) on the west coast.

Norway's largest mining company, State-owned A/S Sydvaranger, announced plans to increase capacity of its separation plant at Kirkenes to 2.4 million tons per year within 2 years. New drilling, loading, and transportation equipment was being installed. The iron ore port at Narvik was being improved to handle ore carriers of 65,000 tons.

Sweden.—The State-owned Luossavaara-Kiirunavaara Aktiebolag (LKAB) placed in operation at Kiruna the largest iron ore pellet plant in Europe. The designed capacity rate, in excess of 1.5 million annual tons of pellets, was reached near the end of 1965. Raw materials for the plant were iron ore concentrates produced by several mills. These were mixed and balled with ferrous sulfate as a binder. Provision was made at the plant to add fluxes if desired.[11] This plant was officially inaugurated along with a sorting and a concentrating plant by the Swedish Prime Minister in September. The three plants form the processing unit called SAK-verken (SAK Works) short for sorting, concentrating and pelletizing in Swedish.

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[9] Kalliokosko, J. The Metamorphosed Iron Ore of El Pao, Venezuela. Econ. Geol., v. 60, No. 1, January–February 1965, pp. 100–116.

[10] Leandri, Joseph. Iron Mining in Eastern France. Min. Cong. J., v. 51, No. 7, July 1965, pp. 85–89.

[11] Johnson, Bryan. Kiruna's New Iron Ore Pelletizing Plant. World Min., v. 18, No. 12, November 1965, pp. 32–37, 83.

The Grängesberg Co., Sweden's second largest iron ore producer, announced that construction of their second pelletizing plant at the Stråssa mines was on schedule. Capacity will be 220,000 tons per year. Grängesberg's shipowning division added a 66,100-ton ore and oil carrier to its fleet. Two new carriers of 71,500 tons each were under construction. Harbor facilities at Oxelösund were improved to handle 60,000-ton ships, and automatic ore loading at 4,000 tons an hour was provided for. The iron ore harbor at Luleå on the Gulf of Bothnia was officially opened. Facilities include two main loaders rated at 4,000 tons per hour.

A Dored iron ore reduction plant was opened in Borlänge to complete a $17 million steel project of Domnarfvets Jernverk Co.

A large deposit of low-grade iron ore at Kaunisvaara near the Finnish border was explored by LKAB.

U.S.S.R.—Scheduled production of iron ore during the Seven Year Plan (1959–65) was reported to have been exceeded by 1.3 percent. Volume in 1965 amounted to 152.8 million tons compared with 88.8 million in 1958. In 1965, 73 percent of the total production of the iron ore mines was by open-pit methods, 53.9 percent in 1958.

United Kingdom.—The United Steel Companies Ltd. started a 4-year development project at its Becketmet and Haile Moor underground mines. Increased mechanization was expected to raise output from 2,300 to 4,000 tons per week. Over the 4-year development period employment was to be reduced by 70 men from 360.

Purchases of iron ore concentrates by British steel interests from U.S.S.R. for 1966 were estimated to be increased to about 1.2 million tons.

Open-pit mining methods in England and restoration of the land as required under English law were described.[12]

The 1964 average monthly output of crude ore per worker was 241 tons for open-pit mining and 121 tons for underground mining. Modernization was in evidence at the iron ore mines. Several were reported to have completely changed from steam to electric locomotives. Automation of processing equipment was noted also.

Concentrates produced had an average iron content of 58.3 percent, and commodity ore 56.3 percent. The production of agglomerates reached 113 million tons in 1965. By 1970 iron content of commodity ore was planned at 58 to 59 percent, and concentrate 64 to 65 percent. Agglomerates and pellets were expected to comprise 95 percent of the blast-furnace charges.[13]

The need of the Comecon, counterpart of OEEC, for Western iron ore was said to be at least 5.4 million tons in 1965.[14] The U.S.S.R. was expected to be able to supply Comecon demands if the new Five-Year-Plan (1966–70) is carried out. This plan called for approximately as much new productive ore capacity as was added during the Seven Year Plan.

AFRICA

Algeria.—Shipments of iron ore were made by the Algerian State mining organization (BAREM) to Bulgaria, Italy, Great Britain, and U.S.S.R. (resold to Poland). Stewarts and Lloyds Ltd., Great Britain, in a contract agreement for 200,000 tons of iron ore provided one-fourth of the purchase price in mining equipment. Algeria increased total production of iron ore in 1965 to 3.1 million tons, 14 percent over that of 1964. This resulted from increased demands in Europe. Italy was largely responsible, supplanting Great Britain as the leading purchaser, followed by Bulgaria, West Germany, and Belgium. The Ouenza/Boukhadra complex in eastern Algeria accounted for about 80 percent of the total iron production. This was mined by the Société de l'Ouenza, a partly Government-owned organization.

Angola.—The production of iron ore at the Cassinga mines of Companhia Mineira do Lobito (CML) was expected to increase to 4.5 million tons per year on completion of improvement contracts. Port facilities at Saco (Moçâmedes) were eventually to provide storage for 1.5 million tons of ore and load vessels of up to 100,000 tons

[12] World Mining. United Open Pit Mining at Steel's Ironstone Colsterworth. V. 18, No. 3, March 1965, pp. 44–46.

[13] Sledzyuk, P. Ye. (Some Results of the Work of the Iron Ore Mining Industry During the Seven-Year-Plan). Gornyi Zhurnal, No. 1, January 1966, pp. 3–18. (English transl.) Min. J., No. 1 (Moscow), Apr. 18, 1966, pp. 3–18.

[14] Baer, F. H. Iron-Hungry Comecon Seeks Western Ore. Eng. and Min. J., v. 166, No. 4, April 1965, pp. 100–102.

at a rate of 6,000 tons per hour.

A rate of production of 500,000 tons per year was expected by the end of 1966, and full capacity in 1967. Exports were scheduled for West Germany, Japan, and the United States. New iron ore deposits of unannounced size were located in the Caroca area, Southern Angola, near the border of Southwest Africa.

Gabon.—A contract was awarded for preliminary work on a rail line from the Mekambo iron district to a proposed deep-water port on the Atlantic. Ten million tons of iron ore were expected to be transported annually. The first ore shipments from this country by SOMIFER were planned for 1974–75.

Large economically exploitable iron ore deposits near Minkebe were verified by surveys of the Bureau de Recherche Géologiques et Minières (BRGM), and the Syndicat Nord-Gabon (formed by the European Coal and Steel Community).

Kenya.—Iron ore deposits were discovered on the lower slopes of Mount Kenya. The deposits, investigated by the Kenya Mines Department, were said to contain 5 percent titanium. German mining and steel companies were reported to have shown an interest in the finds. Indications were that the deposits although high in grade would be of limited quantity.

Liberia.—President Tubman announced in December that a deposit containing 1 billion tons of high-grade ore had been found in the Gbee mountain range of the Lofa County.

Exports of iron ore increased from 12.2 million tons in 1964 to 15.7 million tons in 1965. The Bong Mining Co. exported 1.6 million tons of ore in 1965, its first year of production. This project will have a capacity of 3 million tons of concentrate per year when full-scale production is reached. Bong Mining is owned by a group of German steelworks and the Liberian Government and controlled by the German Liberian Mining Co. (DELIMCO). Kaiser engineers began test pelletizing work on the Bong Range ore under contract with DELIMCO's managing firm, Gerwerkschaft Exploration.

Liberia Mining Co. exported 2.2 million tons of iron ore in 1965, and the National Liberian American-Swedish Minerals Co. (LAMCO) exported 8.3 millions tons of Iron Ore Co., 3.6 million tons.

ore. The company announced the addition of a $51.5 million iron ore washing and pelletizing plant to be constructed at the port of Buchanan. Production capacity was to be increased to 10 million tons and supply 2 million tons of pellets for sale. The Export-Import Bank provided $23.1 million and Bethlehem Steel financed 25 percent of the cost. This was to be the first iron ore pelletizing plant installed in Africa.

Some of the operations of LAMCO since its startup were described by the technical manager in an article.[15]

Mauritania.—The Societé des Mines de Fer de Mauritanie (MIFERMA) produced 6.0 million metric tons of iron ore in 1965, most of which was exported through Port-Etienne. Average value of the ore was $8.50 f.o.b.; average grade 64.5 percent. The production by MIFERMA, carried out at the Tazadit open-pit mine near Fort Gourand, was being increased in stages to a proposed 6 million tons annually by 1969. This has been raised to a goal of 7.5 million tons, which includes exploitation of the F'Derik deposits.

South Africa, Republic of.—The Palabora Mining Co., Ltd. in Northwestern Transvaal contracted to ship 8.8 million short tons of magnetite concentrate, produced as a byproduct of its copper mining operations, to the Kawasaki Steel Corp. and Kobe Steel Works Ltd. companies in Japan over a 10-year period. Construction of a concentration plant was started to upgrade the material.[16] A new iron ore mine owned by Ironstone Minerals Pty., a subsidiary of Highveld Steel and Vanadium Corp. Ltd., was being opened at Roossenekal, in the Transvaal. Full production rate of 1 million tons per year was scheduled for late 1967. Construction work included a spur rail line and a dam.

South African iron ores were discussed by a member of the Government Metallurgical Laboratory in Johannesburg.[17]

Swaziland.—The Bomvu Ridge open-pit iron ore mine of Swaziland Iron Ore Development Co. Ltd. (SIODC) was op-

[15] Pousette, I., and A. Swartling. Operational Experience on the Lamco Project. Min. and Min. Eng. (London), v. 1, No. 11, July 1965, pp. 410–417.

[16] Bureau of Mines. Mineral Trade Notes. V. 61, No. 6, December 1965, p. 21.

[17] Schweigart, Hartmut. Genesis of the Iron Ores of the Pretoria Series, South Africa. Econ. Geol., v. 60, No. 2, March–April 1965, pp. 269–298.

erating to supply the planned shipments through Lourenco Marques for Japan. Shipments were scheduled at a rate of 1.2 million tons per year for 9 years. The world's largest iron ore cargoes in 1965 were of Swaziland iron ore. The ore was loaded on the carriers *Inayama* and *Shigeo Nagano* to the capacity allowed by the port, then moved to sea; there top loading was accomplished by a special ore carrier for the maximum loads of about 78,000 tons.

United Arab Republic (Egypt).—Production of iron ore from the Bahariya Oasis mines was expected to start in 2 or 3 years, depending on progress made in constructing a spur rail line to connect the deposits with an existing rail line. Plans called for 4 million tons per year output of high-grade iron ore from these mines by 1972.

Additional exploration for new iron ore deposits in the country was announced by the Egyptian Mining Organization.

The origin and properties of the Aswan and El-Bahariya ores were discussed.[18]

Zambia.—A high-grade iron ore deposit was reported to have been found by geologists of the Anglo-American Corporation of South Africa Ltd. Size of the deposit, in the Mporokoso region, Luapula Province, was not stated.[19]

ASIA

Afghanistan.—Iron ore deposits at Hajikak were estimated by the Ministry of Mines at 2 billion tons of hematite containing 63 percent iron. Possibilities were being investigated for development, including use of natural gas to produce an iron product for export.

India.—The first fully automated ore-handling facilities in India were commissioned at Visakhapatnam in October. The port has been equipped to handle two 50,000-ton iron ore carriers at the same time. Improvements of the Kiriburu and Bailadila mines were continued in efforts to increase production.

The National Minerals and Metals Trading Corp. signed a 3-year contract with Japan for 8.5 million tons of ore. In addition a long-term contract was pending to supply 2 million tons per year beginning in 1966.

Lurgi of Germany received a contract to set up an ore beneficiation and pelletizing plant in Goa. Designed capacity was 500,000 tons of pellets per year with iron content of 66 percent. Iron ore exports for 1965 including exports from Goa were 11.1 million tons, 13 percent above 1964. The Government-owned Minerals and Metals Trading Corp. was the sole exporter from India, while exports from Goa were largely through private firms. Export targets were 16.2 million tons by 1967 and 24.6 million tons by 1970.

Japan.—Long term contracts signed by Japanese steelmakers during 1965 with the Australian iron ore consortiums made clear that Japan would expect a large portion of her imported ore to be supplied from Australia. The rapid increase in imports by Japan continued, 31.2 million tons being imported in 1964, compared with 26.3 million in 1963. India, Malaysia, Chile, and Peru supplied over two-thirds of the imported ore.[20] Imports of 50 million tons were expected to be received by 1975, with possibly half to be supplied by Australia.

Philippines.—The pelletizing plant of Philippine Iron Mines, Inc., was installed and readied for testing. This plant, designed and constructed by Kawasaki Steel Corp. of Japan, was the last phase of an ore complex designed to produce 750,000 tons of high-grade pellets annually. The other operations, including magnetic separation of underground and surface ore were reviewed.[21]

Black Mountain Inc., continued studies on methods for smelting ores from its Mindanao claims. Philex Mining Corp. had its magnetite concentrator near the production stage.

Viet-Nam, South.—Economic ministry sources in Saigon reported an iron ore discovery estimated at 40 million tons in Quang Ngai Province about 325 miles northeast of Saigon.

OCEANIA

Australia.—Activity in the iron ore areas of Australia, mostly in the west, involved

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[18] El-Hinnawi, Essam E. Contributions to the Study of Egyptian (UAR) Iron Ores. Econ. Geol., v. 60, No. 7, November 1965, pp. 1497–1509.

[19] Bureau of Mines. Mineral Trade Notes. V. 62, No. 1, January 1966, p. 18.

[20] Bureau of Mines. Mineral Trade Notes. V. 62, No. 1, January 1966, pp. 16–17.

[21] Engineering and Mining Journal. U.S. Taconite Method Sparks PIM Mine-Mill Rebirth. V. 166, No. 10, October 1965, pp. 104–107.

major construction projects by several large companies, all with long-term Japanese contracts under negotiation or signed. Value of the contracts amounted to over $2 billion. With reserves estimated at 15 billion tons to draw from, the possibilities of supplying other sectors of the world iron ore market also were being considered.

A special Commonwealth Government committee was established to review terms of export of minerals including iron ore before issuing new contracts. The Australian Foreign Trade Ministry stated that it felt iron ore prices contracted by Western Australian producers were as much as 15 percent below world price levels.

Northern Territory.—The Frances Creek Iron Mining Corp. Pty. Ltd. of the Northern Territory received a contract to supply 3 million tons of iron ore to Sumitomo Shoji Kaisha Ltd. of Japan with shipments over an 8-year period beginning in 1967. Base grade of the ore to be shipped was to be 62 percent iron, at about $0.144 a long ton unit f.o.b. Darwin. A 9-mile railroad spur was planned, and new loading installations at the Darwin port.

South Australia.—The Broken Hill Pty. Co. Ltd. (BHP) awarded a contract for construction of a 1.5-million-ton-per-year pelletizing plant at Whyalla, South Australia. Production was scheduled to begin in 1967 using material from the Iron Prince mine. The company formed a new subsidiary, Dampier Mining Co., to take over all iron ore mining operations of BHP in Western Australia. Included were the activities of Australian Iron and Steel Pty. Ltd. at Cockatoo and Koolan Islands in Yampi Sound.

Western Australia. — Hammersley Iron Pty. Ltd. awarded contracts for work at its new iron ore port at King Bay. Plans called for over 170 miles of standard-gage rail line to the open-pit mining operation at Mt. Tom Price, with towns to be built both at the port and the mines.

An initial contract was concluded with Japanese steelmakers to deliver 15.7 million tons of pellets over a period of 16 years beginning in 1968. Contract price during the first 8 years was $0.185 per long ton unit f.o.b. for pellets of 63 percent iron content. A previous long-term contract was completed with the Japanese for extended deliveries of lump ore totaling 65.5 million tons to begin in 1966, at about $0.155 per long ton unit.

The company also entered into an agreement with the Government of Western Australia to establish an iron and steel industry in the State within 25 years.

Mt. Newman Iron Ore Co. Ltd. planned for construction of a 260-mile railway to link the Mt. Whaleback deposits with a proposed deep-water port at Cooke Point near Port Hedland. Aerial surveys for the railway feasibility study were completed and an initial contract awarded involving engineering work on the various projects. Negotiations were underway with Japan for sale of about 100 million tons of ore over a 22-year period.

Cliffs Western Australian Mining Pty. Ltd. (Cleveland Cliffs-Mitsui) contracted to supply 71.4 million tons of pellets over a 21-year period to Japanese steel mills with delivery starting in 1968. Planned construction included two new towns, a 60-mile railway between a mine site in the Robe River district and a deep-water port at Cape Preston, and a pelletizing plant.

Mt. Goldsworthy Mining Associates had a contract to deliver 16.5 million tons of ore to Japan over a 7-year period beginning in 1966. The company planned to construct 70 miles of railroad between the Mt. Goldsworthy mine site and Port Hedland, where port facilities were to be installed on nearby Finucane Island.

Western Mining Corp. Ltd. continued construction work at the Koolanooka Hills mine and planned to build 11 miles of railroad to connect with the State's line to a port at Geraldton. The Government called for bids to improve port facilities. Contracts with Japan were for delivery of 5.1 million tons of ore starting in 1966.

Iron ores of the Opthalmia Region, Western Australia were described.[22]

Tasmania.—Work started on the Savage River Mines joint venture of Pickands Mather-Mitsubishi to construct a pelletizing plant and dock facilities at Brickmakers' Bay, on the north coast of Tasmania, and a pipeline to transport concentrate from a concentrating plant in northwest Tasmania. Initial output called for over 2 million tons of high-grade pellets per

[22] Neilson, J. M. Iron Ores of the Opthalmia Region, Western Australia. Trans. Soc. Min. Eng., v. 232, No. 4, December 1965, pp. 327–338.

year to be shipped to Japan. Sales contracts were received for 45 million tons of pellets over a 21-year period beginning in 1968.

TECHNOLOGY

Advances continued to be made in iron ore technology. Exploration for iron ore and drilling programs were actively pursued in a number of States. Improvements were noted in mining methods and equipment, beneficiation of low-grade ores, pelletizing procedures, and conversion of ore into metalized furnace feed. Acceptance of the prereduced pellet for furnace use was indicated.

Bills were introduced in the Minnesota State Legislature to provide funds for drilling and study of the taconite formations at depths below 1,000 feet. This was proposed as a part of long-range research programming.

A report issued by the Louisiana State Geological Survey estimated brown iron ore deposits in that State at 800 million tons.[23] The phosphorus content of the deposits was expected to present a problem in exploiting the deposits.

The General Assembly of Georgia allocated $188,500 for mineral exploration, including iron ore, of the State's Coastal Plain.

A report prepared for the Northwestern Wisconsin Planning Commission by the Wisconsin Department of Resource Development called for further research into the technology of iron ore in northern Wisconsin. Efforts were being made to reactivate the iron mining industry which had been reduced to one operating iron mine.[24]

The Federal Geological Survey announced the discovery of low-grade iron deposits in Alaska, approximately 200 miles southwest of Anchorage. Limited analyses showed about 20 percent iron and 1 percent titanium. An outcrop of magnetite containing 35 to 55 percent iron and only a trace of titanium was reported by the Alaska Division of Mines and Minerals to have been found off the shores of Icy Straits. A petrographic study of the Sanford Hill titaniferous magnetite deposit in New York was published, together with a formation hypothesis.[25]

Several new research facilities were announced for studies concerned with iron ore beneficiation. Bethlehem Steel Co. announced a new raw materials and chemical engineering building at their research laboratories in Bethlehem, Pa. The Reserve Mining Co. was building a multimillion dollar research and development center at Siver Bay, Minn. The Hanna Mining Co. enlarged its research facilities at Nashwauk, Minn. A pilot plant using the Surface Combustion Co.'s process of producing pellets having up to 90 percent iron was started up and operated jointly with the National Steel Corp., and the Midland-Ross Corp.

A Federal Bureau of Mines facility was planned near Hibbing, Minn., for pilot plant studies.

The Broken Hill Proprietary Co. Ltd. announced a new research laboratory to be built at Shortland, Australia, for studying iron ore agglomeration problems.

Plans were being made for iron ore transfer facilities and a pelletizing plant at a North Sea port location. The venture was to be built by a number of European steelmakers as a cooperative undertaking.[26] Use of large ore carriers and possible direct reduction were mentioned.

A number of iron mining operations replaced their low-capacity iron ore trucks with improved 65- to 110-ton haulage units. A remote-control loader for underground mining operations was introduced, allowing the operator to work at distances up to 60 feet from the equipment. Use of rigid foam in iron mines was described and cost savings over conventional sealing systems noted. Canadian methods used to dewater open-pit iron mines were described.[27]

Drilling and blasting methods introduced from Canada and used in mining itabirite

[23] Chemical Engineering. V. 72, No. 15, July 19, 1965, p. 78.

[24] Engineering and Mining Journal. V. 166, No. 9, September 1965, p. 202.

[25] Kays, M. Allan. Petrographic and Modal Relations, Sanford Hill Titaniferous Magnetite Deposit. Econ. Geol., v. 60, No. 6, September–October 1965, pp. 1261–1297.

[26] Puhlmann, P. Cooperative Transfer Point and Pellet Plant Project Planned by European Iron Smelters. Steel and Iron (German), v. 85, No. 22, Nov. 4, 1965, pp. 1361–1371.

[27] Stubbins, J. B., and P. Minro. Open-Pit Mine Dewatering—Knob Lake. Canadian Min. and Met. Bull. (Montreal), v. 58, No. 640, August 1965, pp. 814–822.

on the Bong Range in Liberia were discussed.[28]

A comparison of jet and rotary-drill methods was made on field results in Canada over a period of time.[29] The development of blasting procedures was discussed also. Cratering by different explosive-rock combinations in open-pit iron ore mining was discussed by the same author.[30]

Details of the mining and beneficiation facilities of United States Steel's Atlantic City operations [31] and the Sunrise beneficiation plant of The Colorado Fuel and Iron Corp.[32] were published.

The use of a mobile concentrator in recovering a magnetite concentrate from low-grade alluvial iron deposits in Utah was described.[33] The deposits averaged about 10 percent iron.

Research on methods of beneficiating the oxidized semitaconites continued in this country. Test results of the pilot plant operations at Duluth, Minn., conducted by Cleveland-Cliffs and using the natural-gas reduction process of Northern Natural Gas Co. and W. S. Moore Company, were reported to be exceeding expectations. Some of the beneficiation studies on the semitaconites at the University of Minnesota were reviewed in an article by the director of the Mines Experiment Station.[34] Research on upgrading the low-grade Mesabi range ores was in progress all year at the Mines Experiment Station of the University of Minnesota. A paper by one staff member discussed an investigation involving soap flotation of activated silica from iron ores.[35] Another staff member presented a resume of iron ore flotation methods and future possibilities in this field of beneficiation.[36] Processing taconite via routes involving 22 variations of the conventional flow scheme was discussed in an article by the supervisor of ore research for Jones & Laughlin Steel Corp.[37] Process modifications for changes in ore, or for economic reasons, were covered.

The use of lignite as a fuel and reductant for the reduction roasting of taconites was described as successful in a study made at the University of North Dakota.[38]

A patent was issued for a method of treating laterites containing metal impurities by a double roast-leach process to obtain a high-iron residue.[39]

The reduction of iron ores by means of a plasma torch method was reported in a patent from East Germany.[40]

In France progress in beneficiating some of the Lorraine ores was discussed in an article.[41] Two new installations were proposed for treating both siliceous and calcareous ores. Dry grinding methods were incorporated in the circuits for economy.

A Japanese method for magnetic separation of iron sand was reported. The method involved a traveling rubber belt containing magnetized ferrite to collect the magnetic material, use of water spray to remove extraneous material, and final demagnetization of the ferrite to recover the concentrated product.

Pellets produced in a pilot plant and a commercial plant were evaluated in blast furnace tests by the Yawata Iron and Steel Co. Ltd. Tokyo, Japan. Satisfactory results were obtained under some conditions using as high as 80 percent pellet ratios

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[28] Leng, L. C. Mining Itabirite on the Bong Range in Liberia. Canadian Min. J. (Quebec), v. 86, No. 11, November 1965, pp. 75–80.

[29] Bauer, A., N. H. Carr, P. Calder, and G. R. Harris. Drilling and Blasting at Smallwood Mine. Trans. Soc. Min. Eng., v. 235, No. 1, March 1965, pp. 39–45

[30] Bauer, Alan, G R. Harris, L. Land, P. Prezioso, and D. J. Selleck. How IOC Puts Crater Research to Work. Eng. and Min. J., v. 166, No. 9, September 1965, pp. 117–121.

[31] Engineering and Mining Journal. U.S. Steel's Atlantic City Ore Mine First Taconite Producer in the West. V. 166, No. 3, March 1965, pp. 73–91.

[32] Zahn, Gary. New Iron Ore Beneficiation Plant in Wyoming. Min. Cong. J., v. 51, No. 3, March 1965, pp. 26–29.

[33] Mining Congress Journal. Concentrating Iron Ore in a Mobile Plant. V. 51, No. 10, October 1965, pp. 28–33.

[34] Lawver, J. E., R. R. Beebe, and R. M. Hays. New Methods for Beneficiating Semitaconites. Min. Cong. J., v. 51, No. 4, April 1965, pp. 69–74.

[35] Iwasaki, I., and R. W. Lai. Starches and Starch Products as Depressants in Soap Flotation of Activated Silica From Iron Ores. Trans. Soc. Min. Eng., v. 232, No. 4, December 1965, pp. 364–371.

[36] Beebe, R. R. New Directions in Iron Ore Flotation. Skillings' Min. Rev., v. 54, No. 23, June 6, 1965, Front Cover, pp. 6–7, 15.

[37] Young, Earle F., Jr. Iron Ore Processing: 22 Variations. Eng. and Min. J., v. 166, No. 6, June 6, 1965, pp. 166–172.

[38] Gleason, D S., and D. E. Severson. Lignite Gasification for Reduction Roasting of Taconites. J. Metal, v. 17, No. 4, April 1965, pp. 338–339.

[39] Yawata Iron and Steel Co., Ltd. Separation of Nonferrous Metals From Lateritic Iron Ores. British Pat. 996,472, June 30, 1965.

[40] Tischendorf, H. J. Reduction of Iron Ores in the Liquid State With a Plasma Torch. East German Pat. 33,152, Dec. 5, 1964.

[41] Bullet, Alain. Progress Being Made in Beneficiating Very Refractory Iron Ores of France's Lorraine Basin. World Min., v. 18, No. 6, June 1965, pp. 27–29.

in the burden.[42] The tests included studies on swelling of pellets in blast furnace applications. A sintering process to give an arsenic-free fluxed iron ore sinter was patented.[43]

The fluid-bed reduction process for iron pyrites in operation at the plant of Montecatini Soc. Generale per l'Industria Mineraria e Chimica Folloncia, Italy, was described.[44] The plant produced pellets containing 66 to 67 percent iron at a rate of 1,100 metric tons per day.

Staff members of the Institut de Recherches de la Sidérurgie (IRSID), Maizières-les-Metz, France, operated a 3-stage fluid-bed magnetic roasting pilot plant using Lorraine ore. Announcement was made of a 10-ton-per-hour semicommercial unit using the IRSID process at the Bazailles mine in Lorraine district. This plant was sponsored by the French Mining Association, the French Government, and La Haute Autorité de la Communauté Europeenne du Charbon et de l'Acier.[45]

A research project using hot-briquetted iron ore as part of blast furnace charges continued at the Margam plant of the Steel Company of Wales Ltd. Test results were reported to indicate better bed porosity than for comparable use of pellets and also higher furnace capacity due to higher density of the briquet bed.

A large number of papers were published on pellet preparation and use, reflecting the increasing interest in this type of furnace feed. Theoretical considerations in pelletizing operations were discussed in one article.[46] Another reviewed the formation of pellets, and variables encountered that affect operations.[47] Some results of tests using pellets and other types of ore in blast furnace burdens demonstrated the advantages of pellets.[48]

An instrument for fast determination of percentage of magnetic iron present in processing operations such as pelletizing was described.[49] The principal of saturation magnetization was used, and samples were reported to require only 1 minute for analysis. The use of automated controls in pellet production facilities was described in three articles.[50]

Direct reduction of iron ore continued to make news. Installations in this country thus far have been relatively small units. However, an increasing number of commercial operations are gaining a foothold in other countries where more favorable economic factors are encountered.

The Glidden Co. planned to build a commercial H-iron powder plant at Hammond, Ind. The process, under license from Hydrocarbon Research, Inc., was scheduled for operation in 1966.

Esso Research and Engineering Co. reported moving a step nearer large-scale commercial operations with their fluidized hydrocarbons process. An experimental 300-ton-per-day plant was operated in Canada during the year by the Imperial Oil Enterprises of Canada, an affiliate of Standard Oil Co. of New Jersey. The Venezuela Minister of Mines and Hydrocarbons announced that a plant involving this type of process is under consideration for Venezuela.[51] Natural gas from the eastern oilfields would be piped to the Guayana area to supply the reductant for the operation.

Armco Steel Corp. had under development at its Kansas City plant a method for prereducing iron ore pellets. Natural gas was used in a direct-reduction process to give furnace feed containing in excess

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[42] Kodama, Koretaka. On Swelling of Marcona Pellets During Chemical Reaction. Yawata Tech. Rept. 251 (Japan), June 1965, pp. 157–167.

[43] Schwarz, Arthur M. Sintering Process (assigned to Inland Steel Co., Chicago, Ill., a corporation of Delaware). U.S. Pat. 3,166,403, Jan. 19, 1965.

[44] Guccione, Eugene. Fluidization Turns Pyrites into High-Grade Iron Ore. Chem. Eng., v. 72, No. 10, May 10, 1965, pp. 142–144.

[45] Boucraut, M. M., and Imre Toth. IRSID Process of Fluid-Bed Magnetic Roasting. Preprint 29c, 56th National Meeting, San Francisco, Calif., May 16–19, 1965, A.I.Ch.E.

[46] Ruusi, John H. A Review of Theoretical Considerations That Influence Balling Iron Ore Concentrates. Skillings' Min. Rev., v. 54, No. 15, Apr. 10, 1965, Front Cover, pp. 6, 19.

[47] Lyons, John S. How To Pelletize. Rock Products, v. 68, October 1965, pp. 92–94.

[48] Haley, Kenneth R. Pellets Preferred. Blast Furnace & Steel Plant, v. 53, No. 5, May 1965, pp. 303–397.

Smedstam, J. A. Pellets for the Blast Furnace. Steel Times (London), v. 191, No. 5073, Oct. 8, 1965, pp. 465–467.

[49] Mining World. SATMAGAN: And Analyzer for Magnetic Materials. V. 18, No. 11, October 1965, p. 43.

[50] English, Alan, and M. J. Greaves. Automation of a Modern Straight-Grate Pelletizing Plant. Min. Eng., v. 17, No. 7, July 1965, pp. 157–161.

Geist, E. W., and John R. Riede. Automatic Control Systems. Mines Mag., v. 55, No. 2, February 1965, pp. 8–12.

Mining and Minerals Engineering (London). Pelletising Plant Control. V. 1, No. 8, April 1965, pp. 303–305.

[51] Iron and Steel Engineering. V. 42, No. 12, December 1965, pp. 243–244.

of 90 percent iron. Houston was tentatively selected for plant-scale steelmaking operation using the process if tests continued to prove successful.

Stora Kopparbergs Bergslags A.B. announced a new commercial direct-reduction plant in operation at its Domnarvet works in Sweden. Capacity was expected to be 50,000 tons per year of molten iron. Of significant interest is the claim that the method produces hot metal of 0.02 percent phosphorus content from ore containing 1.0 percent phosphorus.[52]

Head Wrightson & Co. Ltd. was licensed to sell and manufacture the Stora-Dored direct-reduction plants for iron ore.[53] The R–N process and the SL process, controlled by the R–N Corp., and The Steel Co. of Canada Ltd., respectively, were combined by agreement. Lurgi of Frankfurt (Main), West Germany, was licensed to market the joint reduction process to be known as the SL/RN process. The Purofer process of direct-reduction of iron ore as developed by test work at the German plant of Hüttenwerk Oberhausen A.G. was described by a member of the firm. A 25-ton-per-day pilot plant was operated using reformed natural gas.[54] The Echeverria iron-ore reduction process operating to produce sponge iron in Spain was reviewed and costs presented for large installations.[55]

Installation was underway in Vera Cruz, Mexico, of a third HyL direct-reduction plant. The 500-ton-per-day unit was to be operated by Tubos de Acero de Mexico, S.A. (TAMSA). The other two units operated by Fierro Esponja S.A., an affiliate of Hojalata y Lamina S.A., in Monterrey, Mexico, have been using reformed natural gas for reduction. Fierro Esponja S.A. was reported to have an expansion of its sponge iron production facilities underway that would bring the daily capacity to about 1,200 tons.

The Michigan Technical Institute of Mineral Research was studying a direct-reduction process for upgrading some of the Upper Michigan ores.

A patent for reducing iron oxides was granted using hydrocarbon injection in a fluid bed.[56]

Bureau of Mines Research. — Field examinations of western iron ore deposits were completed by Bureau engineers, and reports for several Western States were in the process of preparation. The studies have indicated the existence of large low-grade iron ore resources with potential development possibilities.

Cooperative work completed to evaluate brown iron ore resources in selective areas of Alabama and Georgia were published in two reports.[57] Inferred crude ore in four Alabama counties was calculated at 827.7 million tons, with reserves of 12.7 million tons indicated by drilling.

The Minneapolis Metallurgy Research Center continued studies involving flotation, grinding and magnetic reduction, and prereduced pellets. Basic research applicable to the processing of iron ore also was under study. Metallurgists at the station described a method developed in anionic flotation studies of nonmagnetic taconite, to establish a response index by calcium ion measurement.[58]

Iron ore beneficiation research at the Tuscaloosa Metallurgy Research Center was limited mainly to studies of phosphorus removal from brown ores, and gaseous reduction of low-grade iron ores by fluid-bed and entrained-solids methods.

Petrographic studies of samples from the Cuyana iron formation in Minnesota completed under the Bureau of Mines Fellowship program were published.[59] A report was published on evaluation of ore composites from the central Mesabi range. Satisfactory concentrates were produced by

[52] Metal Bulletin (London). No. 5060, Dec. 31, 1965, pp. 17–18.

[53] Mining Journal (London). Iron Ore Reduction. V. 265, No. 6783, Aug. 20, 1965, p. 135.

[54] Pantke, Heinz-Dieter. Iron Ore Reduction by the Purofer Process. J. Metal, v. 17, No. 1, January 1965, pp. 40–44.

[55] Mining and Materials Engineering (London). V. 1, No. 15, November 1965, p. 569.

[56] Mayer, Francis Xavier, and Ivan Mayer (assigned to Esso Research and Engineering Co., a corporation of Delaware). Process for Reducing Iron Oxides. U.S. Pat. 3,205,065, September 1965.

[57] O'Neill, James F. Brown Iron Ore Resources: Barbour, Butler, Crenshaw, and Pike Counties, Ala. BuMines Inf. Circ. 8261, 1965, 59 pp.

———. Brown Iron Ore Resources: Quitman County, Ga. BuMines Inf. Circ. 8264, 1965, 29 pp.

[58] Colombo, A. F., R. T. Sorenson, and D. W. Frommer. Calcium Ion Measurements Provide Insights to Anionic Flotation of Silica. Trans. Soc. Min. Eng., v. 232, No. 2, June 1965, pp. 100–109.

[59] Blake, R. L. Iron Phyllosilicates of the Cuyana District in Minnesota. Amer. Mineral., v. 50, Nos. 1 and 2, January–February 1965, pp. 148–169.

reductive roasting and magnetic separation in most instances.[60]

Thermal decomposition data were obtained for siderite using several methods of analysis, and rate data reported.[61] Reduction studies of magnetite and wustite were made and equilibrium constants determined.[62]

Magnetic roasting of nonmagnetic iron ore using scrap iron to effect reduction was shown to be technically feasible. The process was described as a substantial market for scrap iron if accepted commercially.[63]

The Bureau's experimental blast furnace at Bruceton, Pa., continued to operate, and entered its fourth test year as a cooperative research project with an association of steel producers. Smelting tests with prereduced burdens resulted in both coke savings and increased production.

Tests in the blast furnace using fluxed and unfluxed pellets were described.[64]

[60] Heising, L. F., and D. W. Frommer. Lake Superior Iron Resources: Preliminary Sampling and Metallurgical Evaluation of Central Mesabi Nonmagnetic Taconites. BuMines Rept. of Inv. 6650, 1965, 28 pp.

[61] Powell, H. E. Termal Decompositions of Siderite and Consequential Reactions. BuMines Rept. of Inv. 6643, 1965, 44 pp.

[62] Khalafalla, S. E., C. W. Schultz, and T. N. Rushton. Adsorption Phenomena and the Reduction of Iron Oxides. BuMines Rept. of Inv. 6699, 1965, 18 pp.

[63] Melcher, N. B. Reduction Roasting of Iron Ore—A New Potential Scrap Market. Secondary Raw Materials, v. 3, No. 4, April 1965, pp. 65–68.

[64] Woolf, P. L., F. J. Pearce, W. M. Mahan, and J. A. Basso Blast Furnace Operations with Very Low Slag Rates. BuMines Rept. of Inv. 6678, 1965, 14 pp.

Iron and Steel

By Robert A. Whitman[1]

Contents

Records in shipments of steel mill products, in steel ingot production, and in output and shipments of pig iron were established in 1965. More than 92 million tons of steel mill products was shipped by the steel industry, or 70 percent of the 131 million tons of steel ingots produced.

Steel production in basic oxygen converters increased 48 percent, and shipments of merchant pig iron gained 6 percent over those of 1964. Consumption of over 81 million tons of pig iron in steelmaking furnaces constituted about 54 percent of the total metallics charged to steel furnaces.

The threat of a strike kept the steel industry producing at near capacity for the first 8 months of 1965. Excess inventory accumulated in anticipation of a strike, had been sufficiently reduced by December so that production was increasing. The annual production and shipment totals reflect a real increase in demand over that of 1964.

[1] Commodity specialist, Division of Minerals.

Table 1.—Salient iron and steel statistics

(Thousand short tons)

	1956–60 (average)	1961	1962	1963	1964	1965
United States:						
Pig iron:						
Production	67,460	64,853	65,638	71,840	85,458	88,207
Shipments	67,155	65,307	65,727	72,211	85,693	88,391
Imports for consumption	359	377	500	645	736	880
Exports	275	416	154	70	176	28
Steel:[1]						
Production of ingots and castings (all grades):						
Carbon	92,537	89,338	89,160	98,714	114,442	116,651
Stainless	1,067	1,137	1,085	1,204	1,443	1,493
All other alloy	7,579	7,539	8,083	9,343	11,191	13,318
Total	101,183	98,014	98,328	109,261	127,076	131,462
Index (1956–60) = 100	100.0	96.9	97.2	108.0	125.6	130.0
Total shipments of steel mill products	72,717	66,126	70,552	75,555	84,945	92,666
Exports of major iron and steel products	3,822	2,221	2,266	2,670	r 4,065	2,888
Imports of major iron and steel products[2]	2,556	3,308	4,297	5,637	r 6,630	10,691
World production:						
Pig iron[3]	240,907	282,596	292,525	310,363	351,034	370,065
Steel ingots and castings	330,310	387,560	397,000	426,570	482,570	507,540

r Revised.
[1] American Iron and Steel Institute.
[2] Data not comparable for all years.
[3] Includes ferroalloys.

The steel industry paid over $5.5 billion in wages and salaries in 1965. The net billing value of products shipped was over $17.7 billion compared with the $16.2 million in 1964.

Trends and Developments.—Steel companies reactivated obsolete equipment in order to keep up with the demand. This equipment was inefficient and costly to operate, with low productivity. After the successful labor negotiations the rapid decline in orders led to a corresponding cutback in production. Reactivated equipment was the first to be eliminated, then nonprofitable marginal equipment was the next to be closed.

The steel industry spent over $1.8 billion, both for modernization such as new basic oxygen converters, continuous casting, vacuum degassing, and related control equipment and for new plants. The industry announced plans for new plants in the Midwest and dedicated one at Burns Harbor, Ind.

Table 2.—Pig iron produced and shipped in the United States, by States

(Thousand short tons and thousand dollars)

State	Produced		Shipped from furnaces			
	1964	1965	1964		1965	
	Quantity		Quantity	Value	Quantity	Value
Alabama	4,321	4,296	4,353	$234,346	4,346	$234,944
Illinois	5,671	6,293	5,579	322,098	6,407	361,819
Indiana	11,511	11,081	11,483	658,162	11,071	621,604
Ohio	15,163	15,298	15,355	925,078	15,251	905,459
Pennsylvania	20,986	21,847	21,005	1,207,869	21,898	1,235,522
California, Colorado, Utah	4,726	4,886	4,739	276,743	4,886	285,115
Kentucky, Maryland, Texas, West Virginia	10,582	10,899	10,641	636,785	10,930	629,268
Michigan and Minnesota	7,387	7,537	7,405	409,657	7,511	416,248
New York	5,111	6,070	5,133	320,568	6,091	349,031
Total	85,458	88,207	85,693	4,991,306	88,391	5,039,010

PRODUCTION AND SHIPMENTS OF PIG IRON

There were 85 blast furnaces out of production at the end of 1965, reflecting the lack of orders during the fall months after the labor agreement. There were three fewer blast furnaces on January 1, 1966, and the average production per blast furnace day was 1,434 tons, according to the American Iron and Steel Institute (AISI). Production of pig iron was up 3 percent for a new record. Pennsylvania, Ohio, and Indiana produced 55 percent of the pig iron.

Metalliferous Materials Consumed in Blast Furnaces.—Nearly 1 million tons less domestic ore, 1.6 million tons more foreign ore, and over 3.6 million tons more agglomerates were used in 1965 to produce 2.75 million tons more pig iron than in 1964. The total of metalliferous materials decreased 22 pounds per ton of pig iron produced. The amount of fluxes used per ton of pig iron produced again increased, this year by 16 pounds.

The quantity of sinter and self-fluxing sinter declined to 40 million tons and 13.4 million tons respectively. There were 28.1 million tons of pellets, 1.8 million tons of unclassified agglomerates, 6.4 million tons of foreign agglomerates, and 38,000 tons of nodules used in blast furnaces.

Blast furnace consumption of oxygen increased 0.6 billion cubic feet to a total of 9.5 billion cubic feet. This was from a revised 1964 consumption figure of 8.9 billion cubic feet, according to AISI.

According to data collected by the Bureau of Mines, blast furnaces consumed 44.8 billion cubic feet of natural gas, an increase of 10 percent over that of 1964. There were 3.1 billion cubic feet of coke-oven gas used and 55.6 million gallons of oil, a 19-percent increase. In addition there were 20,369 tons of coal used in blast furnaces in 1965.

Table 3.—Foreign iron ore and manganiferous iron ore consumed in manufacturing pig iron in the United States, by source of ore

(Short tons)

Source	1964	1965 [1]
Brazil	188,745	450,487
Canada	4,658,880	5,821,137
Chile	1,169,654	1,474,125
Peru	354,326	648,896
Venezuela	5,779,531	5,382,452
Other countries	1,148,522	1,107,989
Total	13,299,658	14,885,086

[1] Excludes 25,271,802 tons used in making agglomerates.

Table 4.—Pig iron shipped from blast furnaces in the United States, by grades[1]

(Thousand short tons and thousand dollars)

Grade	1964 Quantity	1964 Value Total	1964 Value Average per ton	1965 Quantity	1965 Value Total	1965 Value Average per ton
Foundry	1,761	$95,984	$54.51	1,664	91,106	$54.75
Basic	78,003	4,546,819	58.29	79,979	4,554,584	56.95
Bessemer	2,789	165,308	59.27	2,703	153,798	56.90
Low-phosphorus	325	19,436	59.80	749	45,595	60.87
Malleable	2,523	146,810	58.19	2,940	173,425	58.99
All other (not ferroalloys)	292	16,949	58.04	356	20,502	57.59
Total	85,693	4,991,306	58.25	88,391	5,039,010	57.01

[1] Includes pig iron transferred directly to steel furnaces at same site.

Table 5.—Number of blast furnaces (including ferroalloy blast furnaces) in the United States, by States

State	January 1, 1965 In blast	January 1, 1965 Out of blast	January 1, 1965 Total	January 1, 1966 In blast	January 1, 1966 Out of blast	January 1, 1966 Total
Alabama	16	3	19	9	10	19
California	4	---	4	4	---	4
Colorado	3	1	4	4	---	4
Illinois	16	6	22	12	10	22
Indiana	21	2	23	21	2	23
Kentucky	2	1	3	2	1	3
Maryland	10	---	10	7	3	10
Michigan	9	---	9	9	---	9
Minnesota	2	---	2	1	1	2
New York	12	3	15	11	4	15
Ohio	36	13	49	26	23	49
Pennsylvania	50	13	63	37	23	60
Tennessee	---	3	3	---	3	3
Texas	2	---	2	2	---	2
Utah	3	2	5	2	3	5
Virginia	1	1	2	1	1	2
West Virginia	4	---	4	3	1	4
Total	191	48	239	151	85	236

Source: American Iron and Steel Institute.

PRODUCTION AND SHIPMENTS OF STEEL

The high rate of increase in oxygen steelmaking continued in 1965. Over 17 percent of a record 131.5 million-ton steel output was made in the converters. Open hearth production decreased to 72 percent and electric furnaces accounted for just over 10 percent. The Great Lakes steelmaking belt of Pennsylvania with 24 percent; Ohio, 17 percent; Indiana, 13 percent; Illinois, 9 percent; and Michigan, 7 percent again accounted for 70 percent of crude ingot production.

Steel shipments were over 92 million tons in 1965. There was very little change in market percentages.

Alloy Steel.[2]—There was a 19-percent increase in alloy steel production in 1965 to 13.3 million tons. Stainless steel production increased a little over 3 percent to 1.5 million tons. These figures include 67,000 tons of alloy steel and 1,500 tons of stain-

[2] The Bureau of Mines uses the American Iron and Steel Institute specifications for alloy steels, which include stainless and any other steel containing one or more of the following elements in the designated percentages: Manganese in excess of 1.65 percent, silicon in excess of 0.60 percent, and copper in excess of 0.60 percent. The specifications also include steel containing the following elements in any quantity specified or known to have been added to obtain a desired alloying effect: Aluminum, boron, chromium, cobalt, columbium, molybdenum, nickel, titanium, tungsten, vanadium, zirconium, and other alloying elements.

Stainless steel includes all grades of steel that contain 10 percent or more of chromium with or without other alloys or a minium combined content of 18 percent of chromium with other alloys. Valve or bearing steels, high-temperature alloys, or electrical grades with analyses meeting the definition for stainless steels are included. All tool-steel grades are excluded.

Heat-resisting steel includes all steel containing 4 percent or more but less than 10 percent of chromium (excluding tool-steel grades).

Table 6.—Iron ore and other metallic materials, coke and fluxes consumed and pig iron produced in the United States, by States

(Short tons)

Year and State	Metalliferous materials consumed: Iron and manganiferous ores: Domestic	Metalliferous materials consumed: Iron and manganiferous ores: Foreign	Metalliferous materials consumed: Agglomerates	Metalliferous materials consumed: Net ores and agglomerates [1]	Metalliferous materials consumed: Net scrap [2]	Metalliferous materials consumed: Miscellaneous [3]	Metalliferous materials consumed: Net total	Net coke	Fluxes	Pig iron produced	Metalliferous materials consumed per ton of pig iron made: Net ores and agglomerates [1]	Metalliferous materials consumed per ton of pig iron made: Net scrap [2]	Metalliferous materials consumed per ton of pig iron made: Miscellaneous [3]	Metalliferous materials consumed per ton of pig iron made: Total	Coke and fluxes consumed per ton of pig iron: Net coke	Coke and fluxes consumed per ton of pig iron: Fluxes
1964:																
Alabama	2,484,443	1,548,083	3,594,910	7,422,462	111,397	55,286	7,589,145	3,649,460	1,079,896	4,320,973	1.718	0.026	0.013	1.756	0.845	0.250
Illinois	4,236,471	(4)	5,220,224	9,022,912	345,039	514,480	9,882,431	3,983,486	1,258,201	5,671,009	1.591	.061	.091	1.743	.702	.222
Indiana	6,555,950	1,156,253	11,523,887	18,205,533	207,269	1,488,275	19,901,077	7,339,461	1,638,002	11,511,028	1.582	.018	.129	1.729	.638	.142
Ohio	6,159,946	1,753,649	14,673,231	21,713,499	1,320,517	1,704,666	24,738,682	9,977,842	3,654,148	15,163,176	1.432	.087	.112	1.632	.658	.241
Pennsylvania	7,857,245	4,048,268	19,781,888	30,825,959	1,059,531	2,423,251	34,308,741	13,455,012	3,585,231	20,986,345	1.469	.050	.115	1.635	.641	.171
California, Colorado, Utah	W	W	4,636,842	8,009,805	991,490	149,258	9,150,553	2,755,970	811,013	4,726,261	1.695	.210	.032	1.936	.583	.172
Kentucky, Maryland, Tennessee, Texas, West Virginia	1,962,501	3,897,716	11,184,176	16,413,990	278,158	1,019,137	17,711,285	6,796,548	1,511,766	10,581,928	1.551	.026	.096	1.674	.642	.143
Michigan and Minnesota	W	W	9,653,049	11,576,902	183,691	348,503	12,109,096	4,573,939	1,479,034	7,386,353	1.567	.025	.047	1.639	.619	.200
New York	1,464,287	645,529	5,897,949	7,767,468	133,326	464,018	8,364,812	3,250,092	1,334,387	5,111,326	1.520	.026	.091	1.636	.636	.261
Total	36,218,021	13,299,658	86,166,156	130,958,530	4,630,418	8,166,874	143,755,822	55,781,720	[4]16,351,678	85,458,399	1.532	.054	.096	1.682	.653	.191

1965:																
Alabama	2,115,483	1,791,493	3,461,985	7,153,044	137,954	46,346	7,337,344	3,664,482	1,122,968	4,296,226	1.665	0.032	0.011	1.708	0.853	0.261
Illinois	4,497,663	W	5,875,992	9,967,880	459,250	693,497	11,120,627	4,463,283	1,381,357	6,292,875	1.584	.073	.110	1.767	.709	.220
Indiana	5,711,891	1,666,213	11,199,282	17,860,400	150,206	1,089,546	19,100,152	6,763,985	1,500,324	11,081,335	1.612	.014	.098	1.724	.610	.135
Ohio	5,817,988	1,652,661	15,154,025	21,726,721	1,390,696	1,733,758	24,851,175	9,688,599	3,890,954	15,298,402	1.420	.091	.113	1.624	.633	.254
Pennsylvania	7,765,836	5,015,439	20,484,822	32,276,885	1,034,579	2,087,893	35,399,357	14,869,045	3,923,875	21,846,537	1.477	.047	.096	1.620	.681	.180
California, Colorado, Utah	W	------	4,843,540	8,353,969	928,568	179,383	9,461,920	2,925,131	896,812	4,885,494	1.710	.190	.037	1.937	.599	.183
Maryland, West Virginia, Kentucky, Texas	W	3,644,590	12,106,987	17,261,548	204,524	962,189	18,428,261	6,919,127	1,643,082	10,898,750	1.584	.019	.088	1.691	.635	.151
Michigan, Minnesota	W	W	10,341,189	11,482,138	174,351	178,815	11,835,304	4,523,336	1,520,731	7,536,531	1.523	.023	.024	1.570	.600	.202
New York	2,325,208	937,629	6,343,750	9,246,939	218,126	363,764	9,828,829	3,937,979	1,641,613	6,070,404	1.523	.036	.060	1.619	.649	.270
Total	35,273,683	14,885,086	89,811,572	135,329,524	4,698,254	7,335,191	147,362,969	57,754,967	[5]17,520,716	88,206,554	1.534	.054	.083	1.671	.655	.199

W Withheld to avoid disclosing individual company confidential data; included with "Total".

[1] Net ores and agglomerates equal ores plus agglomerates plus flue dust used minus flue dust recovered.

[2] Excludes home scrap produced at blast furnaces.

[3] Does not include recycled material.

[4] Fluxes consisted of 10,743,800 tons of limestone and 5,607,878 tons of dolomite, excluding 4,876,636 tons of limestone and 1,820,229 tons of dolomite used in agglomerate production at or near steel plants and an unknown quantity used in making agglomerates at mines.

[5] Fluxes consisted of 11,130,961 tons of limestone, 5,748,892 tons of dolomite, and 640,863 tons of other fluxes, excluding 4,593,166 tons of limestone, 2,189,606 tons of dolomite, and 261,689 tons of other fluxes used in agglomerate production at or near steel plants and an unknown quantity used in making agglomerates at mines.

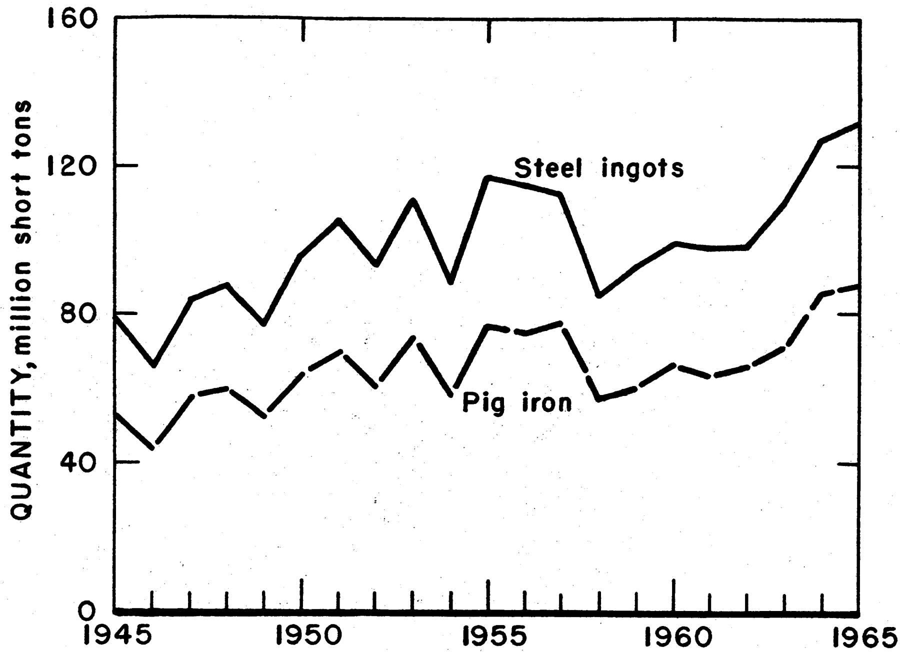

Figure 1.—Trends in production of pig iron and steel ingots in the United States.

less steel for castings. Alloy and stainless together comprise 11 percent of the total ingot production.

Series 400 stainless production increased 9 percent to 335,000 tons and topped the production of 1961. Production of Series 500 and all other high-chromium heat-resisting steels increased nearly 50 percent, but austenitic stainless (Series 200 and 300) steel production dropped slightly.

Basic oxygen converter steelmaking doubled its share of alloy and stainless steel production to 7.4 percent. Open hearth furnaces produced 56.2 percent and electric furnaces 36.4 percent.

Materials Used in Steelmaking.—Pig iron was a little over 54 percent of the 149.3 million tons of metallics charged into steelmaking furnaces in 1965. According to AISI, steelmaking furnaces consumed 345,304 tons of fluorspar, 5,181,467 tons of limestone, 2,912,633 tons of lime, and 619,698 tons of other fluxes. Oxygen converters used 41 percent of the 104.4 billion cubic feet of oxygen used in steelmaking furnaces. Open hearth furnaces used 56 percent and electric furnaces used nearly 3 percent.

Table 7.—Steel production in the United States, by type of furnace [1]

(Thousand short tons)

Year	Open hearth		Bessemer	Basic oxygen process	Electric	Total
	Basic	Acid				
1956–60 (average)	89,177	506	1,934	1,530	8,036	101,183
1961	84,108	394	881	3,967	8,664	98,014
1962	82,578	379	805	5,553	9,013	98,328
1963	88,437	397	963	8,544	10,920	109,261
1964	97,655	443	858	15,442	12,678	127,076
1965	93,866	327	586	22,879	13,804	131,462

[1] Includes only that steel for castings produced in foundries operated by companies manufacturing steel ingots. Omits about 2 percent of total steel production.

Source: American Iron and Steel Institute.

CONSUMPTION OF PIG IRON

Consumption of pig iron increased only 3 percent while domestic steel production increased nearly 3.5 percent. The South Atlantic was the only district in which consumption of pig iron decreased. Plants in the Middle Atlantic and East North Central districts consumed nearly 77 percent of the total production.

Table 8.—Metalliferous materials consumed in steel furnaces in the United States

(Thousand short tons)

Year	Iron ore		Agglomerates [1]	Pig iron	Ferroalloys [2]	Iron and steel scrap
	Domestic	Foreign				
1956–60 (average)	2,317	5,313	1,321	60,259	1,410	52,600
1961	1,913	5,277	855	59,418	1,367	49,455
1962	1,875	4,768	644	60,561	1,408	49,606
1963	1,783	3,995	885	66,188	1,557	56,506
1964	2,114	4,816	1,379	78,925	1,819	64,348
1965	1,818	4,400	[3] 1,061	81,040	1,898	68,272

[1] Includes consumption of pig iron and scrap by ingot producers and iron and steel foundries.
[2] Includes ferromanganese, spiegeleisen, silicomanganese, manganese briquets, manganese metal, ferrosilicon, ferrochromium alloys, and ferromolybdenum.
[3] Includes 567,285 tons of sinter, 385,759 tons of pellets, 99,506 tons of nodules, and 8,199 tons of other agglomerates. (418,452 tons of foreign origin.)

Table 9.—Consumption of pig iron in the United States, by type of furnace

Type of furnace or equipment	1964		1965	
	Thousand short tons	Percent of total	Thousand short tons	Percent of total
Open hearth	65,206	75.5	61,483	69.1
Bessemer	949	1.1	652	.7
Oxygen converter	12,446	14.4	18,518	20.8
Electric [1]	325	.4	387	.5
Cupola	3,704	4.3	3,757	4.2
Air	170	.2	173	.2
Direct castings	3,582	4.1	3,975	4.5
Total	86,382	100.0	88,945	100.0

[1] Includes a small quantity of pig iron consumed in crucible furnaces.

PRICES

In 1965, the weekly wholesale price index for finished steel products stayed at 102.9 for the first quarter. It was 103, through April, rising to 103.2 through May and remaining through June. In July it rose to 103.5 where it remained through August and September. In October it rose to 103.7 and in November to 104 remaining there through December. The base of 100 is the 1957-59 average price.[3] The average value of pig iron is recorded in table 11.

FOREIGN TRADE

The total value of major iron and steel products imported into the United States exceeded the value of those exported by 40 percent. The buildup of excess inventory as a hedge against a steel strike combined with a domestic business slowdown in the European Coal and Steel Community, the United Kingdom, and Japan were the principal factors in this major change in the foreign trade situation from 1964.

[3] U.S. Department of Labor, Bureau of Labor Statistics.

Table 10.—Consumption of pig iron in the United States, by districts and States

(Short tons)

District and State	1964	1965
New England:		
Connecticut	32,833	32,631
Maine and New Hampshire	1,999	2,550
Massachusetts	57,586	58,191
Rhode Island	42,408	41,034
Vermont	6,178	6,607
Total	141,004	141,013
Middle Atlantic:		
New Jersey	112,089	62,603
New York	4,606,010	5,453,068
Pennsylvania	21,373,302	22,074,877
Total	26,091,401	27,590,548
East North Central:		
Illinois	5,858,222	6,598,061
Indiana	11,367,746	10,994,983
Michigan	7,462,185	7,822,953
Ohio	15,092,990	14,936,271
Wisconsin	192,249	199,680
Total	39,973,392	40,551,948
West North Central:		
Iowa	88,128	77,016
Kansas and Nebraska	5,854	5,728
Minnesota	524,912	558,905
Missouri	39,687	41,823
Total	658,581	683,472
South Atlantic:		
Delaware and Maryland	5,691,698	5,428,115
Florida and Georgia	13,535	14,739
North Carolina	33,246	35,427
South Carolina	16,683	16,567
Virginia and West Virginia	2,375,911	2,354,691
Total	8,131,073	7,849,539
East South Central:		
Alabama	3,737,824	3,773,738
Kentucky, Mississippi, Tennessee	1,495,872	1,904,895
Total	5,233,696	5,678,633
West South Central:		
Arkansas, Louisiana, Oklahoma	12,144	12,487
Texas	1,332,816	1,386,743
Total	1,344,960	1,399,230
Rocky Mountain:		
Arizona and Nevada	---------	---------
Colorado, Idaho, Montana, Utah	2,510,068	2,657,102
Total	2,510,068	2,657,102
Pacific Coast:		
California and Hawaii	2,250,640	2,318,820
Oregon and Washington	46,884	74,427
Total	2,297,524	2,393,247
Grand total	86,381,699	88,944,732

WORLD REVIEW

The United States increased production of pig iron by 3 million tons to lead the world. The U.S.S.R. with a 7-percent increase in production became the second country to produce 100 million tons of ingot steel. The United States led in crude steel production with 131.5 million tons in 1965.

Table 11.—Average value of pig iron at blast furnaces in the United States, by States
(Per short ton)

State	1956–60 (average)	1961	1962	1963	1964	1965
Alabama	$54.33	$56.62	$57.46	$55.66	$53.83	$54.06
California, Colorado, Utah	57.01	50.50	51.59	50.31	58.40	58.35
Illinois	58.54	60.42	59.10	57.52	57.74	56.48
Indiana	57.49	58.96	57.34	56.15	57.32	56.15
New York	60.86	60.05	59.13	67.40	62.45	57.30
Ohio	56.72	60.78	59.89	57.78	60.24	59.37
Pennsylvania	58.73	59.48	58.93	59.34	57.50	56.42
Other States [1]	58.52	57.44	57.66	60.26	57.99	56.70
Average	57.98	58.51	58.15	58.47	58.25	57.01

[1] Comprises Kentucky, Maryland, Michigan, Minnesota, Tennessee, Texas, West Virginia, and Massachusetts (1956–60).

Table 12.—Free-on-board value of steel mill products in the United States, in 1964 [1]
(Cents per pound)

Product	Carbon	Alloy	Stainless	Average
Ingots	3.281	12.222	24.584	5.178
Semifinished shapes and forms	5.512	10.511	39.407	6.387
Plates	6.727	9.789	51.756	7.527
Sheets and strips	7.084	14.932	43.897	7.887
Tin mill products	9.136	------	------	9.136
Structural shapes and piling	6.507	(2)	------	6.507
Bars	7.357	13.198	62.378	8.869
Rails and railway-track material	8.288	------	------	8.288
Pipes and tubes	10.188	15.857	123.245	11.411
Wire and wire products	12.822	41.596	86.663	14.061
Other rolled and drawn products	(3)	22.869	57.818	26.316
Average total steel	7.654	13.234	52.826	8.506

[1] This table represents the weighted average value based on the quantity of each type of steel shipped; therefore, it reflects shifts in the distribution of the 3 classes of steel.
[2] Included with "plates."
[3] Included with rails and railway-track material.

Table 13.—U.S. exports of major iron and steel products

Products	1964		1965	
	Short tons	Value	Short tons	Value
Semimanufactures:				
Steel ingots, blooms, billets, slabs, and sheet bars	r 856,454	r $65,460,537	682,134	$52,505,152
Iron and steel bars and rods:				
Carbon-steel bars, hot-rolled, and iron bars	71,119	12,114,341	77,312	14,191,593
Concrete reinforcement bars	60,580	7,828,539	34,555	4,351,744
Other steel bars	42,831	17,221,341	58,247	22,476,144
Wire rods	33,939	5,717,371	19,191	3,144,749
Iron and steel plates, sheets, skelp, and strips:				
Plates, including boilerplate, not fabricated	176,613	35,199,150	161,653	38,342,997
Skelp iron and steel	29,574	3,283,888	44,134	8,024,865
Iron and steel sheets, galvanized	169,006	34,361,158	156,745	32,388,260
Steel sheets, black, ungalvanized	r 858,728	r 164,864,558	335,134	81,056,774
Strip, hoop, band, and scroll iron and steel:				
Cold-rolled	r 54,857	r 25,643,611	49,443	23,520,014
Hot-rolled	68,050	12,944,542	40,693	32,391,910
Tinplate and terneplate	351,642	52,709,046	262,485	37,391,073
Tinplate circles, cobbles, strip, and scroll shear butts	27,542	3,136,681	13,845	1,426,542
Total	r 2,800,935	r 440,484,763	1,935,571	351,211,817

See footnotes at end of table.

Table 13.—U.S. exports of major iron and steel products—Continued

Products	1964 Short tons	1964 Value	1965 Short tons	1965 Value
Manufactures-steel mill products:				
Structural iron and steel:				
Water, gas, and other storage tanks (unlined), complete and knockdown material	15,023	$7,527,697	12,986	$8,901,887
Structural shapes:				
Not fabricated	236,115	36,840,374	228,714	34,260,958
Fabricated	89,914	32,551,537	91,022	37,553,638
Plates and sheets, fabricated, punched, or shaped	11,815	3,727,697	13,653	5,825,901
Metal lath	1,016	407,126	---	---
Frames, sashes, and sheet piling	14,387	2,730,908	7,857	3,468,345
Railway-track material:				
Rails for railways	45,536	5,859,758	36,950	5,448,793
Rail joints, splice bars, fishplates, and tieplates	10,079	2,639,019	32,060	7,837,212
Switches, frogs, and crossings	1,578	1,057,159	9,884	14,729,821
Railroad spikes	756	191,720	896	221,158
Railroad bolts, nuts, washers, and nut locks	727	401,671	16,978	18,028,367
Tubular products:				
Boiler tubes	13,865	8,792,275	8,962	6,290,047
Casing and line pipe	125,486	34,766,192	121,183	41,412,462
Seamless black and galvanized pipe and tubes, except casing, line and boiler, and other pipes and tubes	358,708	129,353,673	39,876	11,080,572
Welded black pipe	13,800	3,745,308	12,190	3,906,913
Welded galvanized pipe	15,029	3,450,149	3,890	1,085,128
Malleable-iron screwed pipe fittings	1,471	1,384,949	1,245	1,166,989
Cast-iron pressure pipe and fittings	32,153	5,764,250	40,808	8,025,759
Cast-iron soil pipe and fittings	6,623	1,607,468	15,329	9,230,023
Iron and steel pipe, fittings, and tubing, n.e.c.	67,333	49,962,115	95,209	73,712,044
Wire and manufactures:				
Barbed wire	592	144,400	1,332	342,716
Galvanized wire	20,290	8,364,891	14,660	6,130,830
Iron and steel wire, uncoated	24,573	10,095,935	16,623	7,938,431
Spring wire	1,760	1,000,337	9,249	4,472,799
Wire rope and strand	10,549	6,306,286	12,796	9,432,300
Woven-wire screen cloth	1,701	[1] 2,629,557	2,746	[1] 4,460,781
All other	18,455	12,150,240	18,143	15,990,736
Nails and bolts, iron and steel, n.e.c.:				
Wire nails, tacks, staples, and spikes	[r] 5,218	[r] 5,001,342	7,179	5,697,373
Bolts, screws, nuts, rivets, and washers, n.e.c.	21,636	26,589,950	13,121	12,238,826
Castings, and forgings: Iron and steel including car wheels, tires, and axles	98,239	35,504,895	67,123	38,487,721
Total	1,264,427	440,548,878	952,664	397,378,530
Advanced manufactures:				
Building (prefabricated and knockdown)	---	7,668,546	---	6,658,982
Chains and parts	13,732	13,454,945	11,721	15,433,929
Construction material	12,461	7,288,026	10,970	4,207,307
Hardware and parts	---	27,354,061	---	21,849,037
House-heating boilers and radiators	---	7,259,766	---	18,311,665
Oil burners and parts	---	10,296,030	---	13,930,278
Plumbing fixtures and fittings	---	6,076,797	---	5,484,653
Tools	---	66,788,075	---	58,953,745
Utensils and parts (cooking, kitchen, and hospital)	---	2,989,943	---	7,413,708
Other	---	57,202,018	---	49,566,929
Total	---	206,378,207	---	201,810,233
Grand total	---	[r] 1,087,411,848	---	950,400,580

[r] Revised.
[1] Includes wire cloth as follows: 1964, $2,035,676 (3,707,046 square feet); 1965, $3,558,661 (14,353,618 square feet).

Table 14.—U.S. imports for consumption of pig iron, by countries
(Short tons)

Country	1956–60 (average)	1961	1962	1963	1964	1965
North America: Canada	285,021	349,403	386,296	387,449	395,202	485,089
South America: Brazil	3,924	---	---	---	67,895	73,537
Europe:						
Belgium-Luxembourg	882	---	---	---	---	221
Finland	2,051	---	681	12,123	73,004	66,422
Germany:						
East	---	---	---	---	57,182	82,289
West	17,232	719	56,341	87,435	51,412	64,220
Italy	---	---	---	---	---	68
Netherlands	1,448	---	---	---	---	---
Norway	168	---	3,584	3,319	101	666
Portugal	879	---	---	---	1,051	---
Spain	21,583	19,113	42,416	45,161	11,683	42,085
Sweden	1,824	1,201	1,416	10,146	9,969	11,203
U.S.S.R.	569	396	---	---	---	34,188
United Kingdom	10	---	94	8	---	6,595
Total	46,646	21,429	104,532	158,192	204,402	307,957
Africa:						
Zambia, Southern Rhodesia and Malawi	1,051	---	---	---	---	---
South Africa, Republic of	15,638	4,096	5,030	76,696	68,620	12,867
Total	16,689	4,096	5,030	76,696	68,620	12,867
Asia:						
India	1,427	---	---	---	---	---
Japan	2,135	---	---	---	---	---
Total	3,562	---	---	---	---	---
Oceania: Australia	2,612	2,252	4,216	22,997	352	801
Grand total:						
Short tons	358,454	377,180	500,074	645,334	736,471	880,251
Value	$19,448,155	$20,511,391	$24,684,220	$28,936,920	$31,591,381	$38,022,760

NORTH AMERICA

Canada.—Dominion Foundries and Steel Ltd. (DOFASCO), who started the first basic oxygen steelmaking in North America in 1954, completed its 10 millionth ton 11 years later.

Algoma Steel Corp. Ltd., ordered two continuous casting machines. One machine is a 4-strand unit producing blooms ranging from 9 to 15 inches wide by 10½ inches thick. The second machine is a 2-strand unit capable of casting beam blanks, as well as slabs up to 6 by 30 inches.

The Steel Co. of Canada Ltd. (Stelco), started up a new 148-inch plate mill. Also, during 1965 Stelco put into operation its new hydrochloric acid pickle line, which is 700 feet long and 74 inches wide.

DOSCO Steel Ltd., a subsidiary of Dominion Steel and Coal Corp. Ltd., planned to construct two steel rolling mills at Contrecoeur, Quebec.

Manitoba Rolling Mills, a division of Dominion Bridge Co. Ltd., ordered two twin-strand, curved mold, continuous casting units. These units will take steel from two 14-foot-diameter electric furnaces.

Atlas Steels Co. Ltd. installed a continuous casting machine at its Tracy, Quebec, plant capable of casting approximately 60 tons of steel in 40 minutes. The machine was being used for stainless steel.

The integrated steel complex to be built at Becancour, Quebec, will be engineered and constructed by two firms of Montreal consulting engineers, together with two other engineering firms, one from France, and one from Canada. The steel firm will be known as Siderurgien d'Quebec (SIDBEC).

Mexico.—Out of 360 industries which were deemed necessary for Mexico's development, open for private or foreign capital investment and eligible for tax exemptions or reductions, there were 18 in the iron and steel sector.

Table 15.—U.S. imports for consumption of major iron and steel products

Products	1964 Short tons	1964 Value	1965 Short tons	1965 Value
Iron products:				
Bar iron, iron slabs, bloom, or other forms	248	$71,221	262	$81,202
Pipes and fittings:				
Cast-iron pipe and fittings	34,655	3,859,069	28,749	3,079,210
Malleable cast-iron pipe fittings	2,884	1,124,632	3,846	1,539,515
Castings and forgings	8,268	6,187,207	12,181	10,312,652
Total	46,055	11,242,129	45,038	15,012,579
Steel products:				
Steel bars:				
Concrete reinforcement bars	411,997	32,132,687	567,545	43,985,640
Solid and hollow, n.e.s	367,869	40,485,012	554,859	61,933,143
Hollow and hollow drill steel	4,757	1,988,406	5,803	2,298,514
Wire rods, nail rods, and flat rods up to 6 inches in width	952,767	88,455,563	1,283,636	123,525,772
Steel ingots, blooms, and slabs; billets, solid and hollow	344,760	36,526,720	282,621	35,267,115
Circular saw plates	(1)	819,951	(1)	876,704
Sheets and plates and steel, n.s.p.f.	1,596,137	r 181,620,109	4,257,282	450,989,793
Tinplate, terneplate, and taggers' tin	80,693	13,754,201	121,941	20,807,444
Structural iron and steel	1,062,864	101,000,875	1,484,537	144,850,891
Rails for railways	10,843	1,044,333	19,851	1,888,706
Rail braces, bars, fishplates, or splice bars and tieplates	828	85,717	967	119,812
Steel pipes and tubes	787,111	114,464,632	950,891	139,371,184
Wire:				
Barbed	72,433	9,191,390	74,855	10,119,393
Round wire, n.e.s.	r 379,997	r 65,981,165	488,485	87,951,341
Telegraph, telephone, etc., except copper, covered with cotton jute, etc	r 937	r 618,700	603	301,761
Flat wire and iron and steel strips	14,238	5,962,758	15,910	7,169,117
Rope and strand	r 51,557	r 14,870,822	64,607	18,059,576
Galvanized fencing wire and wire fencing	42,790	6,003,340	41,129	6,114,766
Iron and steel used in card clothing	(2)	160,559	(2)	171,019
Hoop and band iron and steel, for baling	30,479	4,019,129	32,906	4,408,620
Hoop, band and strips, or scroll iron or steel, n.s.p.f.	44,119	16,257,407	52,707	18,132,351
Nails	310,437	44,643,750	329,174	51,176,620
Steel castings and forgings	16,038	4,075,042	15,568	3,383,102
Total	r 6,583,651	r 784,166,268	10,645,877	1,232,902,384
Advanced manufactures:				
Bolts, nuts, and rivets	74,624	22,744,338	106,106	34,451,073
Chains and parts	12,408	8,179,704	16,101	10,099,806
Hinges and hinge blanks	---	2,353,359	---	2,836,009
Screws (wholly or chiefly of iron or steel)	---	9,306,665	---	13,310,953
Tools	---	r 28,714,759	---	20,425,112
Other	---	r 1,150,150	---	1,478,374
Total	---	r 72,448,975	---	82,601,327
Grand total	---	r 867,857,372	---	1,330,516,290

r Revised.
1 Saws, reported in number; 1964, 190,840; 1965, 162,869.
2 Weight not recorded.

Fabricacion de Maquinas-SA (FAMA) switched from a cupola melting system to two induction electric furnaces, one a 7-ton furnace and a 100-kilowatt power source for two 500-pound furnaces. Tubos de Acero de Mexico (TAMSA) obtained authorization to establish a 500-ton sponge iron plant at Vera Cruz.

SOUTH AMERICA

Argentina.—Dalmine Siderca was authorized to increase the production capacity of its plant for special steels to 300,000 tons a year. Output of seamless steel tubes was expected to increase to 190,000 tons a year.

A new plant of Lametal Unión, a sheet steel producer, was formally opened in the Federal capital in April.

The Argentine Government formally approved by Executive Decree 1106 on February 1965, the 1.5-million-ton integrated steel mill project of Propulsora Siderúrgica. The plant is to be erected in Ensenada, near Buenos Aires. Financing for the project has not yet been obtained.

Table 16.—World production of pig iron (including ferroalloys) by countries[1]
(Thousand short tons)

Country[1]	1961	1962	1963	1964	1965 p[2]
North America:					
Canada	5,064	r 5,415	6,059	6,707	7,246
Mexico (sponge iron)	864	912	947	1,068	1,090
United States	66,717	67,636	73,853	87,922	91,016
Total	72,645	r 73,963	80,859	95,697	99,352
South America:					
Argentina	437	438	467	r 634	730
Brazil	2,050	2,337	r 2,772	r 2,938	2,756
Chile	314	3 440	3 480	482	340
Colombia	208	164	224	243	254
Peru	56	43	36	30	33
Venezuela	6	136	333	357	352
Total	r 3,071	r 3,558	r 4,312	r 4,684	4,465
Europe:					
Austria	2,500	2,339	2,326	2,434	2,429
Belgium	7,104	7,439	7,622	9,327	9,307
Bulgaria	227	246	292	1,026	762
Czechoslovakia	5,529	5,767	5,847	6,361	6,743
Denmark	73	76	76	77	79
Finland	168	r 365	413	r 704	1,085
France	16,372	15,716	16,010	r 17,699	17,653
Germany:					
East	2,239	2,287	2,370	2,491	2,557
West	28,033	26,732	25,253	29,963	29,751
Hungary	1,455	1,543	1,544	r 1,653	1,746
Italy	3,528	4,054	4,264	3,996	6,304
Luxembourg	4,226	3,965	3,954	4,620	4,569
Netherlands	1,606	1,732	1,884	2,147	2,606
Norway	834	798	r 826	976	1,190
Poland	5,258	5,854	5,947	6,220	6,349
Portugal	134	r 243	265	r 295	303
Rumania	1,211	1,666	1,881	2,121	2,226
Spain	2,340	2,374	2,187	r 2,172	2,678
Sweden	2,094	2,164	r 2,232	r 2,563	2,713
Switzerland	e 60	e 60	49	35	30
U.S.S.R.[4]	56,100	60,919	64,697	r 68,759	73,017
United Kingdom	16,517	15,335	16,342	19,347	19,555
Yugoslavia	1,161	1,216	1,168	r 1,184	1,295
Total[4]	158,769	r 162,890	r 167,449	r 186,170	194,947
Africa:					
Rhodesia, Southern	243	266	r 260	r 351	276
South Africa, Republic of	2,566	2,663	r 2,676	r 3,182	3,972
United Arab Republic (Egypt)	192	r 194	r 226	r 212	e 190
Total	3,001	r 3,123	r 3,162	r 3,745	4,438
Asia:					
China, mainland e	16,500	16,500	18,700	19,800	20,900
India	5,621	6,522	7,431	7,432	7,868
Japan	18,059	20,325	22,525	r 26,951	31,041
Korea:					
North	1,047	1,365	1,305	1,510	e 1,800
South	10	2	6	r 7	20
Taiwan	58	69	60	68	79
Thailand	6	6	7	6	6
Turkey[5]	260	323	434	e 440	419
Total[4]	41,561	45,112	50,468	r 56,214	62,133
Oceania: Australia	3,549	3,879	4,113	r 4,524	4,730
World total e	r 282,596	r 292,525	r 310,363	r 351,034	370,065

e Estimate. p Preliminary. r Revised.

1 Pig iron is also produced in Republic of the Congo, but quantity produced is believed insufficient to affect estimate of world total.

2 Compiled mostly from data available July 1966.

3 Including ferroalloys.

4 U.S.S.R. in Asia included with U.S.S.R. in Europe.

5 Includes foundry iron.

Table 17.—World production of steel ingots and castings by countries

(Thousand short tons)

Country	1961	1962	1963	1964	1965 p 1
North America:					
Canada	6,488	7,173	8,190	9,131	10,029
Mexico	1,882	1,896	r 2,247	r 2,593	2,743
United States 2	98,014	98,328	109,261	127,076	131,462
Total	106,384	107,397	r 119,698	r 138,800	144,234
South America:					
Argentina	486	725	1,006	1,394	1,486
Brazil	2,756	2,875	r 3,145	r 3,392	e 3,340
Chile	r 431	r 582	r 574	r 644	515
Colombia	212	173	245	r 254	266
Peru	83	r 78	r 84	r 90	103
Uruguay	10	10	8	15	14
Venezuela	83	248	401	485	1,196
Total	r 4,061	r 4,691	r 5,463	r 6,274	6,920
Europe:					
Austria	3,418	3,274	3,249	3,521	3,553
Belgium	7,728	8,115	8,298	9,624	10,106
Bulgaria	375	466	508	522	648
Czechoslovakia	7,764	8,421	8,375	9,234	9,789
Denmark	356	405	396	r 437	402
Finland	305	r 335	r 340	391	371
France	19,211	18,857	19,214	r 21,501	21,610
Germany:					
East	r 4,303	r 4,508	r 4,511	r 4,841	4,883
West	36,881	35,895	34,830	41,159	40,588
Greece	e 150	e 170	230	r 231	231
Hungary	2,263	2,572	2,617	2,606	2,778
Ireland	31	21	22	22	22
Italy	10,283	10,755	11,196	10,795	13,978
Luxembourg	4,534	4,420	4,445	5,025	5,054
Netherlands	2,173	2,301	2,582	2,924	3,468
Norway	550	538	599	678	756
Poland	7,974	8,470	8,823	9,449	10,018
Portugal	101	184	235	265	292
Rumania	2,344	2,702	2,981	3,350	3,775
Spain	2,579	2,547	2,747	r 3,472	4,134
Sweden	3,926	r 3,980	r 4,300	r 4,899	5,208
Switzerland	327	351	r 355	380	380
U.S.S.R. 3	77,994	84,113	88,403	r 93,738	100,310
United Kingdom	24,737	22,950	25,222	28,918	30,246
Yugoslavia	1,689	1,758	1,750	1,849	1,950
Total 3	r 221,996	r 228,108	r 236,228	r 259,831	274,550
Africa:					
Rhodesia, Southern	101	r 97	r 93	r 141	e 120
South Africa, Republic of	2,738	2,903	3,124	3,414	3,743
United Arab Republic (Egypt)	174	209	217	r 202	e 180
Total	3,013	r 3,209	r 3,434	r 3,757	4,043
Asia:					
Burma e	12	14	17	17	17
China, mainland	10,500	11,000	13,200	e 15,400	e 16,500
India	4,502	r 5,611	r 6,581	r 6,649	6,962
Israel	68	88	r 91	e r 90	e 95
Japan	31,160	30,364	34,724	43,871	45,372
Korea:					
North	855	1,157	1,127	r 1,248	e 1,355
South	73	163	176	r 142	171
Taiwan	218	201	303	331	485
Thailand	9	8	r 3	r 4	8
Turkey	356	323	400	r 536	734
Total 3	r 47,753	r 48,929	r 56,622	r 68,288	71,699
Oceania: Australia	4,351	4,667	r 5,124	r 5,620	6,092
World total e	r 387,560	r 397,000	r 426,570	r 482,570	507,540

e Estimate. p Preliminary. r Revised.
1 Compiled mostly from data available July 1966.
2 Data from American Iron and Steel Institute. Excludes production of castings by companies that do not produce steel ingots.
3 U.S.S.R. in Asia included with U.S.S.R. in Europe.

Brazil.—The Inter-American Development Bank has granted Brazil a $200,000 loan for the partial financing of a survey toward the possible establishment of a steel mill at the Bay of Aaratü, in northeastern Brazil, by Usina Siderúrgica da Bahia, S.A. (USIBA) would set up a blast furnace to process iron ore, using natural gas as a fuel, and manufacture tinplate as well as hot- and cold-rolled thin steel plate. Total construction costs are budgeted at $52 million.

Aços Villares, S.A., a specialty steel producer, obtained assistance from the International Finance Corporation to finance an expansion program on its plant near São Paulo which will increase its ingot steel capacity 16 percent. The company's largest customer is the Brazilian automobile industry.

The Intendente Camara Steel plant with an initial output of 500,000 tons of steel was being built at Ipatinga in the State of Minas Gerais, Brazil.

Colombia.—Acerías Paz del Río, the Government-owned steel mill, supplied 80 percent of domestic steel consumption in 1964. Colombia produced about 400,000 tons of steel in 1965.

Ecuador.—A plant for rolling steel bars will be financed by $400,000 allocated by the Atlantic Community Development Group for Latin America (Adela).

Venezuela.—Siderúrgica del Orinoco accounted for about 49 percent of the 1.2 million tons of steel produced in the country in 1965. The company had reached a record production of 55,000 tons in January.

EUROPE

Austria.—Austria, the cradle of the LD basic oxygen furnace, used this method to produce about 60 percent of the 3.5 million tons of crude steel produced in 1965.

Three Austrian steel producing companies sold an $11 million order of finished steel to Stahl und Metall Handelsgesellschaft of East Germany.

VOEST Steel Manufacturing Company signed an agreement with Communist China to deliver a 700,000-ton Linz-Donawitz oxygen steel plant to China.

Bulgaria.—Bulgaria added a 100-ton electric arc furnace to the facilities of the Kremíkovtsi Iron and Steel Works near Sofia.

Czechoslovakia.—Czechoslovakia, which produced 9.75 million tons of steel in 1965, was rolling some of that steel from continuous casting machines. The first machine of 120,000-ton-annual-capacity was built about 5 years ago. Another one has been ordered by the United Steel Works in Kladno from Motala Verkstad in Sweden. It will probably be an Olsson low curved-mold continuous casting machine.

Czechoslovakia intended to control the entire production of its largest steel works, at Ostrava-Kuncice, by two English Electric computers, a LEO 360 and a KDF 7.

A foundry company near Opava ordered a complete Hallsworth automatic foundry plant. The heart of the system is a four-station rotary mold-making machine upon which the high productivity rate depends. With only one operator this machine can produce up to 240 complete mold boxes, ready for pouring, per hour.

European Coal and Steel Community (ECSC).—A merger of great significance to the world steel industry was that of the ECSC High Authority, the EEC, and Euratom. Thus control of the Community Steel industry passes to a European commission with broad authority, responsibility, and outlook.

Steel production in the common market totaled about 95 million ingot tons, or an increase over the 1964 output of about 4 percent. Output in Italy rose nearly 30 percent, while production in both France and West Germany declined about 1 percent each. Because of overproduction in the Common Market, new investment probably declined about $200 million for 1965.

Two steel companies merged when Bochumer Verein für Gussstahlfabrikation A.G. was absorbed by Fried. Krupp Huettenwerke. The largest steel manufacturer in Luxembourg, Aciéries Réunies de Burbach-Eich-Dudelange (ARBED) took steps to absorb the smaller Luxembourg concern, Hadir.

French and German interests plan to construct a 1-million-ton-per-year oxygen steel plant at Dilling in the Saar. ECSC loaned the French company Société Brentonne de Fonderies et de Mécanique $3.5 million to help set up a big iron and steel plant at Lorient-Hennebont, France. ECSC had $41 million to be loaned to steel and coal firms in Germany, Belgium, and Italy.

The High Authority decided late in the year to extend the application of the specific duty on foundry pig of $7 per ton and also the application of a 9 percent "ad valorem" custom duty on imports of steel products into the Community from nonmember countries through 1966.

Delivery of 100 tons of hot metal over a distance of 190 miles to the Chertal plant of S.A. Métallurgique d'Espérance-Longdoz was accomplished with a temperature drop of only 125° C over a 12-hour period. This follows the successful transporting of hot metal to the Chertal plant from a blast furnace only 14 miles away.

The year was one of uncertainties for the steel industry in Belgium as in all of the Common Market countries. While some Belgium steel companies cut the price of rolled steel strip by up to 6 percent at the end of the year a large producer announced that the decline in steel selling prices appeared to have been checked. Espérance-Longdoz announced a cutback in production while another large steel producer was increasing its output. Overall the steel production for 1965 was only about 400,000 tons above that of 1964.

French steel production was essentially the same in 1965 as in 1964. To stimulate growth the fifth economic plan for France announced a program of modernization and rationalization of the steel industry, which would need a substantial capital investment. The Société des Aciéries de Lorraine (SACILOR) was guaranteed State loans of about $53 million for the establishment of an oxygen steel plant and rolling mill at Gandrange, Moselle, in eastern France. Société des Aciéries de Pompey received nearly $7,300,000 in State-guaranteed loans for improvements and extensions to its plant.

Four West German firms were allowed by the ECSC High Authority to rationalize their output of merchant bars and sections through joint steel rolling programs. All orders will be booked together and the production runs will be distributed amongst the four firms allowing longer runs of any certain type for each company.

Two 60-ton Kaldo furnaces were being built in Essen, Germany, for the new steel works under construction by Sanyo Special Steel Co. Ltd., of Japan. During refining the vessels are to be rotated at rates up to 40 rpm. Their combined annual capacity is 330,000 tons.

Bessemer steelmaking was losing out in West Germany as well as in the United States. A basic Bessemer plant at the Hörde Works was closed down by Dortmund-Hörder-Hüttenunion, AG. The Bessemer plant produced over 30 million tons in its 85 years of operation. Several West German firms cut back operations toward the end of the year.

The newest steelmaking plant in the ECSC was the all-new oxygen plant dedicated in the spring of 1965 at Taranto. Designed for an eventual output of 7 million tons of ingots per year it had two 330-ton oxygen converters in 1965. A new electric furnace melt shop near Milan, Italy, was designed around two 30 Mva 140-ton arc furnaces. This plant was run entirely on scrap. There was a new steel tube production plant at Brescia, Italy. Its two vertical 1,600-ton extrusion presses were furnished by a German firm at Düsseldorf. Italsider established new LD steel works in Bagnoli, a suburb of Naples. The three LD converters had an annual capacity of 2 million tons of crude steel ingots.

A new plant at Follonica was designed to burn 700,000 tons of pyrites for sulfur used in the contact process of manufacturing sulfuric acid. The pyrites cinders are then reduced to an iron oxide of high purity by means of heavy naphtha on a fluidized bed followed by magnetic separation. From 2,200 tons of pyrites per day the plant produces 2,200 tons of sulfuric acid, and 1,000 tons of iron oxide pellets. (66 percent Fe).

The Netherlands increased steel production about 500,000 tons in 1965, and Koninklijke Nederlandsche Hoogovens en Staalfabrieken N.V., the principal producer, was embarking on a $280 million expansion project, which will include a 2.5-million-ton-per-year oxygen steel plant.

N.V. Nederlandsche Kabelfabrieken at Delft put in an electric furnace to considerably increase its steel capacity. It was planned to raise the company's finished products capacity to 500,000 tons a year.

Finland.—A 200-ton-per-day oxygen plant. was ordered from Air Products Ltd., in England, by Rautaruukki Oy, at Raahe. The plant will furnish oxygen for two 50-ton LD converters to be installed. The hot metal comes from a blast furnace commissioned in October 1964 which produces about 550,000 tons of pig iron per year.

Greece.—Several agreements for export of pig iron have been signed. A total of about $4 million worth of pig iron will be exported from the blast furnace at Eleusis. This will materially increase Greece's foreign exchange earnings.

Contracts were let for the establishment of a steel rolling mill at Thessalonika. Also plans were announced to establish a cold-rolling plant at Salonica.

Hungary.—A cold-rolling mill was commissioned in July for the Danube Steel Works at Danaújváros. This was the major investment so far in the integrated steel plant and was designed to eventually roll 256,000 tons a year.

Poland.—Poland announced plans to reconstruct its steel industry and to triple production by 1980. Its industry then was expected to produce 46 percent of output by open hearth, 41 percent by oxygen blown converters, and 13 percent in electric furnaces. This is similar to the production pattern envisioned for 1980 in the United States steel industry.

Sweden.—The Stora Kopparbergs Bergslags, AB installed two new 90-ton Kaldo oxygen converters to refine the output from a new Dored rotating ore-reduction system. Nyby Bruks Aktiebolag invested $3 million with Amsted Industries in pressure pouring equipment for stainless steel. The Oxelösund plant of Grängesberg Co. installed a new Martin furnace.

SKF Hellefors Jernverk steelworks has installed vacuum degassing with induction stirring of steel in the ladle. Sandvikens Jernverks AB has developed a stainless steel thread of .007 mm. diameter for the manufacture of fabrics.

Switzerland.—Concast AG. announced signing of contracts to deliver a four-strand continuous casting machine to the BHP Newcastle works and another four-strand machine to Vereeniging, Republic of South Africa. Both machines will cast about 300,000 tons of steel annually.

United Kingdom.—The Wolsingham Steel Company Ltd., commissioned a new 25-ton 7,500 Kva electric arc furnace. The Stocksbridge works of Samuel Fox & Co. Ltd., awarded $7.7 million in contracts as a start in a modernization project which will replace 5 open-hearth furnaces with two 135-ton electric arc furnaces. Tube Investments, Ltd., announced a 100,000-ton-per-year seamless tube-making mill. It will be the largest tube-mill in England with a complete range of tubes between 1 and 5 inches in diameter up to 300 feet long. It will have the first multi-stand 3-roll stretch reducing facility in England.

Air pollution became a more serious problem. Steel, Peech & Tozer spent over $2 million on electrostatic precipitators for the Spear project and The Steel Company of Wales Ltd., was installing several more of the gas cleaners at its Abbey works.

British Railways was using unit trains to deliver steel directly from the various producing areas to consumers in Birmingham and the West Midlands.

A combustible mixture of gasoline, diesel oil, and air was the power source for a high-energy-rate-forming process developed by the Department of Mechanical Engineering, University of Birmingham.

The first Ruhrstahl Heraeus steel degassing plant in England was installed at the Bilston Works of Stewarts and Lloyds Ltd. The $560,000 plant will treat 100 to 120 tons of both carbon and low-alloy steels per batch.

U.S.S.R.—As a result of the Seven-Year Plan ending in 1965, 18 new blast furnaces have been installed in the U.S.S.R., with a capacity of over 20 million tons of pig iron or hot metal. Nearly 80 percent of the 72 million tons of iron produced was smelted with natural gas although only 67 percent of the blast furnaces use natural gas. Forty-three percent of the blast furnaces use oxygen. During the Seven-Year Plan 51 new open-hearth furnaces with capacity of over 21 million tons were built. Some open-hearths were reported in the 500- to 600-ton capacity, and six were of 900-ton capacity.

During this period six basic oxygen converters, rated at 100 tons per heat, were blown in. These could account for all the 4.8 million tons of oxygen-produced steel reported in 1965. The U.S.S.R. produced much less steel by the oxygen converter process than did Japan or the United States.

Steel plants in the U.S.S.R. reported 1.32 million tons of "workblanks" from continuous casting machines. Most of these were vertical machines. This is more than the reported capacity of commercial installations in the United States.

AFRICA

South Africa, Republic of.—South African Iron & Steel Industrial Corp. Ltd. (ISCOR), put on stream a 120-ton-per-hour tandem hearth furnace at the Vanderbijlpark works. ISCOR also built an additional blast furnace here with a 28-foot-diameter-hearth.

ASIA

Japan.—Yawata Iron and Steel Co., Ltd. (Yawata) planned to use a computer to simulate steel processing and capital equipment planning. Yawata has produced 100 million metric tons of steel ingots since 1901. Yawata with 28 percent of total steel output over the 64-year period, was Japan's largest producer. Yawata kindled a blast furnace at the Sakai works capable of producing 3,800 tons of pig iron daily. Furnace diameter is 32 feet and the height nearly 100 feet. Two 185-ton oxygen converters were blown in to complete the integration of the Sakai works.

The Kobe Steel Works Ltd., and the Amagasaki Iron and Steel Manufacturing Co. Ltd., merged under the Kobe name to become the fourth largest steel company in Japan.

The first unit of a new fully integrated steel mill on the Inland Sea, an 80-inch temper mill, was put into operation after tests runs by Nippon Kokan K.K. The Fukuyama Iron works is built entirely on a land fill, giving it an integral deep water port.

Fuji Iron & Steel Co. Ltd., blew in two 60-ton LD converters at the Kamaishi Works, giving it crude steel capacity in LD furnaces four times that in open-hearth.

A 600,000-ton billet mill was the first production unit at the Mizushima Works of the Kawasaki Steel Corp. This was the company's second integrated works and had a planned annual capacity of 13 million tons.

OCEANIA

Australia.—The Broken Hill Pty. Co. Ltd. (BHP), commissioned a 500,000-ton steel mill using two 100-ton oxygen converters. BHP also blew in a new blast furnace at Whyalla. The 26-foot-hearth furnace was rated to produce 1,700 tons of iron per day.

Australia was reported to have a per capita consumption of 830 pounds of steel, third highest in the world. Some Parliament members advocated establishment of a State-owned company to compete with BHP, which pours most of the steel in Australia.

TECHNOLOGY

The steel industry operated very nearly at capacity during the first half of 1965. It might have been possible to turn out 150 to 170 million tons of ingot steel by utilizing all equipment available, ancient and inefficient as well as modern and efficient. However, in terms of usable steel for today's market, there was not enough processing equipment for that tonnage.

Over $1,800 million was spent on capital improvements in 1965 by the steel industry.

Half of the papers at a 1965 sectional meeting of the National Open Hearth and Basic Oxygen Steel Committee dealt with new technology while the rest treated problems of the open hearth such as that of reducing costs or increasing productivity. Steel producers in areas with large natural

Table 18.—Comparison of operating data prior to and after using end-burner oxygen enrichment in open-hearth furnace

	Without oxygen enrichment (1957–58)	With oxygen enrichment (1963–64)	Improvement
Ingot steel, short tons per heat	229.60	225.10	------
Ingot steel, short tons per hour	21.90	28.50	6.60
Average time, tap to hot metal	4 hr. 3 min.	2 hr. 59 min.	1 hr. 4 min.
Average time, hot metal to tap	6 hr. 15 min.	4 hr. 54 min.	1 hr. 21 min.
Average time, tap to tap	10 hr. 18 min.	7 hr. 53 min.	2 hr. 25 min.
Hot metal, percent[1]	62.00	56.80	------
Million Btu per ingot ton	2.78	2.73	0.05
Cubic feet of oxygen per ton	------	675.60	------

[1] Averages based on AISI reports of all metallics.

Table 19.—Physical characteristics of an incremental degassing unit[1]

Vessel dimensions:
- Inside diameter: 9 feet, 3 inches.
- Inside height: 12 feet.
- Inside nozzle diameter: 2 feet, 6 inches.
- Inside nozzle height: 6 feet.

Vacuum system:
- 4-stage steam ejector.
- Lowest possible pressure: 75 micron.
- Capacity: 1,000 pounds of air per hour at 1 millimeter mercury.

Vessel movement speeds:
- Full speed: 34 feet per minute.
- ⅔ speed: 22 feet per minute.
- ⅓ speed: 11 feet per minute.

Alloying system:
- Three main bins of 105-cubic-foot capacity with 25-cubic-foot trimming bins equipped with vibratory feeders.
- Two main bins of 40-cubic-foot capacity with 10-cubic-foot trimming bins equipped with vibratory feeders.
- One 40-cubic-foot carbon bin equipped with a paddle-wheel feeder.

[1] Dortmund Hörder unit, Pittsburgh Works, Jones & Laughlin Steel Corp.

gas reserves were converting their openhearths to use more natural gas. Others were using oxygen, either by roof-lancing, or in end-burners. Improvement gained by using oxygen in end-burners is found in table 18.[4]

The Steel Co. of Canada Ltd. (Stelco), has experimented with using oxygen both in a single hearth furnace and with a dual hearth arrangement. Jones & Laughlin Steel Corp. installed a Dortmund Hörder (DH) incremental degassing unit in their No. 4 open-hearth shop. The unit was designed to treat a 400-ton heat in 25 minutes. (see table 19.) In this installation the vacuum chamber is raised and lowered over the ladle by its own mobile gantry. The company has made significant improvements in the quality of both fine-grained and semikilled steels with this process.[5]

Basic Oxygen Converters.—The steel industry produced 22.9 million tons of ingot steel in basic oxygen converters. This was nearly 90 percent of a capacity which was rated at only 25.9 million tons at the end of 1965. The United States and Japan together produced about 50 percent of the steel made by the basic oxygen process.

The two 150-ton converters of the Pittsburgh Steel Co. have made as much as 132,000 tons of steel in a month. The company obtained an average of 195 tons of steel from each vessel per heat.

Republic Steel Corp. began operation of the first of 3 new basic oxygen furnaces (BOF) at Warren, Ohio. These 150-ton furnaces are 22 feet in diameter and a little over 32 feet high. All gas emission from the furnace will pass through electrostatic precipitators. A digital computer calculates weight of charge materials before the heat and also calculates during the heat the amount of additives needed as determined by chemical analyses. Republic also has installed two 150-ton basic oxygen converters at Gadsden, Ala., which are monitored by a computer.

The Colorado Fuel and Iron Corp. has completed the replacement of one of its original converters with a 100-ton-per-heat vessel. These new converters have separate trunnion rings instead of integral trunnion rings which the original furnaces had.

The amount of steel made throughout the world now by the oxygen process, having increased from nothing in a little over 10 years, makes it clear that this method will dominate steelmaking within a few years. In the United States most of the installations were of the LD type, a nonrotating vessel fed oxygen through a watercooled lance. One company, Sharon Steel Corp., uses a Kaldo or rotating oxygenlanced vessel. In Western Europe, however, there were five methods in use, LD, LD-AC, Kaldo, Rotor, and the Ajax process. For a company with plenty of low-phosphorous hot metal, such as most of U.S. companies have, the LD type process would seem to be adequate; however, a need to use a

[4] Thompson, M. A. Results of Oxygen Enriched Firing in Open Hearths. J. Metals., v. 17, No. 6, June 1965, pp. 649–651.

[5] Parke, A. J., R. F. Kowal, and F. O. Altimore. DH Unit Operations in a Basic Open Hearth Shop. J. Metals, v. 17, No. 8, August 1965, pp. 897–901.

larger proportion of scrap would indicate the Ajax process or Kaldo converters. These two furnaces have longer charge to tap periods and need less automation for good control. However, the Kaldo, because of its rotation and contained heat, uses more refractories. If use can be found for waste heat the LD is the better converter. To make the best use of the refining speed of the LD converter, however, some system of dynamic control is needed with a computer which uses feed-back information throughout the heat.

The Bureau of Mines studied the use of an oxygen converter rotating on its vertical axis. Six or more oxygen jets, aimed at an angle wide of the vertical, may be used.

The principal problems connected with basic oxygen steelmaking fall into two categories, how to cope with the extreme heat generated by the oxygen and how to take advantage of the increased production that the speed of the steelmaking cycle makes possible. The higher heat of this new method has already required a different type of refractory lining brick to withstand the increased heat of the basic oxygen converter. The extremely high heat affects not only the basic oxygen vessel itself but also the trunnion ring by which the vessel is tilted for charging and for casting. A research program in which temperatures were continuously recorded in order to set up a typical thermal pattern of a furnace shell showed that the highest continuous temperatures occurred at the top, due to the proximity to hot gases and the reflected heat from the hood, and at the middle where the trunnion ring prevented the radiation of heat directly to the atmosphere. These are the areas most subject to distortion and to refractory wear. Ordinarily, temperatures at the bottom of the vessel are from 200° to 300° C below these other points and refractory wear is correspondingly less.[6]

The effects of lime properties in basic oxygen steelmaking were studied at August Thyssen-Hütte A.G. where it was determined that a soft burned lime was much superior to a hard lime and in fact lessened the consumption of fluorspar, caused much less frequent slopping, and generally had a good effect on the metallurgy of the heat.[7]

Consett Iron Co. Ltd., England's most northerly integrated steelworks, solved the problem of which equipment to install for oxygen steelmaking by installing two 120-ton Kaldos and two 120-ton LD vessels along with two 1,000-ton mixers. This dual system also required two different approaches to waste heat recovery. Waste heat boilers are provided for the BOF units and cooling hoods with no provision for waste heat recovery are used on the two Kaldo units.

Both the Ukrainian Institute of Metals and the Moscow Institute of Steel and Alloys report using exothermic ferroalloy briquets to eliminate the heat losses occurring when solid ferroalloys are used. There need no longer be a furnace for melting ferroalloys in the converter shop, and the ferromanganese consumption on the average was 17 percent lower than with liquid ferromanganese.

During the Annual Meeting of the American Society for Testing and Materials (ASTM) in June 1965, revisions to nine specifications were approved to allow the use of basic oxygen steel in boiler and pressure vessel plates.[8]

A self-propelled car for carrying a ladle full of molten iron to oxygen furnaces and for pouring the iron into such furnaces was designed and built by the Pennsylvania Engineering Corp., New Castle, Pa. Dominion Foundries and Steel Ltd., of Hamilton, Ontario, has ordered a unit as a major step toward complete automation of their steelmaking furnaces.

Rapidity of operation is foremost in all of basic oxygen steelmaking. Not only do the original methods of charging scrap and hot metal have to be speeded up but, with refining time measured in minutes, corrections to the heat in the form of additions of lime, fluorspar, or scrap must be made rapidly. One flux-charging system under

[6] Chamberlin, R. S., and P. R. Johnson. Thermal Considerations in Basic Oxygen Furnace Design. Iron and Steel Eng., v. 42, No. 6, June 1965, pp. 111–120.
Journal of Metals. Shell Replacement and/or Major Repairs to Basic Oxygen Furnaces—A Panel Discussion. V. 17, No. 8, August 1965, pp. 902–909.

[7] Behrens, K. F., J. Koenitzer, and T. Kootz. The Effects of Lime Properties on Basic Oxygen Steelmaking. J. Metals, v. 17, No. 7, July 1965, pp. 776–784.

[8] American Society for Testing and Materials. Comparison of the Properties of Basic Oxygen and Open Hearth Steels. ASTM Data Series, DS 30 (formerly STP 364), August 1965.

analog and digital computer control can calculate, prepare, and add a corrective flux charge in approximately 3 minutes.[9]

The Bureau of Mines was investigating the mechanics of fuming in oxygen steelmaking and the feasibility of preheating the oxygen to suppress fuming.

The high fuming rate of basic oxygen steelmaking necessitates use of air pollution control systems. The two most widely used in the United States are electrostatic precipitators and wet scrubber systems. However, a much less expensive cloth filter gas cleaning system has been developed in France. The key to this system is a method to cool the gases to allow treatment in a fabric filter. Some of the advantages claimed for this system are low cost of utilities, low and predictable maintenance costs, "clear stack operation" irrespective of weather conditions, and dry dust collection, which it is claimed, is more easy to handle than dust from spray-cooled systems.[10]

A fume hood system cooled with high-pressure water or steam functions as a heat recovery system and can save annually millions of dollars in the new oxygen steelmaking plants. United States Steel Corp. has installed such a hood at its Duquesne works.[11]

Automation.—Computers were slowly being adapted to iron and steelmaking. There were computer-controlled blast furnaces in the U.S.S.R., France, Japan, and the Netherlands. Engineers at Hoogovens in the Netherlands estimated that instrumentation costs of $100,000 were recovered in the first year of operation. In France the number of casts with the desired chemistry increased 50 percent after automation of the blast furnace. In the United States, however, sequencing and scheduling were the areas of greatest technologic progress.

There was more automation in oxygen steelmaking in Western Europe than in the United States. The Austrian steel industry developed the LD converter and Great Britain and the Common Market countries rapidly adopted oxygen steelmaking. Work has been done on automation on both LD furnaces and LD-AC furnaces. Probably the most advanced control was that of an oxygen-lime process (OLP) basic oxygen furnace operated on an experimental basis by IRSID at the Denain plant of USINOR. Through closed circuit operation the computer actually programs the operations for both phases of refining. When the operator has determined that the converter is ready for the first refining phase, he signals the computer to start. The calculations and decisions made by the computer are as follows: (1) initial positioning of the lance, (2) opening of the oxygen valve, (3) continuous calculation of the carbon content of the bath, (4) continuous calculation of the rate of decarburization, (5) regulation of the height of the lance above the bath as a function of the rate of decarburization, (6) charging of additives calculated on the basis of data from the preceding charge, (7) cessation of blowing (lifting of the lance and closing of the oxygen valve) when the calculated carbon content has reached a predetermined level.

There are several points of control on the various oxygen furnaces. Temperature and/or radiation intensity of the LD flame may be monitored by pyrometers. The ratio of oxygen, carbon dioxide, and carbon monoxide in the waste gas may be continually monitored. The formation of a foaming slag in the converter vessel may be detected by acoustical measurements. Thermocouples have been manufactured in the United States for almost instantaneous determination of the bath temperature. All of these measurements and their effect on the rate of refining must be put into the computer program so that proper control can result.

Control is further complicated by two inherent problems; variations in the rate and direction of the reactions of the vessel during the heat and from one heat to another, and the relative inaccessibility of the interior of the converter vessel during the oxygen blow. During the refining the first element to oxidize usually is silicon followed by manganese, then carbon. After the carbon removal any further oxygen reacts with the iron, reducing the yield and giving a high-iron slag. These reac-

[9] Weiss, Carl J., and Henry L. Te Selle. Flux Addition Control in Oxygen Steelmaking. Iron and Steel Eng., v. 42, No. 5, May 1965, pp 101–112.

[10] Finney, I. A., Jr., and Jean De Coster. A Cloth Filtered Gas Cleaning System for Oxygen Converters. Iron and Steel Eng., v. 42, No. 3 March 1965, pp. 133–140.

[11] Sefcik, A. J., D. E. Lyons, and W. O Williams. Development, Design, and Operation of a Controlled-Circulation Fume Hood for Basic Oxygen Furnaces. Iron and Steel Eng., v. 42 No. 7, July 1965, pp. 87–93.

tions are affected by oxygen pressure, lance position, jet area, bath level, and various other factors. To prepare to take a sample from or check the temperature of an openhearth is a matter of opening the door. In contrast, for the BOF, first the oxygen must be stopped, the dust collecting hood raised, and the vessel titled to the charging platform. All of which takes valuable time when refining time is measured in minutes rather than hours.

Vacuum Degassing.—Vacuum degassing units have been modified and many different systems developed. Although the three principal types are still ladle, stream, and incremental, the various components have been so modified and intermixed, each with its alphabetical designation, that it is almost impossible to keep up with the new developments. In incremental degassing such as the D-H or R-H systems small amounts of molten steel are forced into the vacuum chamber to be degassed and then returned to the ladle. Ladle degassing is distinguished from this in that the entire ladle is enclosed within the vacuum system and the contained molten metal is stirred by electrical induction currents. This induction stirring keeps renewing or changing the surface exposed to the vacuum to promote degassing.

Sweden's SKF Hellefors Jernverk uses induction-stirred ladle degassing. At Republic Steel Corp. it is called "Induction Stirred Ladle Vacuum Degassed" or ISLVD. The advantages claimed for this system are that it reduces total gas content to about one-half that of regular double-slag electric furnace steels. It produces significant improvements in micro-cleanliness as measured by oxide inclusion counts and it provides steels of improved mechanical properties, fatigue characteristics, and service life. Republic has deoxidized over 500,000 tons using the ISLVD system.

British Iron and Steel Research Association (BISRA) has a continuous vacuum degassing system of industrial size. The degassing vessel, 6 feet high and 6 feet in diameter, has an inlet and outlet pipe, both with tundishes raised and lowered by hydraulic rams. After the degassing vessel is evacuated to a pressure usually from 1.5 to 8 torr, and the intake tundish is filled, the seal is broken on the inlet pipe through which the molten steel is moved into the chamber, which it enters in an unrestricted spray. This metal collects and flows across a slanted floor. When enough metal has collected to preserve a vacuum on the outlet side, that tundish is lowered and about 1 ton of steel per minute flows through the degassing chamber in a continuous stream.[12]

Continuous Casting.—The average heat size of 8 continuous casting machines listed as working in 1965 was 30 tons, while the average heat size of 10 machines listed as under construction at the end of 1965 was 180 tons. The machines were listed as casting from one to eight strands with dimensions from 2 to 6 inches by 2 to 50 inches, and are either vertical, vertical with bender, or curved mold installations. The curved mold keeps the total height lower and should save on capital construction cost in building.

Continuous casting machines now installed have a total operating capacity of over 1 million tons. Four other plants were using development units for casting slabs. Installation of 12 more machines averaging 180 tons per heat, or six times the size of those now operating, will greatly increase the continuous casting capacity of this country in the next 2 years. Companies were beginning to increase the size of castings and to build molds to turn out oblong and round shapes. A British firm was rolling H-beams from "dog-bone" shaped blanks cast in Canada. Tube blanks were being continuously cast without an internal mandrel.

Another system of continuous casting which was introduced consisted of a revolving drum which, by turning through a bath of molten steel covered with a bath of molten fused salt, would first pick up a layer of fused salt then a layer of molten steel which would gradually solidify. Then as the layers emerged from the ladle the drum picks up another layer of fused salt. This method would seem to be more feasible for strip and slab steel.

Nearly half of the continuous casting machines operating at the end of 1965 were listed as developmental and they were about evenly divided between vertical and curved mold machines.

In addition to the oscillating mold casting machines, the Hazelett Belt Casting

[12] Steel Times (London). BISRA's Continuous Vacuum Degassing Process for Steel Now Operating Industrially. V. 190, No. 5055, June 4, 1965, pp. 801–803.

machine was being evaluated for the continuous casting of steel. This machine uses endless parallel metal belts moving under tension and cooled by a high-velocity stream of water.

Pressure pouring, which was originated to cast steel wheels for railroad cars, was slowly finding wider use as companies became aware of the savings. Savings result from improved percentage of cast metal from molten metal, lower grinding losses in surface dressing, and the elimination of heating and blooming operations. Companies could make up to 5,000 castings in graphite molds made with new, improved techniques. Larger molds were being constructed. One graphite block made to mold one side of a slab measured 2 by 6 by 26 feet. Individual castings of over 15,000 pounds became possible. Many different types of steel have been cast, and research increased the possibilities. Some companies planned to combine vacuum degassing and vacuum deoxidation with pressure casting.

National Steel Corp. purchased two controlled-circulation boilers which will be installed on their basic oxygen converters at the Weirton Steel Division. These boilers not only burn the waste combustible gases coming from the reaction in the converter but also use the contained heat of the gas by cooling it from about 1,300° F to around 900° F at which temperature it can be handled by gas-cleaning equipment.

Electric Furnaces.—Lukens Steel Co., installed a 150-ton electric furnace to supplement two 100-ton furnaces already in operation.

The Timken Roller Bearing Co. installed a top-charge 110-ton electric furnace equipped with induction stirring and a fume collector.

Continental Steel Corp. announced plans for two 140-ton electric furnaces.

BLH Standard Steel, a division of Baldwin-Lima-Hamilton Corp., fired a 45-ton electric furnace.

The sixth electric arc furnace in the worlds largest electric arc melting shop was commissioned by Steel, Peech and Tozer, bringing their steelmaking capacity to 1.35 million ingot tons per year.

A tapered shell and an internally water-cooled roof are innovations being tried on electric furnaces. Solid state components were used for electrode control. A replaceable shoe-type holder which reduced repair cost as well as power and electrode consumption was introduced.

Ultrahigh power, in the 80-Mva range, was tried by Northwestern Steel & Wire Co. to increase production from its 150-ton electric furnace to 2,000 tons per day.[13]

The Bureau of Mines published the results of two investigations on the use of substituted metals in stainless steel. Research on the effects of adding gadolinium was carried out in cooperation with the Atomic Energy Commission.[14] Another paper describes the corrosion rates determined when substituting cobalt for nickel in stainless steel.[15]

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[13] Robinson, C. G., and W. E. Schwabe. Ultrahigh Power Electric Steel Furnace Operation. J. Metals, v. 17, No. 1, January 1965, pp. 75–80.

[14] Copeland, M., W. Barstow, C. Armantrout, and H. Kato. Stainless Steel-Gadolinium Alloys. BuMines Rept. of Inv. 6636, 1965, 29 pp.

[15] Tilman, M. M. Effects of Substituting Cobalt for Nickel on the Corrosion Resistance of Two Types of Stainless Steel. BuMines Rept. of Inv. 6591, 1965, 17 pp.

Iron and Steel Scrap

By Robert A. Whitman [1]

The accumulation of junk cars, which comprise most of the metal in No. 2 bundles, was highlighted as a national problem and became the concern of all levels of government during 1965. The total consumption of iron and steel scrap increased about 7 percent. Ferrous scrap consumption was over 8 million tons for 4 consecutive months in the first half of 1965; nevertheless, the available supply of scrap remained adequate throughout the year.

Exports of iron and steel scrap were below those of 1964, but the ratio of export to import was a little higher.

Legislation and Government Programs.—The U.S. Maritime Commission sold 125 ships for scrap during 1965.

Public Law 89–61 extended, for 2 years from July 1, 1965, the suspension of duties on the imports of scrap metal.

The Bureau of Mines began a nationwide resource study to determine how fast junk cars accumulate, how long they are held, how they are finally disposed of, and how the situation could be improved.

[1] Commodity specialist, Division of Minerals.

Table 1.—Salient iron and steel scrap, and pig iron statistics in the United States
(Short tons)

	1964	1965
Stocks Dec. 31:		
Scrap at consumer plants	r 7,427,407	7,637,656
Pig iron at consumer and supplier plants	r 2,463,943	2,328,961
Total	9,891,350	9,966,617
Consumption:		
Scrap	84,625,664	90,359,335
Pig iron	86,381,699	88,944,732
Inports for consumption, scrap (including tinplate scrap)	r 281,790	212,470
Exports, iron and steel scrap	r 7,898,473	6,248,728
Price: Scrap No. 1 heavy-melting, Pittsburgh, average—per long ton [1]	$34.18	$34.81
Value: Scrap, all grades, for export [2]	r $34.50	$35.80

r Revised.
[1] Iron Age.
[2] As computed from export data obtained from the Bureau of the Census.

AVAILABLE SUPPLY

The new supply of iron and steel scrap available for consumption increased with the record steel production. Receipts from dealers increased more than home produced scrap.

Table 2.—Iron and steel scrap supply [1] available for consumption in 1965, by districts and States

(Short tons)

District and State	Home production	Receipts from dealers and all others	Total new supply	Shipments [2]	New supply available for consumption
New England:					
Connecticut	93,067	107,549	200,616	6,491	194,125
Maine and New Hampshire	5,256	9,134	14,390	89	14,301
Massachusetts	91,182	121,570	212,752	7,432	205,320
Rhode Island	57,860	64,890	122,750	2,586	120,164
Vermont	9,337	15,734	25,071	26	25,045
Total:					
1965	256,702	318,877	575,579	16,624	558,955
1964	227,877	304,007	531,884	14,296	517,588
Middle Atlantic:					
New Jersey	230,307	524,121	754,428	13,192	741,236
New York	2,799,469	1,564,141	4,363,610	203,061	4,160,549
Pennsylvania	12,495,896	7,075,335	19,571,231	1,558,927	18,012,304
Total:					
1965	15,525,672	9,163,597	24,689,269	1,775,180	22,914,089
1964	14,118,919	8,074,615	22,193,534	1,611,882	20,581,652
East North Central:					
Illinois	4,969,234	4,459,080	9,428,314	294,189	9,134,125
Indiana	6,756,406	3,433,719	10,190,125	746,140	9,443,985
Michigan	4,703,329	4,392,876	9,096,205	111,594	8,984,611
Ohio	9,650,384	6,896,969	16,547,353	1,143,569	15,403,784
Wisconsin	648,593	579,528	1,228,121	126,498	1,101,623
Total:					
1965	26,727,946	19,762,172	46,490,118	2,421,990	44,068,128
1964	25,980,131	18,385,301	44,365,432	2,165,294	42,200,138
West North Central:					
Iowa	243,585	459,773	703,358	23,602	679,756
Kansas and Nebraska	54,791	100,308	155,099	1,846	153,253
Minnesota	267,136	237,072	504,208	7,184	497,024
Missouri	265,256	939,491	1,204,747	6,388	1,198,359
Total:					
1965	830,768	1,736,644	2,567,412	39,020	2,528,392
1964	777,523	1,393,386	2,170,909	27,303	2,143,606
South Atlantic:					
Delaware and Maryland	3,273,759	561,285	3,835,044	334,168	3,500,876
Florida and Georgia	129,994	440,664	570,658	1,248	569,410
North Carolina	33,617	150,135	183,752	170	183,582
South Carolina	22,134	49,279	71,413	----------	71,413
Virginia and West Virginia	962,958	1,233,424	2,196,382	14,671	2,181,711
Total:					
1965	4,422,462	2,434,787	6,857,249	350,257	6,506,992
1964	4,234,972	2,064,706	6,349,678	279,718	6,069,960
East South Central:					
Alabama	1,882,370	1,639,585	3,521,955	203,248	3,318,707
Kentucky, Mississippi, Tennessee	1,022,218	1,364,721	2,386,939	117,074	2,269,865
Total:					
1965	2,904,588	3,004,306	5,908,894	320,322	5,588,572
1964	2,656,605	2,654,796	5,311,401	228,829	5,082,572
West South Central:					
Arkansas, Louisiana, Oklahoma	78,698	264,060	342,758	7,348	335,410
Texas	1,210,608	1,601,345	2,811,953	92,996	2,718,957
Total:					
1965	1,289,306	1,865,405	3,154,711	100,344	3,054,367
1964	1,166,437	1,144,072	2,310,509	85,151	2,225,358

See footnotes at end of table.

Table 2.—Iron and steep scrap supply [1] available for consumption in 1965, by districts and States—Continued

(Short tons)

District and State	Home production	Receipts from dealers and all others	Total new supply	Shipments [2]	New supply available for consumption
Rocky Mountain:					
Arizona, Colorado, Idaho, Montana, Nevada, Utah	1,449,674	732,888	2,182,562	38,708	2,143,854
Total:					
1965	1,449,674	732,888	2,182,562	38,708	2,143,854
1964	1,384,824	610,168	1,994,992	33,894	1,961,098
Pacific Coast:					
California and Hawaii	1,619,230	1,616,293	3,235,523	361,870	2,873,653
Oregon and Washington	186,488	604,256	790,744	10,728	780,016
Total:					
1965	1,805,718	2,220,549	4,026,267	372,598	3,653,669
1964	1,665,038	2,033,216	3,698,254	386,835	3,311,419
U.S. total:					
1965	55,212,836	41,239,225	96,452,061	5,435,043	91,017,018
1964	52,262,326	36,664,267	88,926,593	4,833,202	84,093,391

[1] New supply available for consumption is a net figure computed by adding home production to receipts from dealers and all others and deducting consumers scrap shipped, transferred, or otherwise disposed of during the year. The plus or minus difference in stock levels at the beginning and end of the year are not taken into consideration.

[2] Includes scrap shipped, transferred, or otherwise disposed of during the year.

Table 3.—Consumption of iron and steel scrap and pig iron in the United States in 1965, by type of consumer and type of furnace or equipment

(Short tons)

Type of furnace or equipment	Type of consumer		
	Scrap	Pig iron [1]	Total
Manufacturers of steel ingots and castings: [2]			
Open-hearth	42,975,739	61,391,805	104,367,544
Basic oxygen converter [3]	7,773,611	18,518,520	26,292,131
Bessemer	35,776	645,393	681,169
Electric [4]	13,959,918	312,494	14,272,412
Total steelmaking furnaces	64,745,044	80,868,212	145,613,256
Cupola	1,507,536	288,569	1,796,105
Air	46,730	15,036	61,766
Blast [5]	5,054,491		5,054,491
Direct castings		3,167,001	3,167,001
Miscellaneous	64,691		64,691
Total:			
1965	71,418,492	84,338,818	155,757,310
1964	67,271,284	82,028,321	149,299,605
Manufacturers of steel castings: [6]			
Open-hearth	749,203	91,014	840,217
Bessemer	5,083		5,083
Electric	2,478,378	39,031	2,517,409
Total steelmaking furnaces	3,232,664	130,045	3,362,709
Cupola	341,897	15,618	357,515
Air	221,948	42,588	264,536
Total:			
1965	3,796,509	188,251	3,984,760
1964	3,527,050	192,022	3,719,072
Iron foundries and miscellaneous users:			
Bessemer	38,897	6,955	45,852
Electric [4]	255,401	35,120	290,521
Total steelmaking furnaces	294,298	42,075	336,373
Cupola	12,931,678	3,452,704	16,384,382
Air	1,279,323	115,348	1,394,671
Direct castings		807,536	807,536
Ferroalloy	512,141		512,141
Miscellaneous	126,894		126,894
Total:			
1965	15,144,334	4,417,663	19,561,997
1964	13,827,330	4,161,356	17,988,686
Total:			
Open-hearth	43,724,942	61,482,819	105,207,761
Basic oxygen converter [3]	7,773,611	18,518,520	26,292,131
Bessemer	79,756	652,348	732,104
Electric [4]	16,693,697	386,645	17,080,342
Total steelmaking furnaces	68,272,006	81,040,332	149,312,338
Cupola	14,781,111	3,756,891	18,538,002
Air	1,548,001	172,972	1,720,973
Blast [5]	5,054,491		5,054,491
Direct castings		3,974,537	3,974,537
Ferroalloy	512,141		512,141
Miscellaneous	191,585		191,585
Total:			
1965	90,359,335	88,944,732	179,304,067
1964	84,625,664	86,381,699	171,007,363

[1] Includes molten metal.
[2] Includes only those castings made by companies producing steel ingots.
[3] Includes scrap and pig iron processed in metallurgical blast cupola and used in oxygen converters.
[4] Includes small quantities of scrap and pig iron consumed in crucible furnaces and vacuum melting.
[5] Includes consumption in all blast furnaces producing pig iron.
[6] Excludes companies that produce both steel ingots and steel castings.

CONSUMPTION BY DISTRICTS AND STATES

The East North Central District consumed half of all the scrap used in 1965. Pennsylvania, which consumed 20 percent, led all States. Ohio was second with 17 percent. The overall increase in scrap consumption was twice that for steel production and the increase was more evenly distributed throughout all districts. The West South Central District and the Pacific Coast District had gains of 14 and 12 percent, respectively. Pennsylvania, Ohio, Indiana, Illinois, and Michigan, which produced 70 percent of the steel, consumed 68 percent of all scrap and 70 percent of all pig iron.

Table 4.—Proportion of iron and steel scrap and pig iron used in furnaces in the United States

(Percent)

Type of furnace	1964		1965	
	Scrap	Pig iron	Scrap	Pig iron
Open-hearth	40.2	59.8	41.6	58.4
Basic oxygen converter	30.6	69.4	29.6	70.4
Bessemer	11.1	88.9	10.9	89.1
Electric [1]	97.9	2.1	97.7	2.3
Cupola	78.4	21.6	79.7	20.3
Air	89.5	10.5	89.9	10.1

[1] Includes crucible furnaces and vacuum melting.

Table 5.—Consumption of iron and steel scrap and pig iron in the United States in 1965, by districts and States

(Short tons)

District and State	Scrap	Pig iron	Total
New England:			
Connecticut	186,389	32,631	219,020
Maine and New Hampshire	13,099	2,550	15,649
Massachusetts	205,265	58,191	263,456
Rhode Island	117,897	41,034	158,931
Vermont	25,072	6,607	31,679
Total:			
1965	547,722	141,013	688,735
1964	516,879	141,004	657,883
Middle Atlantic:			
New Jersey	738,896	62,603	801,499
New York	4,210,896	5,453,068	9,663,964
Pennsylvania	17,733,858	22,074,877	39,808,735
Total:			
1965	22,683,650	27,590,548	50,274,198
1964	20,778,616	26,091,401	46,870,017
East North Central:			
Illinois	9,234,278	6,598,061	15,832,339
Indiana	9,630,729	10,994,983	20,625,712
Michigan	8,973,915	7,822,953	16,796,868
Ohio	15,520,266	14,936,271	30,456,537
Wisconsin	1,102,069	199,680	1,301,749
Total:			
1965	44,461,257	40,551,948	85,013,205
1964	42,321,496	39,973,392	82,294,888
West North Central:			
Iowa	659,910	77,016	736,926
Kansas and Nebraska	154,474	5,728	160,202
Minnesota	487,894	558,905	1,046,799
Missouri	1,095,940	41,823	1,137,763
Total:			
1965	2,398,218	683,472	3,081,690
1964	2,232,972	658,581	2,891,553
South Atlantic:			
Delaware and Maryland	3,496,306	5,428,115	8,924,421
Florida and Georgia	547,461	14,739	562,200
North Carolina	188,272	35,427	223,699
South Carolina	69,649	16,567	86,216
Virginia and West Virginia	2,239,995	2,354,691	4,594,686
Total:			
1965	6,541,683	7,849,539	14,391,222
1964	6,147,647	8,131,073	14,278,720

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Table 5.—Consumption of iron and steel scrap and pig iron in the United States in 1965, by districts and States—Continued

(Short tons)

District and State	Scrap	Pig iron	Total
East South Central:			
Alabama	3,237,761	3,773,738	7,011,499
Kentucky, Mississippi, Tennessee	2,192,159	1,904,895	4,097,054
Total:			
1965	5,429,920	5,678,633	11,108,553
1964	5,119,879	5,233,696	10,353,575
West South Central:			
Arkansas, Louisiana, Oklahoma	294,596	12,487	307,083
Texas	2,313,551	1,386,743	3,700,294
Total:			
1965	2,608,147	1,399,230	4,007,377
1964	2,292,093	1,344,960	3,637,053
Rocky Mountain:			
Arizona, Colorado, Idaho, Montana, Nevada, Utah	2,056,414	2,657,102	4,713,516
Total:			
1965	2,056,414	2,657,102	4,713,516
1964	1,969,124	2,510,068	4,479,192
Pacific Coast:			
California and Hawaii	2,862,943	2,318,820	5,181,763
Oregon and Washington	769,381	74,427	843,808
Total:			
1965	3,632,324	2,393,247	6,025,571
1964	3,246,958	2,297,524	5,544,482
U.S. total:			
1965	90,359,335	88,944,732	179,304,067
1964	84,625,664	86,381,699	171,007,363

Table 6.—Consumption of iron and steel scrap and pig iron by districts and States, by type of manufacturers in 1965

(Short tons)

District and State	Steel ingots and castings [1]		Steel castings [2]		Iron foundries and miscellaneous users	
	Scrap	Pig iron	Scrap	Pig iron	Scrap	Pig iron
New England:						
Connecticut	61,688		7,116	288	117,585	32,343
Maine and New Hampshire			2,707	62	10,392	2,488
Massachusetts			7,787	1,208	197,478	56,983
Rhode Island	56,528	27,079			61,369	13,955
Vermont					25,072	6,607
Total:						
1965	118,216	27,079	17,610	1,558	411,896	112,376
1964	119,301	28,607	15,621	682	381,957	111,715
Middle Atlantic:						
New Jersey	265,375	7,362	71,501	2,445	402,020	52,796
New York	3,254,906	5,241,846	181,099	13,952	774,891	197,270
Pennsylvania	16,363,113	21,849,289	506,420	41,437	864,325	184,151
Total:						
1965	19,883,394	27,098,497	759,020	57,834	2,041,236	434,217
1964	18,121,074	25,581,829	733,656	54,894	1,923,886	454,678
East North Central:						
Illinois	7,315,129	6,113,275	536,456	27,644	1,382,693	457,142
Indiana	8,613,231	10,752,087	216,043	4,991	801,455	237,905
Michigan	5,326,632	6,991,541	159,596	1,385	3,487,687	830,027
Ohio	13,087,969	14,181,726	497,484	64,137	1,934,813	690,408
Wisconsin			365,050	5,668	737,019	194,012
Total:						
1965	34,342,961	38,038,629	1,774,629	103,825	8,343,667	2,409,494
1964	33,182,928	37,787,043	1,702,650	111,670	7,435,918	2,074,679
West North Central:						
Iowa			52,874	479	607,036	76,537
Kansas and Nebraska			109,458	527	45,016	5,201
Minnesota	(3)	(3)	51,469	237	141,221	48,836
Missouri	1,135,284	511,678	127,642	8,928	128,218	31,049
Total:						
1965	1,135,284	511,678	341,443	10,171	921,491	161,623
1964	1,092,629	484,114	319,634	8,697	820,709	165,770
South Atlantic:						
Delaware and Maryland	3,352,924	5,418,529	38,460	661	104,922	8,925
Florida and Georgia	572,524		17,205	111	45,097	14,628
North Carolina	(4)				100,907	35,427
South Carolina					69,649	16,567
Virginia and West Virginia	1,665,501	2,221,870	186,985	4,133	387,509	128,688
Total:						
1965	5,590,949	7,640,399	242,650	4,905	708,084	204,235
1964	5,398,889	7,931,841	129,778	6,382	618,980	192,850
East South Central:						
Alabama	2,145,812	3,038,244	117,787	154	974,162	735,340
Kentucky, Mississippi, Tennessee	1,560,972	1,695,237	28,607	2,379	602,580	207,279
Total:						
1965	3,706,784	4,733,481	146,394	2,533	1,576,742	942,619
1964	3,427,341	4,233,537	125,649	2,091	1,566,889	998,068
West South Central:						
Arkansas, Louisiana, Oklahoma	(5)		69,316	910	56,231	11,577
Texas	1,886,690	1,331,144	119,533	860	476,377	54,739
Total:						
1965	1,886,690	1,331,144	188,849	1,770	532,608	66,316
1964	1,635,196	1,268,739	173,512	2,139	483,385	74,082

See footnotes at end of table.

Table 6.—Consumption of iron and steel scrap and pig iron by districts and States, by type of manufacturers in 1965—Continued

(Short tons)

District and State	Steel ingots and castings [1]		Steel castings [2]		Iron foundries and miscellaneous users	
	Scrap	Pig iron	Scrap	Pig iron	Scrap	Pig iron
Rocky Mountain:						
Arizona, Colorado, Idaho, Montana, Nevada, Utah	1,766,829	2,650,460	96,886	1.479	192,699	5,163
Total:						
1965	1,766,829	2,650,460	96,886	1,479	192,699	5,163
1964	1,673,966	2,503,897	98,246	1,307	196,912	4,864
Pacific Coast:						
California and Hawaii	2,350,910	2,236,237	135,019	2,625	377,014	79,958
Oregon and Washington	636,475	71,214	94,009	1,551	38,897	1,662
Total:						
1965	2,987,385	2,307,451	229,028	4,176	415,911	81,620
1964	2,619,960	2,208,714	228,304	4,160	398,694	84,650
U.S. total:						
1965	71,418,492	84,338,818	3,796,509	188,251	15,144,334	4,417,663
1964	67,271,284	82,028,321	3,527,050	192,022	13,827,330	4,161,356

[1] Includes only those castings made by companies producing steel ingots.
[2] Excludes companies that produce both steel ingots and steel castings.
[3] Minnesota included with Missouri in Type 1.
[4] North Carolina included with Florida and Georgia in Type 1.
[5] Oklahoma included with Texas in Type 1.

Table 7.—Consumption of iron and steel scrap and pig iron in open-hearth furnaces in the United States in 1965, by districts and States

(Short tons)

District and State	Scrap	Pig iron	Total
New England and Middle Atlantic:			
New York and Rhode Island	1,986,249	2,848,009	4,834,258
Pennsylvania	10,716,540	16,198,662	26,915,202
Total:			
1965	12,702,789	19,046,671	31,749,460
1964	12,533,253	20,443,885	32,977,138
East North Central:			
Illinois	3,940,072	4,593,707	8,533,779
Indiana	8,415,782	10,474,464	18,890,246
Michigan and Wisconsin	1,344,218	1,045,119	2,389,337
Ohio	7,429,534	11,269,531	18,699,065
Total:			
1965	21,129,606	27,382,821	48,512,427
1964	21,737,113	29,338,817	51,075,930
West North Central:			
Minnesota and Missouri	331,939	497,276	829,215
Total:			
1965	331,939	497,276	829,215
1964	346,338	478,286	824,624
South Atlantic:			
Delaware, Maryland, West Virginia	4,519,267	7,637,984	12,157,251
Total:			
1965	4,519,267	7,637,984	12,157,251
1964	4,481,465	7,930,031	12,411,496
East and West South Central:			
Alabama, Kentucky, Texas	2,774,776	4,280,413	7,055,189
Total:			
1965	2,774,776	4,280,413	7,055,189
1964	2,764,624	4,403,005	7,167,629
Rocky Mountain and Pacific Coast:			
California, Colorado, Utah	2,266,565	2,637,654	4,904,219
Total:			
1965	2,266,565	2,637,654	4,904,219
1964	2,018,588	2,612,227	4,630,815
U.S. total:			
1965	43,724,942	61,482,819	105,207,761
1964	43,881,381	65,206,251	109,087,632

Table 8.—Consumption of iron and steel scrap and pig iron in electric [1] steel furnaces in the United States in 1965, by districts and States

(Short tons)

District and State	Scrap	Pig iron	Total
New England:			
Connecticut and New Hampshire	84,839	3,699	88,538
Massachusetts	7,787	1,208	8,995
Total:			
1965	92,626	4,907	97,533
1964	81,672	2,333	84,005
Middle Atlantic:			
New Jersey	227,810	1,978	229,788
New York	310,776	6,367	317,143
Pennsylvania	3,308,210	72,729	3,380,939
Total:			
1965	3,846,796	81,074	3,927,870
1964	3,288,030	56,715	3,344,745
East North Central:			
Illinois	2,458,596	35,419	2,494,015
Indiana	170,801	4,946	175,747
Michigan	620,094	30,147	650,241
Ohio	2,973,718	40,979	3,014,697
Wisconsin	264,645	4,664	269,309
Total:			
1965	6,487,854	116,155	6,604,009
1964	5,925,070	107,442	6,032,512
West North Central:			
Iowa, Kansas, Nebraska	165,619	1,035	166,654
Minnesota and Missouri	976,485	2,463	978,948
Total:			
1965	1,142,104	3,498	1,145,602
1964	1,063,451	7,142	1,070,593
South Atlantic:			
Delaware and Maryland	123,398	1,742	125,140
Florida, Georgia, North Carolina	586,042	219	586,261
Virginia and West Virginia	335,413	300	335,713
Total:			
1965	1,044,853	2,261	1,047,114
1964	786,887	2,741	789,628
East South Central:			
Alabama	661,926	48,557	710,483
Kentucky, Mississippi, Tennessee	574,757	502	575,259
Total:			
1965	1,236,683	49,059	1,285,742
1964	1,179,940	51,163	1,231,103
West South Central:			
Arkansas, Louisiana, Oklahoma	236,582	3,058	239,640
Texas	738,017	15,943	753,960
Total:			
1965	974,599	19,001	993,600
1964	792,178	32,473	824,651
Rocky Mountain:			
Arizona, Colorado, Nevada, Utah	194,962	869	195,831
Total:			
1965	194,962	869	195,831
1964	187,766	717	188,483
Pacific Coast:			
California and Hawaii	945,289	37,322	982,611
Oregon and Washington	727,931	72,499	800,430
Total:			
1965	1,673,220	109,821	1,783,041
1964	1,556,958	64,394	1,621,352
U.S. total:			
1965	16,693,697	386,645	17,080,342
1964	14,861,952	325,120	15,187,072

[1] Includes small quantities of scrap and pig iron consumed in crucible furnaces and vacuum melting.

Table 9.—Consumption of iron and steel scrap and pig iron in cupola furnaces in the United States in 1965, by districts and States

(Short tons)

District and State	Scrap	Pig iron	Total
New England:			
Connecticut	68,655	21,993	90,648
Maine and New Hampshire	6,532	430	6,962
Massachusetts	193,811	55,038	248,849
Rhode Island	52,223	12,822	65,045
Vermont	25,072	6,607	31,679
Total:			
1965	346,293	96,890	443,183
1964	322,603	98,996	421,599
Middle Atlantic:			
New Jersey	417,766	52,541	470,307
New York	676,848	188,289	865,137
Pennsylvania	650,939	194,966	845,905
Total:			
1965	1,745,553	435,796	2,181,349
1964	1,654,241	448,365	2,102,606
East North Central:			
Illinois	1,203,230	195,763	1,398,993
Indiana	728,951	231,157	960,108
Michigan	4,142,476	761,956	4,904,432
Ohio	2,044,371	353,513	2,397,884
Wisconsin	651,920	162,179	814,099
Total:			
1965	8,770,948	1,704,568	10,475,516
1964	7,691,884	1,556,602	9,248,486
West North Central:			
Iowa	424,928	74,492	499,420
Kansas and Nebraska	44,992	5,201	50,193
Minnesota	146,540	48,538	195,078
Missouri	98,472	29,229	127,701
Total:			
1965	714,932	157,460	872,392
1964	652,552	158,772	811,324
South Atlantic:			
Maryland	126,504	10,296	136,800
Florida	12,264	4,056	16,320
Georgia	31,406	10,572	41,978
North Carolina	100,700	35,319	136,019
South Carolina	52,952	16,567	69,519
Virginia	342,715	112,698	455,413
West Virginia	8,699	13,110	21,809
Total:			
1965	675,240	202,618	877,858
1964	595,395	191,456	786,851
East South Central:			
Alabama	887,944	741,072	1,629,016
Kentucky	201,187	50,401	251,588
Tennessee	343,028	158,755	501,783
Total:			
1965	1,432,159	950,228	2,382,387
1964	1,430,668	1,004,833	2,435,501
West South Central:			
Louisiana and Oklahoma	52,931	9,429	62,360
Texas	453,578	79,676	533,254
Total:			
1965	506,509	89,105	595,614
1964	481,556	127,092	608,648
Rocky Mountain:			
Colorado, Montana, Utah	167,607	39,560	207,167
Total:			
1965	167,607	39,560	207,167
1964	175,444	35,069	210,513

Table 9.—Consumption of iron and steel scrap and pig iron in cupola furnaces in the United States in 1965, by districts and States—Continued

(Short tons)

District and State	Scrap	Pig iron	Total
Pacific Coast:			
California	391,135	78,738	469,873
Oregon and Washington	30,735	1,928	32,663
Total:			
1965	421,870	80,666	502,536
1964	403,100	83,298	486,398
U.S. total:			
1965	14,781,111	3,756,891	18,538,002
1964	13,407,443	3,704,483	17,111,926

Table 10.—Consumption of iron and steel scrap and pig iron in air furnaces in the United States in 1965, by districts and States

(Short tons)

District and State	Scrap	Pig iron	Total
New England:			
Connecticut	35,602	7,001	42,603
Massachusetts, New Hampshire, Rhode Island	16,673	5,136	21,809
Total:			
1965	52,275	12,137	64,412
1964	50,391	10,936	61,327
Middle Atlantic:			
New Jersey and New York	31,196	11,053	42,249
Pennsylvania	215,843	40,421	256,264
Total:			
1965	247,039	51,474	298,513
1964	215,193	49,638	264,831
East North Central:			
Illinois	281,259	12,368	293,627
Indiana	78,743	10,825	89,568
Michigan	236,616	1,674	238,290
Ohio	414,642	43,200	457,842
Wisconsin	130,366	29,405	159,771
Total:			
1965	1,141,626	97,472	1,239,098
1964	1,085,289	94,836	1,180,125
West North Central:			
Iowa, Minnesota, Missouri	14,756	4,230	18,986
Total:			
1965	14,756	4,230	18,986
1964	10,053	6,652	16,705
South Atlantic:			
West Virginia	17,131	6,676	23,807
Total:			
1965	17,131	6,676	23,807
1964	15,024	6,845	21,869
East and West South Central:			
Alabama and Texas	75,174	983	76,157
Total:			
1965	75,174	983	76,157
1964	62,779	919	63,698
Pacific Coast:			
Total:			
1965			
1964	2,323	131	2,454
U.S. total:			
1965	1,548,001	172,972	1,720,973
1964	1,441,052	169,957	1,611,009

Table 11.—Consumption of iron and steel scrap in blast furnaces in the United States in 1965, by districts and States
(Thousand short tons)

District and State	Scrap
Middle Atlantic:	
New York	347
Pennsylvania	1,234
Total:	
1965	1,581
1964	1,505
East and West North Central:	
Illinois	645
Indiana	191
Michigan and Minnesota	310
Ohio	1,573
Total:	
1965	2,719
1964	2,559
South Atlantic, East and West South Central:	
Alabama	192
Kentucky, Maryland, Texas, West Virginia	376
Total:	
1965	568
1964	535
Rocky Mountain:	
Colorado and Utah	186
Total:	
1965	186
1964	217
U.S. total:	
1965	5,054
1964	4,816

Table 12.—Consumption of iron and steel scrap for miscellaneous uses in the United States in 1965, by districts and States
(Short tons)

District and State	Scrap
New England and Middle Atlantic:	
New York	16,761
New Jersey	26,023
Pennsylvania	1,601
Total:	
1965	44,385
1964	60,835
East North Central:	
Illinois, Indiana, Michigan	50,552
Ohio	3,273
Total:	
1965	53,825
1964	38,634
West North Central:	
Minnesota and Missouri	10,731
Total:	
1965	10,731
1964	13,055
South Atlantic:	
Florida, Georgia, Virginia	7,045
Total:	
1965	7,045
1964	5,552
East and West South Central:	
Alabama and Texas	1,893
Total:	
1965	1,893
1964	24,803
Rocky Mountain:	
Arizona, Idaho, Montana, Utah	43,996
Total:	
1965	43,996
1964	37,368
Pacific Coast:	
California and Washington	29,710
Total:	
1965	29,710
1964	21,587
U.S. total	
1965	191,585
1964	201,834

Table 13.—Consumption of iron and steel scrap by type of manufacturers by grades, in 1965
(Thousand short tons)

Grades of scrap	Steel ingots and castings	Steel castings	Iron foundries and miscellaneous users
Steel scrap, excludes rerolling rails:			
Carbon	61,417	3,211	5,147
Alloy, excludes stainless	3,036	165	153
Stainless	785	32	23
Cast iron, includes borings	6,180	389	9,821
Total:			
1965	71,418	3,797	15,144
1964	[r] 67,271	3,527	13,827

[r] Revised.

Table 14.—Consumption of iron and steel scrap, by grades, by districts and States, in 1965

(Short tons)

District and State	Carbon steel (excludes rerolling rails)	Alloy steel (excludes stainless)	Stainless steel	Cast iron (includes borings)
New England:				
Connecticut	90,015	7,883	28,900	61,058
Maine and New Hampshire	3,844			9,255
Massachusetts	41,358		(1)	162,440
Rhode Island	56,407	4,054		57,436
Vermont	4,419			20,653
Total:				
1965	196,043	11,937	28,900	310,842
1964	190,505	11,897	28,720	285,757
Middle Atlantic:				
New Jersey	365,911	11,390	3,630	357,965
New York	3,311,507	101,301	79,457	718,631
Pennsylvania	13,371,156	1,613,190	404,983	2,344,529
Total:				
1965	17,048,574	1,725,881	488,070	3,421,125
1964	15,764,337	1,502,160	441,619	3,070,500
East North Central:				
Illinois	7,220,114	213,305	40,594	1,760,265
Indiana	8,455,423	119,244	19,953	1,036,109
Michigan	5,778,291	33,783	89,165	3,072,676
Ohio	12,025,042	910,109	91,096	2,494,019
Wisconsin	581,524	5,084	3,735	511,726
Total:				
1965	34,060,394	1,281,525	244,543	8,874,795
1964	32,952,700	1,193,558	290,921	7,884,317
West North Central:				
Iowa	434,674		1,897 (Iowa, Kansas and Nebraska, Minnesota, Missouri)	225,073
Kansas and Nebraska	110,929			43,521
Minnesota	335,500	10,508 (Minnesota, Missouri)		148,495
Missouri	910,646			176,975
Total:				
1965	1,791,749	10,508	1,897	594,064
1964	1,636,358	12,807	2,395	581,412
South Atlantic:				
Delaware and Maryland	3,167,206	25,486	63,338	240,395
Florida and Georgia	509,325			38,136
North Carclina	94,379			93,893
South Carolina	7,667	13,303	(2)	48,560
Virginia and West Virginia	1,994,286	8,951		236,758
Total:				
1965	5,772,863	47,740	63,338	657,742
1964	5,466,669	41,860	65,271	573,847
East South Central:				
Alabama	2,466,354	50,476	W	720,828
Kentucky, Mississippi, Tennessee	1,659,421	80,831	W	447,435
Total:				
1965	4,125,775	131,307	W	1,168,263
1964	3,735,313	130,794	W	1,248,754
West South Central:				
Arkansas, Louisiana, Oklahoma	256,491	216		37,889
Texas	1,707,032	53,268	W	551,921
Total:				
1965	1,963,523	53,484	W	589,810
1964	r 1,703,047	r 43,683	W	r 544,470
Rocky Mountain:				
Arizona, Colorado, Idaho, Montana, Nevada, Utah	1,792,988	45,685		217,741
Total:				
1965	1,792,988	45,685		217,741
1964	1,658,212	48,146		262,766

See footnotes at end of table.

Table 14.—Consumption of iron and steel scrap, by grades, by districts and States, in 1965—Continued

(Short tons)

District and State	Carbon steel (excludes rerolling rails)	Alloy steel (excludes stainless)	Stainless steel	Cast iron (includes borings)
Pacific Coast:				
California and Hawaii	2,313,707	25,698	2,031	521,407
Oregon and Washington	709,355	19,644	5,850	34,532
Total:				
1965	3,023,162	45,342	7,881	555,939
1964	2,756,068	42,776	3,863	444,251
U.S. total:				
1965	69,775,071	3,353,409	840,534	16,390,321
1964	r 65,863,209	r 3,027,681	838,700	r 14,896,074

W Withheld to avoid disclosing individual company confidential data; included in U.S. total.
[1] Data for Massachusetts included in Connecticut.
[2] Data for South Carolina included in total for Delaware and Maryland.

Table 15.—Home scrap produced by source, by type of manufacturers in 1965

(Thousand short tons)

	Source of scrap			Total
	Recirculating [1]	Obsolete [2]	Other, including slag	
Manufacturers of steel ingots and castings	40,802	3,742	2,434	46,978
Manufacturers of steel castings	1,577	7	1	1,585
Iron foundries and miscellaneous users	6,551	91	8	6,650
Total:				
1965	48,930	3,840	2,443	55,213
1964	47,058	3,346	1,858	52,262

[1] Includes home, plant, or recycled iron and steel scrap.
[2] Includes molds, stools, machinery, buildings; excludes rerolling rails.

Table 16.—Consumers receipts and total consumption of iron and steel scrap, by grades, in 1965

(Thousand short tons)

Grades of scrap (excludes rerolling rails)	Receipts			Total consumption
	From dealers	From others	Total	
Carbon steel:				
Low-phosphorus plate and punchings	2,929	696	3,625	4,560
Cut structural and plate	1,048	80	1,128	1,268
Steel car wheels	170	4	174	174
No. 1 heavy melting	5,655	2,108	7,763	30,355
No. 1 and electric furnace bundles	5,015	1,852	6,867	7,131
No. 2 and all other bundles	4,581	547	5,128	5,735
Turnings and borings	2,539	162	2,701	2,950
Slag scrap (Fe content)	367	584	951	3,106
All other carbon steel	4,177	927	5,104	14,496
Alloy steel, excludes stainless	436	212	648	3,354
Stainless steel	304	55	359	840
Cast iron: Borings	780	379	1,159	1,402
All other cast iron scrap	4,396	1,236	5,632	14,988
Total:				
1965	32,397	8,842	41,239	90,359
1964	28,521	8,143	36,664	84,626

Table 17.—Iron and steel scrap production, receipts, consumption, consumer stocks, imports and exports

(Thousand short tons)

Year	Home scrap produced	Purchased scrap received from dealers and all others	Consumption	Stocks Dec. 31	Imports	Exports [1]
1961	38,475	27,553	64,327	8,824	268	9,714
1962	40,645	27,499	66,160	8,471	210	5,112
1963	44,655	32,248	74,621	7,945	217	6,364
1964	52,262	36,664	84,626	r 7,427	282	r 7,898
1965	55,213	41,239	90,359	8,085	212	6,249

r Revised.
[1] Includes tinplate scrap.

STOCKS

Consumers' stocks of all grades of scrap, except cast iron, were higher than in 1964. Scrap stocks were lowest at the end of March and highest at the end of December. Pig iron stocks were lowest at the end of April and highest at the end of June. The average daily consumption rate for scrap was 248,000 tons per day, 7 percent more than in 1964.

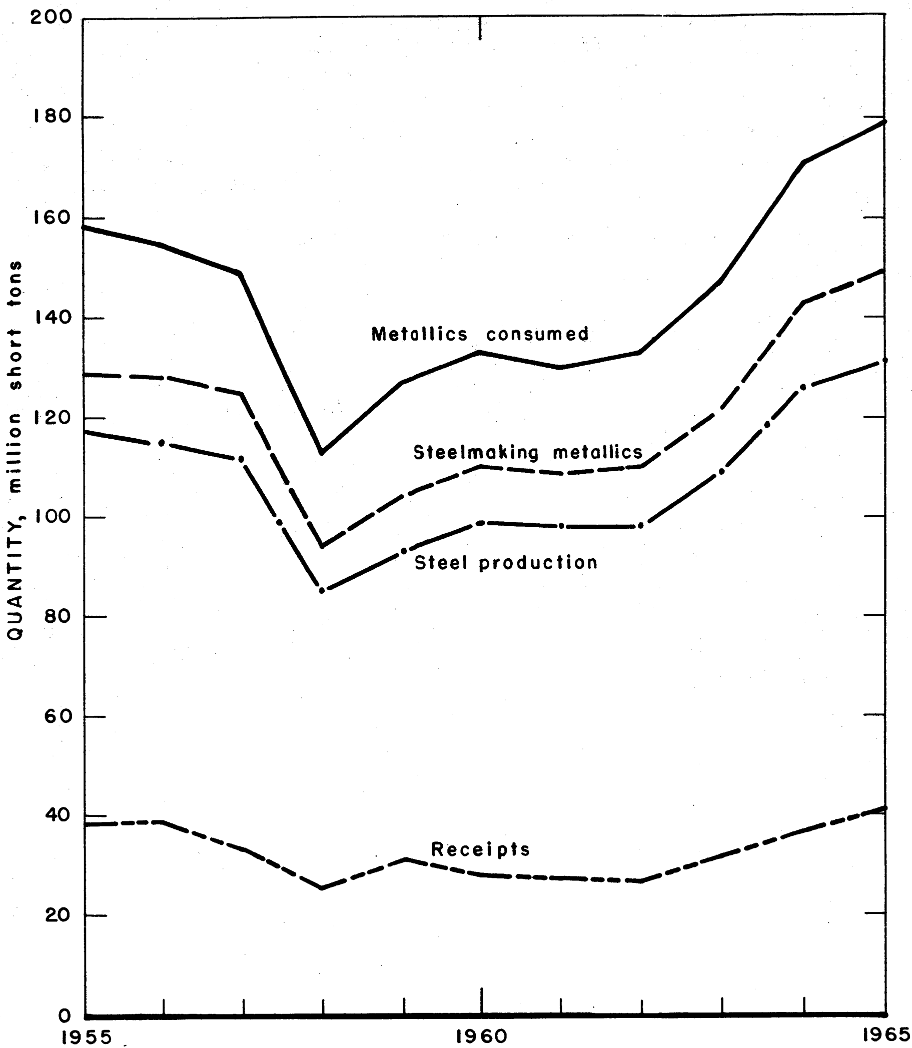

Figure 1.—Metallics consumed—Total iron and steel scrap plus pig iron; Steelmaking metallics—Total iron and steel scrap plus pig iron consumed in steelmaking furnaces; Steel production—Steel ingot production (AISI); Receipts—Receipts of purchased scrap by consumers.

Table 18.—Consumer stocks of iron and steel scrap and pig iron Dec. 31, in the United States, by districts and States

(Short tons)

District and State	1964		1965	
	Scrap	Pig iron	Scrap	Pig iron
New England:				
Connecticut	15,020	4,066	19,134	4,134
Maine and New Hampshire	773	204	1,844	387
Massachusetts	13,633	6,784	16,230	8,149
Rhode Island	13,251	4,870	14,355	6,955
Vermont	1,630	416	1,575	566
Total	44,307	16,340	53,138	20,191
Middle Atlantic:				
New Jersey	78,038	21,843	85,265	12,766
New York	683,801	334,793	629,812	321,346
Pennsylvania	r 1,451,044	r 490,099	1,689,993	445,088
Total	r 2,212,883	r 846,735	2,405,070	779,200
East North Central:				
Illinois	866,288	289,568	803,183	180,368
Indiana	886,358	99,380	711,865	106,275
Michigan	388,334	172,145	386,845	219,281
Ohio	962,397	388,984	850,489	424,679
Wisconsin	56,939	27,261	56,202	29,335
Total	3,160,316	977,338	2,808,584	959,938
West North Central:				
Iowa	47,944	5,185	66,411	7,972
Kansas and Nebraska	8,776	826	9,660	1,114
Minnesota	55,989	28,525	72,450	45,058
Missouri	131,517	11,081	166,272	3,967
Total	244,226	45,617	314,793	58,111
South Atlantic:				
Delaware and Maryland	224,738	45,573	232,994	40,440
Florida and Georgia	51,804	2,056	73,218	2,637
North Carolina	13,034	1,851	8,273	797
South Carolina	2,922	2,696	5,629	2,601
Virginia and West Virginia	158,360	43,904	111,277	27,273
Total	450,858	96,080	431,391	73,748
East South Central:				
Alabama	259,466	291,330	343,767	254,385
Kentucky, Mississippi, Tennessee	185,674	18,491	265,543	22,429
Total	445,140	309,821	609,310	276,814
West South Central:				
Arkansas, Louisiana, Oklahoma	16,859	1,405	52,064	1,779
Texas	139,909	37,875	185,283	37,545
Total	156,768	39,280	237,347	39,324
Rocky Mountain:				
Arizona, Colorado, Idaho, Montana, Nevada, Utah	220,505	82,322	304,051	84,758
Total	220,505	82,322	304,051	84,758
Pacific Coast:				
California and Hawaii	360,138	45,868	327,918	25,491
Oregon and Washington	132,266	4,542	146,054	11,386
Total	492,404	50,410	473,972	36,877
U.S. total	r 7,427,407	r 2,463,943	7,637,656	2,328,961

r Revised.

Table 19.—Consumer stocks of iron and steel scrap, by grades, by districts and States, Dec. 31, 1965

(Short tons)

District and State	Carbon steel (excludes rerolling rails)	Alloy steel (excludes stainless)	Stainless steel	Cast iron (includes borings)
New England:				
Connecticut	6,424	[1] 1,282	[2] 3,059	8,616
Maine and New Hampshire	291			1,553
Massachusetts	5,947		(2)	10,211
Rhode Island	10,703	(1)		3,477
Vermont	542			1,033
Total:				
1965	23,907	1,282	3,059	24,890
1964	21,130	834	1,897	20,446
Middle Atlantic:				
New Jersey	45,835	3,870	303	35,257
New York	421,119	11,705	34,286	162,702
Pennsylvania	1,195,140	176,055	41,125	277,673
Total:				
1965	1,662,094	191,630	75,714	475,632
1964	r 1,503,572	184,239	64,057	461,015
East North Central:				
Illinois	589,729	27,808	7,051	178,595
Indiana	538,251	12,795	3,214	157,605
Michigan	277,284	3,942	10,601	95,018
Ohio	636,065	67,511	16,477	130,436
Wisconsin	36,462	54	155	19,531
Total:				
1965	2,077,791	112,110	37,498	581,185
1964	2,217,234	95,520	25,879	821,683
West North Central:				
Iowa	57,326		262	8,885
Kansas and Nebraska	7,191			2,469
Minnesota	56,671	1,441		15,047
Missouri	129,320			36,181
Total:				
1965	250,508	1,441	262	62,582
1964	175,009	1,789	284	67,144
South Atlantic:				
Delaware and Maryland	150,184	4,120	[3] 10,850	68,031
Florida and Georgia	70,253			2,965
North Carolina	6,271			2,002
South Carolina	1,265	2,498	(3)	1,675
Virginia and West Virginia	100,164	820		10,293
Total:				
1965	328,137	7,438	10,850	84,966
1964	399,906	5,284	8,171	37,497
East South Central:				
Alabama	289,128	58,169	W	54,429
Kentucky, Mississippi, Tennessee	181,180		W	23,494
Total:				
1965	470,308	58,169	2,910	77,923
1964	338,837	24,920	W	79,208
West South Central:				
Arkansas, Louisiana, Oklahoma	49,743			2,321
Texas	146,536	6,649	W	31,929
Total:				
1965	196,279	6,649	W	34,250
1964	122,755	9,243	W	24,662
Rocky Mountain:				
Arizona, Colorado, Idaho, Montana, Nevada, Utah	178,114	9,030		116,907
Total:				
1965	178,114	9,030		116,907
1964	172,254	4,666		43,585

See footnotes at end of table

Table 19.—Consumer stocks of iron and steel scrap, by grades, by districts and States, Dec. 31, 1965—Continued

(Short tons)

District and State	Carbon steel (excludes rerolling rails)	Alloy steel (excludes stainless)	Stainless steel	Cast iron (includes borings)
Pacific Coast:				
California and Hawaii	231,710	1,460	446	94,302
Oregon and Washington	140,530	719	740	4,065
Total:				
1965	372,240	2,179	1,186	98,367
1964	370,885	2,871	657	117,991
U.S. total:				
1965	5,559,378	389,928	131,648	1,556,702
1964	r 5,321,582	329,366	103,228	1,673,231

r Revised.
W Withheld to avoid disclosing individual company confidential data.
[1] Data for Connecticut includes Rhode Island.
[2] Data for Connecticut includes Massachusetts.
[3] Data for Delaware and Maryland includes South Carolina.

Table 20.—Consumers stocks, production, receipts, consumption, and shipments of iron and steel scrap, by grades, in 1965

(Thousand short tons)

	Stocks Jan. 1 r	Home scrap produced	Receipts from dealers and all others	Total consumption	Shipments	Stocks [1] Dec. 31
Steel scrap, excludes rerolling rails:						
Carbon	5,322	40,848	33,441	69,775	3,786	6,050
Alloy, excludes stainless	330	2,871	648	3,354	117	378
Stainless	103	549	359	840	39	132
Cast iron, includes borings	1,672	10,945	6,791	16,390	1,493	1,525
Total	7,427	55,213	41,239	90,359	5,435	8,085

r Revised.
[1] Will not agree with tables 19 and 21 because of last minute corrections from industry of reported receipts and consumption figures.

Table 21.—Stocks of iron and steel scrap and pig iron at major consuming industries plants, Dec. 31

(Thousand short tons)

Year	Manufacturers of steel ingots and castings	Manufacturers of steel casting	Iron foundries and miscellaneous users	Total
Scrap stocks:				
1963	6,703	349	893	7,945
1964 r	6,168	365	894	7,427
1965	6,244	373	1,021	7,638
Pig iron stocks:				
1963	2,368	31	407	2,806
1964 r	2,029	27	408	2,464
1965	1,859	27	443	2,329

r Revised.

PRICES

Price of iron and steel scrap was steady through the first half of the year; however, once the steel strike was settled, the excess hot metal production from reactivated blast furnaces, combined with a definite drop in steel production, caused scrap prices to drop as much as $5 to $10 per ton. Prices generally made a slight recovery in December. The average price for No. 1 heavy melting scrap did not fluctuate more than $10 throughout the year. The price per ton of export scrap averaged 3 percent above the price per ton in 1964.

Table 22.—Average monthly price and composite price for No. 1 heavy melting scrap in 1965

(Per long ton)

Month	Chicago	Pittsburgh	Philadelphia	Composite price [1]
January	$39.50	$39.50	$35.50	$38.17
February	37.50	37.75	35.50	36.92
March	38.30	36.50	36.80	37.20
April	38.75	37.25	36.63	37.54
May	37.10	36.70	36.20	36.67
June	34.50	34.50	34.50	34.50
July	34.50	34.50	34.50	34.50
August	33.10	34.10	33.10	33.43
September	31.25	31.25	29.50	30.67
October	29.75	31.50	27.50	29.58
November	32.10	31.70	29.10	30.97
December	34.25	32.50	29.50	32.08
Average:				
1965	35.05	34.81	33.19	34.35
1964	35.95	34.18	30.89	33.67

[1] Composite price, Chicago, Pittsburgh, Philadelphia.

Table 23.—Stocks, production, receipts, consumption and shipments of pig iron

(Thousand short tons)

Year	Stocks Jan. 1, 1965	Production	Receipts	Consumption	Shipments	Stocks Dec. 31, 1965
1964	2,806	85,693	7,584	86,382	[r] 7,237	[r] 2,464
1965	2,464	88,295	8,099	88,945	7,584	2,329

[r] Revised.

FOREIGN TRADE

Canada furnished 97 percent and France and West Germany together supplied 2.5 percent of all scrap imported in 1965. Imports of scrap decreased 25 percent.

The United States exported five times more scrap to Canada than was imported from that country. Four countries took 80 percent of our scrap exports, but all are expected to import less in the future. Exports to Canada and Mexico were up 14 percent, but all other major consumers imported much less scrap in 1965 than in 1964. The most favorable future export market will probably be those countries attempting to start the manufacture of their own steel products in nonintegrated plants. International trade in iron and steel scrap contributed over $192 million to reduce the U.S. trade deficit.

Table 24.—U.S. exports of iron and steel scrap, by countries

(Short tons)

Destination	Iron and steel scrap including tinplate and terneplate scrap		Rerolling material
	1964	1965	1964 [1]
North America:			
Canada	844,033	1,011,227	960
Dominican Republic		1,297	
Guatemala	24	3,010	
Mexico	794,790	857,032	6,708
Nicaragua	832	5	
Other	176	48	
Total	1,639,855	1,872,619	7,668
South America:			
Argentina	176,096	115,184	
Brazil	252	376	16
Colombia	10,693	6,438	
Peru	23,340	34,770	
Venezuela	164	2,241	
Other		59	
Total	210,545	159,068	16
Europe:			
Finland		9,473	
France	110,527	3,575	
Germany, West	494,104	34,645	
Italy	662,019	776,514	
Netherlands	26,590	18,123	
Spain	r 202,354	148,662	
Sweden	184,478	56,236	
United Kingdom	903	66,785	1,435
Yugoslavia	53,923	101,642	
Other		356	
Total	r 1,734,898	1,216,011	1,435
Africa:			
South Africa, Republic of	21,520	33,133	
United Arab Republic (Egypt)	41,486	66,363	
Other	6	259	
Total	63,012	99,755	
Asia:			
Hong Kong	19	10,624	181
India	696	34	
Japan	3,889,005	2,389,751	24,552
Korea, South	41,456	95,264	
Nansei and Nanpo Islands	3,908	11,774	2,672
Pakistan	872	432	
Philippines	10,852	10,542	
Taiwan	144,252	335,706	95,690
Turkey	26,495	41,411	
Viet-Nam		644	
Other	278	181	
Total	4,117,833	2,896,363	123,095
Oceania:			
Australia	116	7	
French Pacific Islands		4,905	
Total	116	4,912	
Grand total:			
Short tons	r 7,766,259	6,248,728	132,214
Value	r $236,685,150	$199,744,289	$6,647,497

r Revised.

[1] Beginning Jan. 1, 1965 no longer separately classified, included with iron and steel scrap.

Table 25.—U.S. imports for consumption of iron and steel scrap, by countries

(Short tons)

Country	1964	1965
North America:		
Bahamas	29	4
Barbados	258	
Canada	r 269,203	206,359
Dominican Republic	511	
Mexico	301	39
Total	r 270,302	206,402
South America:		
Brazil	1	
Chile	1	
Total	2	
Europe:		
France	(1)	1,179
Germany, West	r 6,175	4,157
Greece	5	
Italy	807	4
Netherlands	131	69
Spain	3,856	92
Sweden		44
United Kingdom	r 347	22
Total	r 11,321	5,567
Africa: South Africa, Republic of		66
Asia:		
India	29	67
Israel		8
Japan	64	304
Total	93	379
Oceania: Australia	72	56
Grand total:		
Short tons	r 281,790	212,470
Value	r $8,266,653	$7,450,367

r Revised.
1 Revised to none.

WORLD REVIEW

Moderation in steel demand definitely retarded the ferrous scrap market in most industrial countries outside North America. Since Western European countries and Japan have many oxygen converters, a slowdown in steel production would account for the loss of one-half million tons of our scrap exports to the Common Market and a 1.5-million-ton loss in our Japanese export trade. With the exception of Italy and Spain, the countries of Western Europe are net exporters of scrap. Spain is the only European country expected to expand its imports of scrap in the near future. Japan for several years has been assiduously lining up long term contracts to buy iron ore in order to reduce dependence of the steel mills on scrap, most of which must be imported. Japan, whose 1965 scrap imports were nearly 2.4 million tons, has experimented with bulk carriers for scrap and early in the year imported a record shipload of 32,000 tons from New Jersey.

TECHNOLOGY

The junk automobile dominated the technology of the iron and steel scrap industry during 1965. Although scrap processors are not directly responsible for the scrap car storage areas which dot and may deface the countryside, they took the lead

Table 26.—U.S. imports for consumption and exports of iron and steel scrap by classes

Class	1964		1965	
	Short tons	Value	Short tons	Value
Imports:				
Iron and steel scrap	r 259,229	$7,794,739	193,482	$6,999,397
Tinplate scrap	22,561	471,914	18,988	450,970
Total	r 281,790	r 8,266,653	212,470	7,450,367
Exports:				
Nos. 1 and 2 heavy melting steel scrap	4,386,323	145,950,027	3,090,645	102,785,618
Nos. 1 and 2 baled steel scrap	2,161,445	55,351,612	1,797,063	45,268,073
Borings, shovelings, and turnings	261,984	5,547,079	216,004	5,071,576
Iron scrap	388,104	11,360,377	394,131	12,516,470
Rerolling material 1	132,214	6,647,497	750,885	34,102,552
Other steel scrap (terneplate and tinplated)	r 568,403	r 18,476,055		
Total	r 7,898,473	r 243,332,647	6,248,728	199,744 289

r Revised.
1 Not separately classified in 1965, included with other steel scrap.

in searching for solutions to the problem. Elimination or removal of auto wrecking or scrap processing yards is not a solution since these facilities are necessary to handle and dispose of obsolete material. Furthermore, this obsolete scrap is a valuable secondary raw material. The emphasis should be on conservation by modifying the scrap to make it acceptable to iron and steel making processes or by modifying these processes so that they are able to use this ferrous scrap, thus conserving iron ore and other resources.

The extent to which junk cars dominated the industry is illustrated by the descriptions of new machinery. Shredders of all sizes are rated by their capacity in "car bodies per day." Construction plans were announced for smaller shredding units in Dallas, Philadelphia, Tampa, and in the State of Connecticut. Balers that can handle a certain number of car bodies or that are large enough to handle a complete car body were announced. New guillotine shears are large enough to handle compressed car bodies, and alligator shears have been redesigned for the same purpose. There was continued expansion in the installation of guillotine shears with particular emphasis on ancillary equipment such as vibrating conveyors for the eliminating of waste and nonmetallics. There was more emphasis on preparation of scrap for the foundry industry.

Cupola furnaces have been suggested for melting scrap so that a definite analysis could be furnished to a buyer with the resulting pig metal or hot metal.

Bureau of Mines.—Bureau metallurgical research on the scrap auto problem was directed toward overcoming presently known economical and technological barriers, such as changes in steelmaking and automobile manufacturing practices that have caused once sizable market for these discarded cars to shrink. Bureau research contributed two promising metallurgical processes that will be tested in large scale demonstration plants. One of these processes uses the scrap as a reductant for low-grade nonmagnetic taconite that is abundant in the United States. By carefully controlled roasting of the scrap and taconite in a rotating kiln, both the iron in the taconite, and the iron and steel in the scrap, are converted to high-grade magnetic iron oxide. The product is then concentrated by magnetic separation during which all nonferrous materials in the scrap, as well as the gangue in the taconite, are rejected. In another process being developed by the Bureau, cylindrical bales made from automobiles, less engines and transmissions, will be run through a rotary kiln at a temperature high enough to burn the combustible materials and melt the nonferrous metal parts. The resulting clean iron scrap will be compacted to any desired density for steelmaking charges. Further testing with an electric steelmaking furnace will be made to show the many types of steel that can be produced using only thermally treated automotive scrap.

Countries other than the United States are beginning to have problems with unsightly and uneconomic accumulations of junk cars and other ferrous scrap. The English Steel Corporation announced a process for making a high-quality steel from scrap using a plasma-flame instead of an electric arc both for melting and refining. The plasma shields the melt from gaseous contamination, the gas-metal reaction eliminates the conventional slag, there is no electrode consumption, heat transfer is more efficient, and melting is faster than in arc melting. The resulting steel is said to be suitable for toolsteel and aircraft.[2]

In Japan, the "Carbecue" rotates scrap car hulks at 2 revolutions per minute while the heat is increased rapidly to 1,000° C. Nonferrous metals are supposed to melt and be eliminated by centrifugal action. The resultant clean metal is then baled and melted in steel furnaces. Japan probably retired 300,000 cars to scrap in 1965, and this scrap, if usable, could reduce their scrap import 10 percent.

[2] Steel Times (London). V. 190, No. 5039, Feb. 12, 1965, p. 229.

Iron Oxide Pigments

By F. E. Brantley [1]

Interest in iron oxide pigments was high throughout 1965. Several companies new to the industry conducted surveys with a view of entering the market. The rapidly increasing use of iron oxides for ferrite and high-purity iron powder production was largely responsible for the increased activity.

Table 1.—Salient iron oxide pigments statistics in the United States

	1956–60 (average)	1961	1962	1963	1964	1965
Mine production .... short tons	56,400	46,000	57,500	56,700	r 59,300	57,000
Crude pigments sold or used .... do	55,500	45,900	60,100	55,900	r 59,700	56,200
Value .... thousands	$496	$453	$500	$500	r $446	$419
Finished pigments sold .... short tons	108,200	106,500	113,000	118,800	119,500	127,500
Value .... thousands	$17,263	$18,345	$19,798	$21,135	$22,991	$23,549
Exports .... short tons	4,200	3,200	3,800	4,200	5,100	4,700
Value .... thousands	$1,033	$855	$1,076	$1,306	$1,817	$1,380
Imports for consumption .... short tons	13,400	10,500	13,100	13,700	16,300	17,800
Value .... thousands	$1,319	$1,059	$1,295	$1,469	$1,817	$2,165

r Revised.

DOMESTIC PRODUCTION

Finished iron oxide pigments were sold by 13 companies with 17 plants in 8 States. Eight companies in five States mined, and sold or used crude iron oxide pigments.

Chas. Pfizer & Co., Inc., announced expansion of iron oxide production facilities for plants in California and Illinois.

Startup of a new plant in Missouri to manufacture synthetic iron oxides was announced by Columbian Carbon Co.

CONSUMPTION AND USES

Sales of finished iron oxide pigments in the United States during 1965 reached a new high of 127,500 tons.

No data are collected by the Bureau of Mines on uses of iron oxide pigments. However, it was apparent that increasing amounts of the material were being used in the manufacture of ferrites. Iron oxide is the basic constituent for the praparation of most ferrites and may comprise a high weight-percent of the final product. Pure iron oxides of the type manufactured for use as paint pigments are ideal as a starting material in ferrite production.

Ferrite applications include use in radio antennas, electric motors, magnetic switches, memory devices, computers, recorders, microwave equipment, and certain types of transformers.

[1] Commodity specialist, Division of Minerals.

Table 2.—Finished iron oxide pigments sold by processors in the United States, by kinds

Pigment	1964 Short tons	1964 Value	1965 Short tons	1965 Value
Natural:				
Brown:				
Iron oxide (metallic)[1]	14,164	$2,431,300	21,795	$2,844,200
Umbers:				
Burnt	2,922	582,900	2,907	586,500
Raw	737	143,900	571	116,600
Red:				
Iron oxide	27,351	1,338,000	29,101	1,504,200
Sienna, burnt	1,140	337,000	1,069	331,000
Pyrite cinder	3,104	179,200	2,440	154,000
Yellow:				
Ocher[2]	3,156	177,800	3,887	211,600
Sienna, raw	622	152,200	760	191,800
Total natural	53,196	5,342,300	62,530	5,939,900
Manufactured:				
Black: Magnetic	2,713	820,400	2,742	857,300
Brown: Iron oxide	3,165	1,487,000	3,984	1,883,000
Red:				
Pure red iron oxides:				
Calcined copperas	18,866	5,240,300	20,056	5,601,700
Other chemical processes	8,988	2,553,200	7,039	2,088,300
Other manufactured red iron oxides	3,346	769,300	2,256	393,400
Venetian red	1,313	196,700	814	128,300
Yellow: Iron oxide	19,360	5,101,800	20,377	5,533,000
Total manufactured	57,751	16,168,700	57,268	16,485,000
Unspecified including mixtures of natural and manufactured red iron oxides	8,592	1,480,000	7,742	1,124,100
Grand total	119,539	22,991,000	127,540	23,549,000

[1] Includes some black magnetite and vandyke brown.
[2] Includes some yellow iron oxide.

PRICES

No significant changes were noted during the year in quoted prices for the various iron oxide pigments. Differences in quantity, quality, locality, or individual suppliers' views may be cause for variations.

Table 3.—Prices quoted on finished iron oxide pigments, per pound, in bags, unless otherwise noted, as of Dec. 27, 1965

Pigment	Low	High	Pigment	Low	High
Black:			Red:		
Pure	$0.1475	$0.1625	Domestic primers	$0.0575	$0.0575
Synthetic	.1275	.1300	Persian Gulf	[1] .0925	.1000
Brown:			Pure, synthetic	.1425	.1450
Pure, synthetic	.1550	.1650	Spanish, docks, New York	[1] .0550	.0625
Metallic	.0625	.0725	Sienna, burnt	.1100	.2200
Umber, American, burnt	[1] .0775	.1150	Yellow:		
Umber, American, raw	[1] .0900	.1100	Ocher, domestic	.0300	.0425
Vandyke:			Ocher, French type	.0675	.0725
American	[1] .1075	.1100	Pure, light lemon	.1325	.1350
Pure, domestic	.4525	.4525	Other shades	.1250	.1275
Sienna, American:			Sienna, raw	.1100	.2200
Burnt	[1] .1600	.2150			

[1] Barrels.

Source: Oil, Paint and Drug Reporter and American Paint Journal.

FOREIGN TRADE

The value of exported iron oxide pigments declined from an average of 17.8 cents per pound in 1964 to 14.8 cents in 1965.

Imports of synthetic iron oxide pigments increased by 14 percent over the comparable figure for 1964. Average value per pound was 8.7 cents, compared with 8.1 cents in 1964.

All imported ochers were from the Republic of South Africa, except for 13 tons from Sweden and 5 tons from the United Kingdom.

Italy and Cyprus suplied most of the crude and processed siennas; small amounts of processed material were received from the United Kingdom and West Germany.

All crude and most of the processed umber came from Cyprus. The United Kingdom supplied approximately 23 percent of the total processed umber. West Germany supplied all imported vandyke brown.

Synthetic iron oxide imports were distributed as follows: West Germany 63 percent, Canada 21 percent, United Kingdom 8 percent, Japan 6 percent, with the remaining 2 percent from France, Netherlands and Gaza Strip.

Table 4.—U.S. exports of iron oxide pigments, by countries

Destination	1964		1965	
	Short tons	Value	Short tons	Value
North America:				
Canada	1,957	$453,055	2,258	$410,634
El Salvador	17	5,292	16	4,849
Guatemala	26	7,238	24	7,930
Mexico	50	26,257	19	13,199
Panama	10	4,907	13	3,816
Other	67	22,485	27	10,162
South America:				
Argentina	67	30,415	58	25,050
Brazil	15	8,487	21	11,057
Chile	19	7,579	46	15,754
Colombia	128	56,462	59	17,882
Peru	33	7,015	8	2,604
Venezuela	178	53,761	118	26,313
Other	13	6,315	4	2,014
Europe:				
Belgium-Luxembourg	36	11,486	23	11,601
France	143	49,419	136	49,274
Germany, West	266	141,457	153	52,352
Italy	77	77,571	107	64,763
Netherlands	68	7,552	35	11,371
Sweden	30	14,098	30	13,486
Switzerland	34	15,618	24	8,677
United Kingdom	680	350,057	415	228,668
Other	7	2,614	28	9,640
Africa:				
South Africa, Republic of	77	16,381	33	5,489
Other	4	1,602	6	1,130
Asia:				
Hong Kong	5	2,486	5	2,353
Japan	501	140,268	301	92,971
Lebanon	12	17,907	10	4,438
Philippines	130	43,304	183	50,863
Viet-Nam	3	1,095	99	30,476
Other	25	10,124	6	5,316
Oceania	419	224,195	391	185,712
Total	5,097	1,816,502	4,656	1,379,844

Table 5.—U.S. imports for consumption of selected iron oxide pigments

Pigments	1964		1965	
	Short tons	Value	Short tons	Value
Natural:				
Ocher, crude and refined	191	$17,614	186	$13,514
Siennas, crude and refined	726	97,478	1,025	105,132
Umber, crude and refined	3,412	117,934	3,195	118,149
Vandyke brown	259	21,133	296	24,922
Other [1]	2,902	136,159	2,978	155,375
Total	7,490	390,318	7,680	417,092
Manufactured (synthetic)	8,829	1,426,211	10,071	1,747,631
Grand total	16,319	1,816,529	17,751	2,164,723

[1] Classified by the Bureau of the Census as "Natural iron-oxide and iron-hydroxide pigments, n.s.p.f."

Table 6.—U.S. imports for consumption of iron-oxide and iron-hydroxide pigments, n.s.p.f.,[1] by countries

Country	Natural				Synthetic			
	1964		1965		1964		1965	
	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value
North America: Canada	30	$2,813	1	$495	1,784	$364,957	2,116	$419,714
Europe:								
Belgium-Luxembourg			5	1,375	41	6,475		
France			33	3,114	196	26,068	139	17,482
Germany, West	35	6,125	5	3,322	5,507	832,267	6,324	977,334
Netherlands					57	8,553	8	5,622
Spain	2,758	115,575	2,828	131,155				
Sweden					2	1,861		
Switzerland			(2)	739				
United Kingdom	79	11,646	106	15,175	1,242	186,030	821	126,468
Asia:								
Gaza Strip							18	2,378
Japan							645	198,633
Total	2,902	136,159	2,978	155,375	8,829	1,426,211	10,071	1,747,631

[1] Not specifically provided for.
[2] Less than ½ unit.

WORLD REVIEW

Canada.—Ferrox Iron Ltd., a subsidiary of Quebec Smelting & Refining Ltd., started construction of a plant to produce ferrites in connection with its iron oxide plant. The iron oxide plant capacity was expanded to 50 tons per day.

Production of natural iron oxide pigments in Canada dropped to 235 tons, valued at Can$22,325 in 1965, compared with 1,033 tons (revised) valued at Can$79,250 (revised) in 1964. All natural iron oxide was mined in Quebec.

South Africa, Republic of.—The Republic of South Africa produced 3,399 tons of ocher in 1965. Exported ocher amounted to 2,627 tons with a value of approximately $75,800.

United Kingdom.—Pfizer Ltd., of Sandwich, Kent, affiliate of Chas. Pfizer & Co., Inc., acquired the firms of Bridge Colour Co., and Hull and Liverpool Red Oxide Co.

TECHNOLOGY

Inorganic pigments in general, including recent developments and predictions of future developments in the field, were described.[2]

The properties of micaceous iron oxide (flaky specular hematite) were described, and its advantages as a pigment in protective paints discussed.[3]

A study of the critical pigment volume, concentration, and particle size relationship of red iron oxide primers was reported.[4]

A British patent was granted for a colloidal, hydrous iron oxide pigment dispersed in a water-immiscible liquid, given a molecular coating, and dried to produce a pigment with a transparent, two-tone effect.[5]

A Canadian patent described the use of concentrated natural specular hematite as a starter material in producing pigment extenders or as the sole pigment for dark colors. The hematite was treated to provide a final 99.75-percent crystalline ferric oxide pigment.[6]

A second patent to produce a yellow iron oxide pigment from magnetite, hematite, or pyrites by chemical treatment was reported. The pigment was claimed to be useful in producing coloring pigments, polishing material, and in manufacturing ferrite electronic components.[7]

Another Canadian patent was issued to produce colored nacreous flake pigments such as a golden metallized-effect pigment containing 18.1 weight percent Fe_2O_3. All particles are below 0.1 micron in size, and the metal layer constitutes 10 to 40 percent of the pigment.[8]

A method of producing a ferric oxide sol having discrete ferric oxide particles of uniform size was patented. The particles were produced from an aqueous salt solution and averaged about 25 millimicrons in size.[9]

Mill scale (essentially iron oxides) was found suitable as a raw material in making a metallic ink for use as a magnetic memory indicator on bank record cards.

Technology of ferrites including recent developments in the processing and use of these materials was reviewed. Four types were listed, and characteristics peculiar to each discussed.[10]

A German patent was issued for a magnetic ink containing 20 to 75 weight-percent magnetizable iron oxide in a suitable varnish-type base.[11]

A second German patent was issued to make heat-resistant nonferromagnetic pigments having iron to manganese ratios in definite ranges to produce desired browns and blacks of controlled depth and color.[12]

A coral pink iron-ceramic pigment consisting essentially of the oxides of zirconium, silicon, and iron was patented. About 40 weight-percent of the oxides were stated to be in the form of an iron-containing zircon-crystal lattice.[13]

A number of patents were issued on methods of manufacturing ferrites. One patent describes a method of forming a ceramic ferrite containing 37 to 60 percent iron oxide as Fe_3O_4,[14] another gives a method of making a sintered ferrite core,[15] and a third covered the composition of rare-earth ferrites having a garnet crystal structure and containing at least 10 atoms of rare-earth metals to 50 atoms of iron.[16]

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[2] Huckle, W. G. Inorganic Pigments—Present and Future. Color Eng., v. 3, No. 4, July–August 1965, pp. 23–27, 38.

[3] Faucutt, F. Micaceous Iron Oxide. Paint Manufacture, v. 35, No. 12, December 1965, pp. 43–44, 47.

[4] Kresse, Peter. The CPVC of Red Oxide Primers. Paint Manufacture, v. 35, No. 12, December 1965, pp. 39–42, 56.

[5] General Aniline and Film Corp. Iron-Oxide Pigment. British Pat. 916,829, 1965.

[6] Canterman, Paul A. F., and G. A. Ingram (assigned to Northern Pigment Co. Ltd.). Pigment Base Materials Comprising Crystalline Ferric Oxide. Canadian Pat. 698,711, November 1964.

[7] Canterman, Paul A. F., and G. A. Ingram (assigned to Northern Pigment Co. Ltd.). Iron Oxide Pigment. Canadian Pat. 698,712, November 1964.

[8] Linton, H. (assigned to E. I. du Pont de Nemours & Co., Inc.). Colored Nacreous Flake Pigments. Canadian Pat. 715,639, 1965.

[9] MacCallum, Robert B., and Forrest R. Hurley (assigned to W. R. Grace & Co., New York). Method for Producing Ferric Oxide Particles. U.S. Pat. 3,198,743, Aug. 3, 1965.

[10] Allen, A. C. Ferrites '65. Ceram. Ind., v. 85, No. 1, July 1965, pp. 34–35, 72, 74.

[11] Shoemaker, C., and R. Hoffmann (assigned to A. B. Dick Co.). Magnetic Inks for Lithography. German Pat. 1,189,564, 1965.

[12] Hund, Franz, and others. Manganiferous Iron Oxide Pigments. German Pat. 1,191,063, 1965.

[13] Seabright, Clarence A. (assigned to The Harshaw Chemical Co., Cleveland, Ohio). Iron Ceramic Pigment. U.S. Pat. 3,166,430, Jan. 19, 1965.

[14] Smith, William E. (assigned to Owens-Illinois Glass Co., Ohio). Magnetic Ceramic Ferrites and Method for Making Same. U.S. Pat. 3,193,503, July 6, 1965.

[15] Simpkiss, John O., Jr. (assigned to Radio Corporation of America, Delaware). Method for Preparing Ferrite Core. U.S. Pat. 3,178,369, April 13, 1965.

[16] Schieber, Michael (assigned to The Weizmann Institute of Science, Rehovoth, Israel). Rare Earth Ferrites. U.S. Pat. 3,193,502, July 6, 1965.

Kyanite and Related Minerals

By James D. Cooper [1]

Production of kyanite and synthetic mullite increased substantially in 1965 and established new highs. Estimated consumption of kyanite group minerals and synthetic mullite was in excess of 100,000 tons. Output of kyanite concentrate increased by 14 percent, and synthetic mullite production increased by 11 percent over that of 1964.

Kyanite, sillimanite, andalusite, dumortierite, topaz, and synthetic mullite are included in this chapter because all are aluminum silicates, have similar properties, and can be used to produce mullite refractories.

DOMESTIC PRODUCTION

Output of domestic kyanite concentrate increased by 14 percent in 1965, establishing a record high for the fifth consecutive year. Production of crude ore was 25 percent above that of 1964, indicating a decline in the concentrate to ore ratio. Quantitive production figures are withheld to prevent disclosing individual company confidential data. There were three producers in 1965: Aluminum Silicates, Inc., with a mine near Lincolnton, Ga.; Commercialores, Inc., with mines near Clover, S.C.; and Kyanite Mining Corp., with mines near Farmville and Dillwyn, Va. During the year Aluminum Silicates, Inc., and Commercialores, Inc., were acquired by Combustion Engineering, Inc. Kyanite Mining Corp. completed a new and modern processing plant near Dillwyn, making a total of four plants operated by the firm.

Western Industrial Minerals, of Winterhaven, Calif., leased the kyanite deposit at Ogilby, formerly operated by Vitrefrax Co., and were studying plans for addition of kyanite processing facilities to their Mica Schist mill. Sunshine Mining Co. obtained a lease on 1,760 acres of State owned land in the Woodrat Mountain area near Kamiah, Idaho, and announced plans for production beginning in 1966.

Synthetic mullite output was 11 percent higher than that in 1964. Raw materials used in production of synthetic mullite include bauxite, alumina, clays, and silica sand. Fused mullite was produced in electric furnaces, and sintered mullite was made in rotary and periodic kilns. There were nine producing firms:

The Babcock & Wilcox Co., Refractories Division, New York, N.Y. (plant at Augusta, Ga.).

The Carborundum Co., Niagara Falls, N.Y. (plant at Niagara Falls, N.Y.).

General Abrasive Co., Inc., Niagara Falls, N.Y. (plant at Niagara Falls, N.Y.).

Harbison-Walker Refractories Co., Pittsburgh, Pa. (plant at Eufaula, Ala.).

Norton Co., Worcester, Mass. (plant at Huntsville, Ala.).

H. K. Porter Co., Inc., Refractories Division, Pittsburgh, Pa. (plant at Shelton, Conn.).

Remmey Division of A. P. Green

[1] Commodity specialist, Division of Minerals.

Fire Brick Co., Philadelphia, Pa. (plant at same address).

The Chas. Taylor Sons Co., subsidiary of National Lead Co., Cincinnati, Ohio (plant at South Shore, Ky.).

Tennessee Electro Minerals Co., Greeneville, Tenn. (plant at Greeneville, Tenn.).

Table 1.—Synthetic mullite production in the United States

Year	Short tons	Value (thousands)
1956–60 (average) [e]	19,940	$2,074
1961	14,798	1,720
1962	19,021	2,090
1963	29,588	3,529
1964	36,108	4,450
1965	40,049	4,866

[e] Estimate.

CONSUMPTION AND USES

Kyanite and synthetic mullite were used principally in production of mullite refractories for the metallurgical and glass industries. Smaller quantities were used in boiler and other refractories, kiln furniture, ceramic and glass mixes.

Mullite refractories are resistant to spalling, slagging, and chemical reactions and have low thermal expansion and reheat shrinkage. They were used extensively to line furnaces for melting high-copper brasses and bronzes, copper-nickel alloys, and certain steels. In glass furnaces mullite refractories were used in critical areas such as the port arches, crowns, and pouring spouts. In many cases arch hearth supports, door linings, electrode openings, and other critical furnace areas were made of the highest purity mullite products available.

In ceramic products kyanite was beneficial in a number of ways. Workability was often improved, and this in turn increased production rates and reduced losses due to processing defects; the growth of interlocking mullite crystals in the products during the firing process increased their strength; and expansion of the kyanite on conversion to mullite was used to compensate for firing shrinkage of other materials in the ceramic mixes.

PRICES

Quoted prices for domestic kyanite concentrates remained unchanged throughout 1965, while the price of imported kyanite increased slightly. E&MJ Metal and Mineral Markets for December 13, 1965, gave kyanite prices as follows:

Kyanite, short ton,
- f.o.b. Virginia and South Carolina:
  - 35 mesh, carload lots, bulk — $47
  - 35 mesh, carload lots, bags — 50
  - 200 mesh, carload lots, bags — 58

Imported kyanite, 60 per-cent grade, c.i.f. Atlantic ports — $79–84

FOREIGN TRADE

Exports were nearly 70 percent greater than in 1964, with the largest increases going to Australia and Japan. Canada remained the largest recipient country, taking 21 percent of the total. In all, refractories manufacturers in 23 countries throughout the world purchased kyanite and mullite produced in the United States.

Imports of kyanite increased sharply in 1965 after 4 years of declines. Indian kyanite accounted for 94 percent of the volume and 95 percent of the value. The balance was supplied by the Republic of South Africa.

Table 2.—U.S. exports and imports for consumption of kyanite and related minerals

Country	1956–60 (average) Short tons	1956–60 (average) Value	1961 Short tons	1961 Value	1962 Short tons	1962 Value
Exports:						
Argentina	6	$396	76	$4,314	53	$3,028
Australia	----	----	20	1,040	39	3,737
Belgium-Luxembourg	(1)	106	----	----	30	1,377
Canada	1,319	72,730	647	100,237	611	100,480
Finland	----	----	----	----	30	1,746
France	56	3,809	45	2,821	99	7,012
Germany, West	144	8,318	395	30,252	719	45,464
Indonesia	18	1,333	89	5,200	57	3,248
Italy	104	6,143	135	9,379	424	28,426
Japan	76	6,204	880	64,668	242	15,792
Mexico	662	32,005	677	33,748	587	33,073
Netherlands	26	1,420	46	4,362	----	----
United Kingdom	45	4,771	878	50,536	530	30,754
Venezuela	13	952	37	4,642	81	3,782
Other countries	11	1,293	75	6,434	66	8,821
Total	2,480	139,480	4,000	317,633	3,568	286,740
Imports:						
India	3,259	$161,796	3,809	$173,307	3,845	$174,948
South Africa, Republic of	2,005	68,743	1,351	51,739	1,328	49,483
Other countries	56	5,870	255	19,143	108	9,980
Total	5,320	236,409	5,415	244,189	5,281	234,411

Country	1963 Short tons	1963 Value	1964 Short tons	1964 Value	1965 Short tons	1965 Value
Exports:						
Argentina	44	$2,500	84	$4,790	115	$7,842
Australia	103	6,673	226	21,507	1,558	111,777
Belgium-Luxembourg	----	----	45	2,470	144	8,537
Canada	765	133,360	1,680	109,548	2,117	127,968
Finland	40	2,304	----	----	30	1,817
France	204	38,669	98	7,398	168	15,754
Germany, West	939	53,524	953	54,453	1,349	78,185
Indonesia	----	----	----	----	----	----
Italy	459	42,535	370	32,079	431	26,824
Japan	862	53,203	553	38,829	1,127	134,134
Mexico	698	42,952	704	36,435	1,070	70,616
Netherlands	18	1,007	----	----	122	7,354
United Kingdom	625	40,782	788	47,183	1,150	85,802
Venezuela	228	16,409	323	17,396	594	32,893
Other countries	65	8,152	256	21,069	263	22,344
Total	5,050	442,070	6,080	393,157	10,238	731,847
Imports:						
India	2,500	$110,532	2,329	$101,307	3,815	$158,051
South Africa, Republic of	65	3,299	57	2,300	232	8,877
Other countries	59	5,287	----	----	----	----
Total	2,624	119,118	2,386	103,607	4,047	166,928

[1] Less than ½ unit.

WORLD REVIEW

Australia.—Production of sillimanite in 1964 was 2,950 tons, about 60 percent of which came from South Australia and 40 percent from New South Wales. An additional 4,200 tons of kaolinized sillimanite was produced but not included with the sillimanite output. A total of 2,172 tons of sillimanite and kyanite was imported, mostly from India.[2]

British Guiana.—A 50,000 tons per year rotary kiln plant for production of sintered synthetic mullite was completed and production was initiated.

Korea, South.—Output of kyanite group minerals in 1964 consisted of 123 tons of

[2] Australia Bureau of Mineral Resources, Geology and Geophysics. The Australian Mineral Industry, 1964 Review, 1965, pp. 244, 245.

andalusite. A total of 2,208 tons of kyanite and andalusite was produced in 1963.

Rhodesia, Southern.—Output of kyanite group minerals in the first 9 months of 1965 consisted of 456 tons of kyanite and 72 tons of topaz.

South Africa, Republic of.—Production of kyanite group minerals in the first 9 months of 1965 was comprised of 17,278 tons of andalusite and 34,615 tons of sillimanite. Exports of the two minerals during the period totaled 41,853 tons, and 6,720 tons was sold to South African firms.[3] Output of andalusite by the major producer, Zeerust Andalusite (Pty.), Ltd., was increased from 500 tons per month to 1,000 tons per month beginning in February, 1965. A new heavy-media separation plant was installed about 12 miles from the open cast workings in western Transvaal.

TECHNOLOGY

A comprehensive report on the kyanite group minerals and synthetic mullite was published. The report contains descriptions of the minerals, refractory quality and specifications, information on deposits throughout the world including reserves where available, mining and processing methods, world trade, prices, and uses. Synthetic mullite production is also covered. The bibliography is extensive and is broken down into major subject headings.[4]

The results of recent laboratory research at the Atomic Energy Establishment, Trombay, Bombay, India, indicated that sillimanite and other industrial minerals could be recovered by selective flotation from Manavalakurichi beach sands in Madras State which are presently processed for recovery of ilmenite and monazite. Other valuable minerals are rutile and zircon.[5]

New data were published to support recent research reports which indicated that previously accepted values for free energy of formation of andalusite, kyanite, and sillimanite were considerably in error.[6]

Patents were issued on use of kyanite in railroad brake shoes,[7] and in improved high temperature lightweight refractories having discrete, uniform cells.[8]

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[3] Republic of South Africa Department of Mines. Quarterly Inf. Cir. Minerals, July to September 1965, pp. 36–41.

[4] Varley, E. R. Sillimanite. Overseas Geol. Surveys, Miner. Res. Div., H. M. Sta. Off., 1965, 165 pp.

[5] Madhaven, T. R., V. M. Karve, and J. Y. Somnay. Selective Flotation of Beach Sand Sillimanite, Zircon and Rutile. Min. Mag. (London), v. 113, No. 3, September 1965, pp. 202–203, 205, 207.

[6] Waldbaum, David R. Thermodynamic Properties of Mullite, Andalusite, Kyanite and Sillimanite. Am. Mineralogist, v. 50, Nos. 1 and 2, January-February 1965, pp. 186–195.

[7] Spokes, R. E., and E. C. Keller (assigned to American Brake Shoe Co., New York). Friction Composition of a Rubber, Cashew Nut Shell Resin and Lead Sulfite. U.S. Pat. 3,168,487, Feb. 2, 1965.

[8] Dreyling, L. J., and A. P. Dreyling (assigned to Quigley Co., Inc., New York). Method for Producing Lightweight High Temperature Refractory Products. U.S. Pat. 3,213,166, Oct. 19, 1965.

Lead

By Donald E. Moulds [1]

Contents

Industrial requirements for lead in 1965 established a domestic record and, despite the marketing of Government stockpile lead, increased secondary production, and increased metal imports, the stock of refined soft lead at producers and consumers declined during the year. Mine production of recoverable lead increased primarily as a result of expanded Missouri facilities, but output at primary refineries declined as imports of bullion decreased and ore imports remained essentially the same, even though ore import quotas were terminated in October. The world production of primary metal, excluding the East European and Far Eastern Communist areas, increased about 7 percent in mine production and over 3 percent in refined metal production. The increase in consumption was indicated to be about 1.5 percent, and producer stocks increased during the year by some 13,000 tons. The price of lead in the domestic market was stable during the year at 16 cents per pound while the London Metal Exchange price (U.S. equivalent) ranged from a high of 19.9 cents per pound to a low of 11.9 cents and closed the year at 13.9 cents.

Legislation and Government Programs.—The report of the Tariff Commission on its investigation of import quotas, pursuant to the provisions of the Trade Expansion Act of 1962, was submitted to President Johnson in June. After consideration of the findings of the Tariff Commission, import quotas on lead ores and metal, established October 1, 1958, were terminated by Presidential proclamation effective October 22 for ores and November 21 for metal. Lead materials previously entered as general imports and held in bond awaiting individual country quota entry for consumption were cleared after quota termination and resulted in a significantly larger entry for consumption in comparison to general imports in 1965.

The small mines stabilization program, enacted in October 1961 under Public Law 87–374 and amended in July 1963 by Public Law 88–75, was again amended on October 5, 1965, by Public Law 89–238. Public Law 89–238, effective January 1, 1966, extends the program of payments to qualified producers of lead and zinc, when

[1] Commodity specialist, Division of Minerals.

market price of these metals is less than 14.5 cents per pound, to January 1, 1970. The qualifications of a "small domestic producer" were redefined to expand coverage and new maximum limitations were established on amount of payments and quantities of lead and zinc which are allowable for any one producer in a calendar year. Revised regulations were being prepared by General Services Administration, the authorized government agent.

During the year 1965, the quoted price of lead and zinc remained at levels exceeding the 14.5 cents per pound under which payments are authorized and no payments were made on 1965 production. Under the amendments of Public Law 87–374, effective through 1965, a total of 76 applications had been received of which 59 were certified as eligible. The cumulative stabilization payments made on lead and zinc production for the period 1962–65 were $2,135,100.

The disposal of 200,000 tons of lead in the Government stockpile was authorized under Public Law 89–9, enacted in March 1965, of which 50,000 tons was designated for direct Government use and 150,000 tons for domestic industry use. The first offering of 60,000 tons under this authorization was made by General Services Administration in April, and disposal of 19,565 tons was made to domestic producers of primary and secondary lead, importers of lead, and domestic consumers. In October General Services Administration announced the remaining 40,000 tons would be offered for sale on an on-the-shelf basis with offers to purchase accepted during the third week of each calendar month. Sales during the fourth quarter on this basis amounted to 16,904 tons, essentially all to domestic primary producers of lead. Of the 50,000 tons available for direct government use, 1,184 tons was used by government agencies. Government holdings of lead in the various stockpiles at the end of the year amounted to 1,284,636 tons, of which 10 tons was nonstockpile grade. Average acquisition cost of the lead remaining in the stockpile was 14.4 cents per pound.

The International Lead and Zinc Study Group held its ninth session in Tokyo, Japan, from November 1 through November

Table 1.—Salient lead statistics

	1956–60 (average)	1961	1962	1963	1964	1965
United States:						
Production:						
Domestic ores, recoverable lead content___short tons__	292,135	261,921	236,956	253,369	286,010	301,147
Value _______thousands__	$77,318	$53,956	$43,602	$54,727	$74,936	$93,959
Primary lead (refined):						
From domestic ores and base bullion short tons__	284,023	288,078	245,645	239,660	294,254	305,007
From foreign ores and base bullion short tons__	169,850	161,487	130,418	155,072	155,175	113,242
Antimonial lead (primary lead content)__short tons__	12,952	24,966	27,383	9,256	8,607	6,612
Secondary lead (lead content) _________short tons__	463,812	452,792	444,202	493,471	541,582	575,819
Exports of lead materials, excluding scrap _____short tons__	3,909	6,570	5,006	1,092	10,194	7,811
Imports, general:						
Lead in ores and matte__do__	176,211	147,186	138,631	147,742	123,257	122,661
Lead in base bullion___do____	189	422	4,599	5,437	4,838	566
Lead in pigs, bars, and old short tons__	295,455	261,794	259,522	235,902	212,898	224,942
Stocks December 31 (lead content):						
At primary smelters and refineries _______short tons__	179,294	262,102	196,661	120,836	84,398	83,443
At consumer plants___do____	119,994	99,140	93,496	119,930	113,444	109,195
Consumption of metal, primary and secondary_____short tons__	1,089,308	1,027,216	1,109,635	1,163,358	1,202,138	1,241,482
Price: New York, common lead, average, cents per pound______	13.39	10.87	9.63	11.14	13.62	16.00
World:						
Production:						
Mine ___________short tons__	2,582,000	2,640,000	2,765,000	2,820,000	2,835,000	2,975,000
Smelter _______________do____	2,474,000	2,645,000	2,630,000	2,715,000	2,825,000	2,905,000
Price: London, common lead, average, cents per pound______	10.72	8.03	7.06	7.93	12.59	14.37

5, and delegates representing each of the 25 member countries were in attendance. The session was preceded by meetings of the various committees designated to review statistics and other special projects. The group noted that world production of ore and metal had increased at a slightly higher rate than consumption to offset the 1964 shortfall, and supply and demand in 1965 were approximately in balance. Further rises in production of ore and metal in 1966 were expected to adequately meet the steadily rising demand and 1966 would show a continuing reasonable supply-demand balance. Discussions at the meetings centered on improvement of statistics concerning production, consumption, and international trade in lead and on methods of short-range projection of the world supply-demand relationship. Further studies of the various factors influencing production, marketing, and international trade were recommended for consideration at the 1966 session.

Incorporation of the International Lead and Zinc Research Organization as an autonomous worldwide group to promote the economic health of the lead and zinc industries was announced at the Tokyo meeting. Representatives of 25 companies located in Australia, Canada, Italy, Japan, Mexico, Peru, South-West Africa, the United Kingdom, and the United States formed the sponsoring group of producers and consumers.

DOMESTIC PRODUCTION

MINE PRODUCTION

The domestic output of 301,100 tons of recoverable lead was about 15,000 tons above the 1964 total. The substantial increase in production of the Missouri mines and increases reported for nine of the other lead-producing States more than offset a major decrease in Idaho and Utah and small decreases reported in five other States. Missouri contributed 44 percent of the domestic output; Idaho, 22 percent; Utah, 13 percent; and Colorado, 7 percent. Output of these four States represented 86 percent of the total domestic output.

Activity in the new lead belt in southeast Missouri continued to be the most important development in the producing industry. During the year, the Federal, Indian Creek, and Viburnum Divisions of St. Joseph Lead Co. operated continuously on a 40-hour-week basis to produce 186,367 tons of lead concentrate in comparison to 167,623 tons in 1964. The No. 29 shaft unit at Viburnum initiated output during the year. The development of the Fletcher mine and mill facilities proceeded on schedule toward production late in 1966

Table 2.—Mine production of recoverable lead in the United States, by States
(Short tons)

State	1956–60 (average)	1961	1962	1963	1964	1965
Arizona	10,965	5,937	6,966	5,815	6,147	5,913
Arkansas	8	--------	--------	--------	--------	--------
California	2,712	103	455	823	1,546	1,810
Colorado	17,192	17,755	17,411	19,918	20,563	22,495
Idaho	58,973	71,476	84,058	75,759	71,312	66,606
Illinois	2,796	3,430	3,610	2,901	2,180	3,005
Kansas	2,891	1,449	970	1,027	1,185	1,644
Kentucky	424	656	743	831	858	756
Missouri	116,073	98,785	60,982	79,844	120,148	133,521
Montana	10,585	2,643	6,121	5,000	4,538	6,981
Nevada	3,771	1,791	771	1,126	809	2,277
New Mexico	3,056	2,332	1,134	1,014	1,626	3,387
New York	1,022	879	1,063	1,009	732	601
North Carolina	89	318	219	62	--------	--------
Oklahoma	4,952	980	2,710	3,192	2,781	2,813
Utah	42,082	40,894	38,199	45,028	40,249	37,700
Virginia	2,807	3,733	4,059	3,500	3,857	3,651
Washington	10,289	8,053	6,033	5,374	5,731	6,328
Wisconsin	1,438	680	1,394	1,116	1,742	1,645
Other States	10	27	58	30	6	14
Total	292,135	261,921	236,956	253,369	286,010	301,147

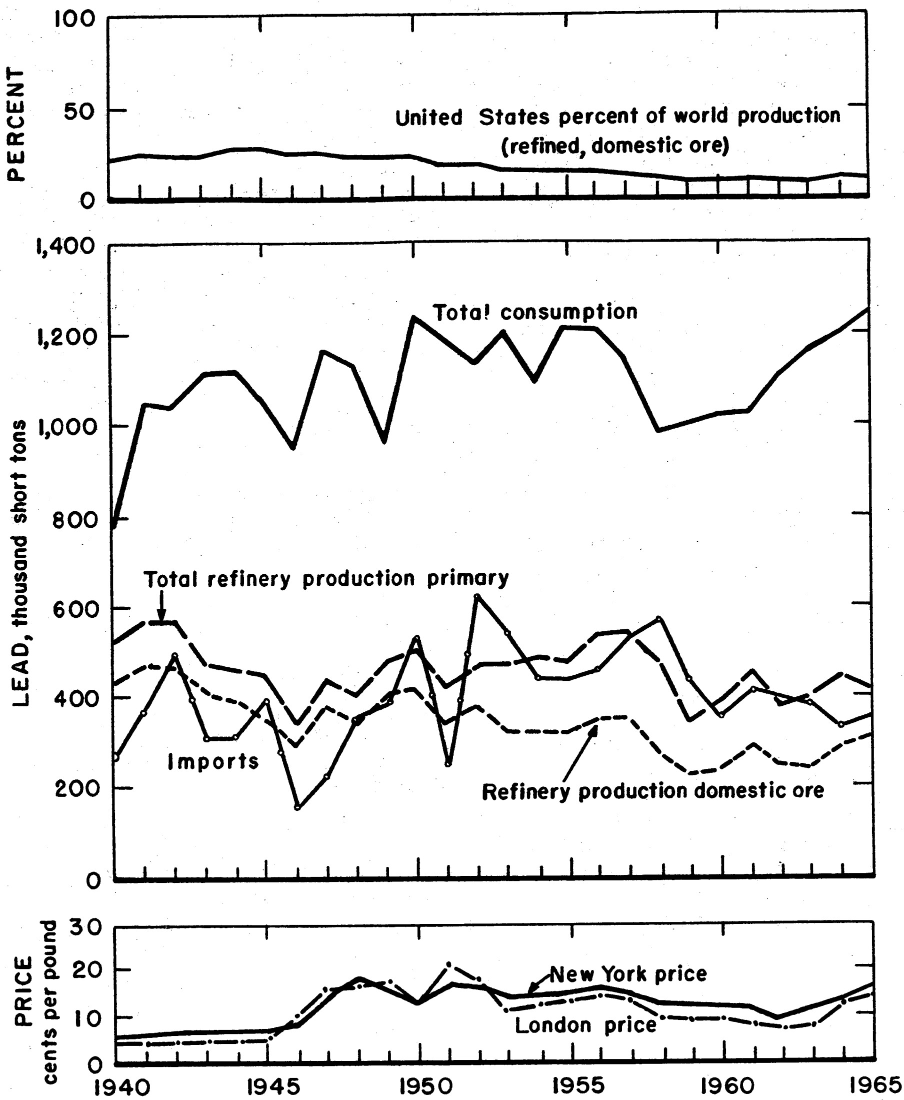

Figure 1.—Trends in the lead industry in the United States. Consumption includes primary refined, antimonial, and secondary lead, and lead pigments made directly from ore. Imports, general, are factored to include 95 percent of lead content of ore, mattes, and concentrates and 100 percent of pigs, bars, base bullion, and scrap.

Table 3.—Ore, old tailings, etc., yielding lead and zinc in the United States in 1965

(Short tons)

State	Lead ore			Zinc ore			Lead-zinc ore			Copper-lead, copper-zinc, and copper-lead-zinc ores			All other sources [1]			Total		
	Gross weight	Lead	Zinc	Gross weight	Lead	Zinc	Gross weight	Lead	Zinc	Gross weight	Lead	Zinc	Gross weight	Lead	Zinc	Gross Weight	Lead	Zinc
Arizona	1,403	55	4	2,763	56	498	336,557	5,732	15,433	85,172	11	4,699	13,990,426	59	1,123	14,416,321	5,913	21,757
California	8,881	1,706	192	—	—	—	523	101	30	—	—	—	2,825	3	3	12,229	1,810	225
Colorado	5,534	256	46	260,860	3,151	24,632	346,658	10,140	17,022	378,644	8,872	12,044	13,505	76	126	1,005,201	22,495	53,870
Idaho	221,412	21,016	1,686	96,112	978	2,507	740,111	38,630	49,060	—	—	—	640,129	5,982	4,781	1,697,764	66,606	58,034
Illinois	—	—	—	(2)	(2)	(2)	(2)	(2)	(2)	—	—	—	[2] 681,130	[2] 3,005	[2] 18,314	681,130	3,005	18,314
Kansas	—	—	—	263,789	1,289	5,869	46,979	355	639	—	—	—	—	—	—	310,768	1,644	6,508
Kentucky	—	—	—	42,000	—	4,603	—	—	—	—	—	—	153,898	756	1,051	195,898	756	5,654
Missouri	5,279,420	133,521	4,312	—	—	—	—	—	—	—	—	—	—	—	—	5,279,420	133,521	4,312
Montana	20,465	1,100	290	1,006,871	4,617	25,938	1,123	69	63	—	—	—	111,946	1,195	7,495	1,140,405	6,981	33,786
Nevada	1,427	192	25	1,489	26	395	166,721	1,666	3,115	—	—	—	52,567	393	323	222,204	2,277	3,858
New Jersey	—	—	—	223,928	—	38,297	—	—	—	—	—	—	—	—	—	223,928	—	38,297
New Mexico	1,210	346	2	402,641	726	29,868	59,436	2,289	6,576	—	—	—	732	26	14	464,019	3,387	36,460
New York	—	—	—	159,793	—	15,915	629,168	601	53,965	—	—	—	—	—	—	788,961	601	69,880
Oklahoma	—	—	—	418,247	1,643	9,938	175,616	1,160	2,743	—	—	—	1,342	10	34	595,205	2,813	12,715
Pennsylvania	—	—	—	549,427	—	27,635	—	—	—	—	—	—	—	—	—	549,427	—	27,635
Tennessee	—	—	—	4,007,082	—	111,637	—	—	—	1,520,755	—	10,750	—	—	—	5,527,837	—	122,387
Utah	11,280	1,619	424	87	2	13	486,941	35,647	25,907	1,076	170	137	25,679	262	1,266	525,063	37,700	27,747
Virginia	—	—	—	—	—	—	666,413	3,651	20,491	—	—	—	—	—	—	666,413	3,651	20,491
Washington	1,322	36	3	(3)	(3)	(3)	[3] 1,104,777	[3] 6,292	[3] 22,227	—	—	—	(3)	(3)	—	1,106,099	6,328	22,230
Wisconsin	—	—	—	967,083	1,645	26,993	—	—	—	—	—	—	—	—	—	967,083	1,645	26,993
Other States	39	7	—	—	—	—	—	—	—	—	—	—	3,674	7	W	3,713	14	W
Total	5,552,393	159,854	6,984	8,402,172	14,133	324,738	4,761,023	106,333	217,271	1,985,647	9,053	27,630	15,677,853	11,774	34,530	36,379,088	301,147	611,153

W Withheld to avoid disclosing individual company confidential data.

[1] Lead and zinc recovered from other ores (copper, gold, silver, etc.) and from smelter slags, mill tailings, and miscellaneous cleanups.

[2] Combined with "other sources" to avoid disclosing individual company confidential data.

[3] Combined with lead-zinc ore to avoid disclosing individual company confidential data.

and construction of a new shaft was begun at the Indian Creek mine. The Herculaneum smelter produced 105,799 tons of refined lead in 1965. Its modernization and expansion program continued on schedule for completion during the fourth quarter of 1966 and will raise refining capacity to over 200,000 tons of lead annually.[2]

The Missouri Lead Operating Co. proceeded with mine development and with the design and construction of a mine-mill complex to produce 50,000 tons per year of lead and a 100,000-ton-per-year lead refinery in the Bixby, Mo., area for completion late in 1967. This is a joint venture of American Metal Climax, Inc., and Homestake Mining Co. Shaft sinking was in progress at the Magmont mine operated by Cominco American, Inc., and jointly owned with Magnet Cove Barium Corp. This unit has a planned mine-mill capacity of 50,000 tons of lead annually, with completion early in 1968. Ozark Lead Co., a wholly owned subsidiary of Kennecott Copper Corp., started development of a mine-mill complex with a capacity of 60,000 tons of lead annually in the new lead belt and expected to have the concentrates smelted and refined in a new facility to be built by American Smelting and Refining Company. Initial work of shaft sinking was started late in July at the Higdon mine near Fredericktown, Mo., a joint venture of National Lead Co. and The Bunker Hill Co.

Table 4.—Mine production of recoverable lead in the United States, by months

(Short tons)

Month	1964	1965
January	24,907	24,053
February	22,799	23,322
March	24,454	26,529
April	24,054	26,176
May	23,547	22,065
June	24,037	23,802
July	23,445	22,692
August	23,620	25,575
September	22,937	25,865
October	23,775	26,028
November	23,388	25,821
December	25,047	29,219
Total	286,010	301,147

The output of lead in Colorado increased some 1,900 tons in 1965 as several small mines and mills began production. The Idarado Mining Co. milled about 375,000 tons of ore, a decrease of some 10 percent, but produced approximately the same amount of lead due to the higher grade of ore. Development of the new "Cross Vein" on the 2,400- and 2,900-foot levels was a factor in increasing ore reserves some 213,000 tons during the year.[3] The New Jersey Zinc Co. maintained a high output at its Eagle mine near Gilman. Rico Argentine Mining Co. increased mill production to full capacity during the year with a substantial increase in recoverable lead in concentrates and also completed an extensive program of mine development and equipment installation. Federal Resources Corp. began limited mining and milling at the Camp Bird mine and expects to be at full operating capacity of 650 tons per day early in 1966. Dewatering of the Irene shaft in Leadville, a joint venture of American Smelting and Refining Co. and Resurrection Mining Co., was completed preparatory to development above the 1,750-foot level. The Sunnyside mine at Eureka, operated by Standard Metals Corp., produced 143,000 tons of lead-zinc ore in 1965 compared with 136,000 tons in 1964.[4]

The Hecla Mining Co. operated the Lucky Friday mine and the Star unit with production slightly below the 1964 level. Considerable development was accomplished with reserves at the Star Unit increased about 26 percent and the Lucky Friday shaft deepened preparatory to development of the 3,650-foot level.[5] The 17,000-foot crosscut from the Bunker Hill mine to the Crescent mine, driven at a depth 400 feet below sea level, was completed at midyear and development of the area started. An extensive exploration and development program was initiated in the lead-silver belt of the Coeur d'Alene area by several of the operating companies. Output of ore at the Bunker Hill mine declined and reserves of high grade lead-silver ore declined substantially. The Bunker Hill Co. concentrator operated on a 7-day-week basis treating 627,000 tons of ore from company mines, domestic purchased ore, and toll processing of high-grade ore from the Pine Point mine in Canada. Milling of the old Bunker Hill mine tailings was continued. The lead

[2] St. Joseph Lead Co. Annual Report. 1965, p. 3.

[3] Newmont Mining Corp. Annual Report. 1965, p. 7.

[4] United States Smelting, Mining and Refining Co. Annual Report. 1965, p. 6.

[5] Hecla Mining Co. Annual Report. 1965, p. 7.

Table 5.—Twenty-five leading lead-producing mines in the United States in 1965, in order of output

Rank	Mine	State	County	Operator	Source of lead
1	Viburnum	Missouri	Crawford, Iron, and Washington	St. Joseph Lead Co.	Lead ore.
2	Federal	do	St. Francois	do	Do.
3	Bunker Hill	Idaho	Shoshone	The Bunker Hill Co.	Lead-zinc ore.
4	United States and Lark	Utah	Salt Lake	United States Smelting, Refining and Mining Co.	Lead-zinc, lead ore.
5	Lucky Friday	Idaho	Shoshone	Hecla Mining Co.	Lead ore.
6	Indian Creek	Missouri	Washington	St. Joseph Lead Co.	Do.
7	Star-Morning unit	Idaho	Shoshone	Hecla Mining Co.	Lead-zinc ore.
8	Idarado	Colorado	Ouray and San Miguel	Idarado Mining Co.	Copper-lead-zinc ore.
9	Page	Idaho	Shoshone	American Smelting and Refining Co.	Lead-zinc ore.
10	Iron King	Arizona	Yavapai	Shattuck Denn Mining Corp.	Do.
11	United Park City	Utah	Summit and Wasatch	United Park City Mines Co.	Do.
12	Mayflower	do	Wasatch	Hecla Mining Co.	Do.
13	Butte Hill Zinc Mines	Montana	Silver Bow	The Anaconda Company	Zinc ore.
14	Pend Oreille	Washington	Pend Oreille	Pend Oreille Mines and Metals Co.	Lead-zinc ore.
15	Austinville and Ivanhoe Mines	Virginia	Wythe	The New Jersey Zinc Co.	Do.
16	Sunnyside	Colorado	San Juan	Standard Metals Corp.	Do.
17	Burgin	Utah	Utah	Kennecott Copper Corp.	Lead-zinc, lead ore.
18	Eagle	Colorado	Eagle	The New Jersey Zinc Co.	Zinc ore.
19	Keystone	do	Gunnison	McFarland & Hullinger	Lead-zinc ore.
20	Silver Star-Queens	Idaho	Blaine	Federal Resources Corp.	Silver ore.
21	Ophir	Utah	Tooele	United States Smelting, Refining and Mining Co.	Lead-zinc ore.
22	Van Stone	Washington	Stevens	American Smelting and Refining Co.	Zinc ore.
23	Emperius	Colorado	Mineral	Emperius Mining Co.	Lead-zinc ore.
24	Ground Hog	New Mexico	Grant	American Smelting and Refining Co.	Do.
25	Rico Argentine	Colorado	Dolores	Rico Argentine Mining Co.	Do.

smelter produced 93,800 tons of lead, including toll, compared with 86,300 tons in 1964.[6]

In Utah, production at the Mayflower mine of New Park Mining Co., operated by the Hecla Mining Co., was slightly higher in 1965 with 113,200 tons of ore mined, averaging 4.3 percent lead. The operating property was expanded by purchase of the Lucy mining claim and lease of other claims owned by New Park Mining Co. and San Diego Mining Co. Reserves of ore were increased by almost 370,000 tons.[7] Operation of the U.S. and Lark mine and Midvale concentrator by United States Smelting, Refining and Mining Co. was interrupted by a strike which began on May 4 and terminated July 22. Tonnage of company ore and receipts of custom ore was substantially reduced, although grade of ore was higher than the previous year. Concentrates were smelted at the Tooele smelter and the bullion refined at the subsidiary lead refinery in East Chicago, Ind.; 29,100 tons of lead bullion was treated at the refinery in comparison to 35,400 tons in 1964.[8] United Park City Mines Co. produced 95,000 tons of ore from company and lease operations at the Ontario and Keystone mines and produced 5,940 tons of lead. The Ontario mine production shaft was being deepened to the 2,400-foot level where improvement of grade and quantity of ore was indicated.[9] Kennecott Copper Corp. continued development on the 1,200-foot level of the Burgin No. 2 production shaft in the Tintic area and shipped development ore during the year.

In the Washington area, the Pend Oreille Mines and Metals Co. maintained output of lead at essentially the same level as in 1964. American Zinc, Lead and Smelting Co. continued development and construction of a mill at the Calhoun mine with a 1,200-ton-per-day capacity; operation was scheduled for early 1966. The Northport mines of American Smelting and Refining Co. maintained the production rate achieved in 1964 after startup in July 1964. Development was underway at the Lucky Joe Mining Co. lead-zinc property near Newport and at the Rocky Creek Silver Mine, Inc., in Pend Oreille County.

The Pan American mine, a joint venture of Grand Deposit Mining Co. and Combined Metals Reduction Co. in New Mexico, completed its first year of lead-zinc production. The ore is concentrated at the Caselton mill at a rate of about 27,000 tons per month. The Groundhog mine of American Smelting and Refining Co. near Bayard was closed by a strike in September after being reopened for production early in the year. Shattuck Denn Mining Corp. initiated production from the 2,400-foot level of the Iron King mine at Humboldt, Ariz., and the No. 7 shaft was extended 200 feet below this level.

Activity in the Tri-State area continued strong with a 12-percent increase in lead production reported for the combined Kansas-Oklahoma area in 1965. The Central Mill of The Eagle-Picher Co. continued to treat the major portion of concentrates produced. Production of lead as a byproduct of the zinc ores of Wisconsin, New York, and Virginia was lower than in 1964.

SMELTER AND REFINERY PRODUCTION

Production of refined lead at primary refineries declined in 1965 due to a decrease in feed materials of foreign origin. The domestic component of the feed materials, both primary and secondary, continued the upward trend exhibited in recent years and contributed 74 percent of the total refined lead compared with 66 percent in 1964. The increase in price of lead in December 1964 and stability at this price during the year resulted in an 11-percent increase in value of the refined lead to over $130 million, almost double the 1962 valuation. The increased production from secondary material also reflected the short supply of feed materials which reached a low of some 90,000 tons of raw material and material in process and gradually improved to about 98,000 tons at yearend. The 10 primary plants operated by the following companies—American Smelting and Refining Co., The Bunker Hill Co., St. Joseph Lead Co., The Eagle-Picher Co., International Smelting & Refining Co., and United States Smelting Lead Refinery, Inc.—operated throughout the year except for a short strike at the El Paso, Tex., smelter of American Smelting

[6] The Bunker Hill Co. Annual Report. 1965, p. 3.
[7] Hecla Mining Co. Annual Report. 1965, p. 9.
[8] United States Smelting, Refining and Mining Co. Annual Report. 1965, pp. 6–12.
[9] United Park City Mines Co. Annual Report. 1965, p. 3.

and Refining Co. Secondary smelters achieved a record-breaking production of almost 5 percent above the total output of metal and alloy in 1964 and a 26-percent increase in value to about $180 million. Secondary lead produced by both primary and secondary plants in 1965 comprised 41 percent of the domestic supply of refined and antimonial lead in comparison to 39 percent in 1964, including imports of metal. The 25 major companies producing secondary lead and reporting to the Bureau of Mines were listed in the Minerals Yearbook, 1963.

Refined Lead, Primary and Secondary.—Production of refined (soft) lead in the United States from all sources—primary, secondary, and remelt—amounted to 600,200 tons compared with 598,600 tons in 1964. Primary plants supplied 431,400 tons, of which 71 percent was from domestic ores and 3 percent from purchased scrap. Secondary plants produced a record 168,800 tons, 20 percent more than in 1964 and approximately 28 percent of the total; 38,300 tons of this secondary output was remelt lead.

Antimonial Lead, Primary and Secondary.—The lead content of domestically produced antimonial lead was 277,300 tons, slightly below the 279,100 tons produced in 1964. Of the total, 91 percent was produced at secondary plants and the remainder at primary plants and almost 98 percent was derived from scrap.

Raw Material Source.—Domestic ores in 1965 provided the largest tonnage of smelter feed since 1957 and represented 73 percent of the primary ores and bullion consumed, compared with 65 percent in 1964. The upward trend in smelting of scrap at primary smelters, initiated in 1962, was continued with scrap representing 3 percent of the total primary plant feed in 1965. Stocks of material at primary plants, including primary and secondary raw materials and materials in process, fluctuated in total between the high of 99,000 tons in February and the low of 90,000 tons in April and at yearend amounted to 98,500 tons. Primary raw materials trended upward after May to a yearend total of 57,000 tons while secondary materials declined to 1,700 tons and material in process amounted to 39,800 tons.

Consumption of scrap in 1965 totaled 748,300 tons, gross weight, of which 86 percent was old scrap, primarily scrapped batteries, and 14 percent was new scrap from drosses and residues. The response of the scrap metal industry to the improved market for lead materials in 1965 was satisfactory and despite the upward trend in consumption of scrap, stocks at smelters reflected only a gradual decline from the high of 75,000 tons at the end of January to 55,000 tons on hand at the end of the year.

Table 6.—Refined lead produced at primary refineries in the United States, by source material

(Short tons)

	1956–60 (average)	1961	1962	1963	1964	1965
Refined lead:						
From primary sources:						
Domestic ores and base bullion	284,023	288,078	245,645	239,660	294,254	305,007
Foreign ores and base bullion	169,850	161,487	130,418	155,072	155,175	113,242
Total	453,873	449,565	376,063	394,732	449,429	418,249
From secondary sources	3,128	1,569	1,842	3,741	8,505	13,140
Grand total	457,001	451,134	377,905	398,473	457,934	431,389
Average sales price per pound	$0.130	$0.103	$0.093	$0.108	$0.131	$0.156
Calculated value of primary refined lead (thousands)[1]	$118,007	$92,610	$69,948	$85,262	$117,750	$130,494

[1] Excludes value of refined lead produced from scrap at primary refineries.

Table 7.—Antimonial lead produced at primary lead refineries in the United States

Year	Production (short tons)	Antimony content		Lead content by difference (short tons)			
		Short tons	Percent	From domestic ore	From foreign ore	From scrap	Total
1956–60 (average)	50,515	2,543	5.1	6,586	6,366	35,020	47,972
1961	35,080	1,894	5.4	12,988	11,978	8,220	33,186
1962	33,325	2,249	6.7	14,838	12,545	3,693	31,076
1963	18,818	1,890	10.0	4,553	4,703	7,672	16,928
1964	24,023	1,995	8.3	4,522	4,085	13,421	22,028
1965	27,895	1,984	7.1	2,809	3,803	19,299	25,911

Table 8.—Stocks and consumption of new and old lead scrap in the United States in 1965

(Short tons, gross weight)

Class of consumers and type of scrap	Stocks Jan. 1 [r]	Receipts	Consumption			Stocks Dec. 31
			New scrap	Old scrap	Total	
Smelters and refiners:						
Soft lead	3,782	65,664	—	67,003	67,003	2,443
Hard lead	1,044	16,844	—	17,000	17,000	888
Cable lead	1,781	27,484	—	28,427	28,427	838
Battery-lead plates	38,294	452,660	—	468,431	468,431	22,523
Mixed common babbitt	267	3,597	—	3,679	3,679	185
Solder and tinny lead	339	13,576	—	13,722	13,722	193
Type metals	1,126	36,750	—	35,597	35,597	2,279
Drosses and residues	24,286	102,338	101,694	—	101,694	24,930
Total	70,919	718,913	101,694	633,859	735,553	54,279
Foundries and other manufacturers:						
Soft lead	27	389	—	360	360	56
Hard lead	107	—	—	64	64	43
Cable lead	12	79	—	88	88	3
Battery-lead plates	—	—	—	—	—	—
Mixed common babbitt	97	12,315	—	12,265	12,265	147
Solder and tinny lead	—	—	—	—	—	—
Type metals	—	—	—	—	—	—
Drosses and Residues	202	69	5	—	5	266
Total	445	12,852	5	12,777	12,782	515
All consumers:						
Soft lead	3,809	66,053	—	67,363	67,363	2,499
Hard lead	1,151	16,844	—	17,064	17,064	931
Cable lead	1,793	27,563	—	28,515	28,515	841
Battery-lead plates	38,294	452,660	—	468,431	468,431	22,523
Mixed common babbitt	364	15,912	—	15,944	15,944	332
Solder and tinny lead	339	13,576	—	13,722	13,722	193
Type metals	1,126	36,750	—	35,597	35,597	2,279
Drosses and residues	24,488	102,407	101,699	—	101,699	25,196
Grand total	71,364	731,765	101,699	646,636	748,335	54.794

[r] Revised.

Table 9.—Secondary metal recovered[1] from lead and tin scrap in the United States in 1965, by type of products
(Short tons, gross weight)

	Lead	Tin	Antimony	Other	Total
Refined pig lead	143,641	-----	-----	---	143,641
Remelt lead	38,273	-----	-----	---	38,273
Total	181,914	-----	-----	---	181,914
Refined pig tin	------	3,433	-----	---	3,433
Remelt tin	------	376	-----	---	376
Total	------	3,809	-----	---	3,809
Lead and tin alloys:					
Antimonial lead	270,653	341	16,574	315	287,883
Common babbitt	17,264	945	1,593	146	19,948
Genuine babbitt	60	234	21	9	324
Solder	34,723	6,051	549	58	41,381
Type metals	36,882	2,200	5,306	9	44,397
Cable lead	18,892	1	205	---	19,098
Miscellaneous alloys	1,293	584	73	57	2,007
Total	379,767	10,356	24,321	594	415,038
Tin content of chemical products	------	1,035	-----	---	1,035
Grand total	561,681	15,200	24,321	594	601,796

[1] Most of the figures herein represent actual reported recovery of metal from scrap.

Table 10.—Secondary lead recovered in the United States
(Short tons)

	1956–60 (average)	1961	1962	1963	1964	1965
As metal:						
At primary plants	3,128	1,569	1,842	3,741	8,505	13,140
At other plants	126,796	139,100	116,626	130,788	140,702	168,774
Total	129,924	140,669	118,468	134,529	149,207	181,914
In antimonial lead:						
At primary plants	35,020	8,220	3,693	7,672	13,421	19,299
At other plants	182,084	197,349	225,699	237,125	257,101	251,354
Total	217,104	205,569	229,392	244,797	270,522	270,653
In other alloys	116,784	106,554	96,342	114,145	121,853	123,252
Grand total:						
Quantity	463,812	452,792	444,202	493,471	541,582	575,819
Value (thousands)	$121,367	$93,275	$82,622	$106,590	$141,894	$179,656

Table 11.—Lead recovered from scrap processed in the United States, by kind of scrap and form of recovery
(Short tons)

Kind of scrap	1964	1965	Form of recovery	1964	1965
New scrap:			As soft lead:		
Lead-base	64,876	72,234	At primary plants	8,505	13,140
Copper-base	6,490	7,323	At other plants	140,702	168,774
Tin-base	555	528			
			Total	149,207	181,914
Total	71,921	80,085			
			In antimonial lead[1]	270,522	270,653
Old scrap:			In other lead alloys	99,168	108,170
Battery-lead plates	304,523	313,146	In copper-base alloys	22,618	15,022
All other lead-base	144,900	161,963	In tin-base alloys	67	60
Copper-base	20,233	20,621			
Tin-base	5	4	Total	392,375	393,905
Total	469,661	495,734	Grand total	541,582	575,819
Grand total	541,582	575,819			

[1] Includes 13,421 tons of lead recovered in antimonial lead from secondary sources at primary plants in 1964 and 19,299 tons in 1965.

CONSUMPTION AND USES

Industrial requirements for lead in the United States increased for the fourth successive year and, at 1,241,000 tons, exceeded the previous high of 1,238,000 tons established in 1950. The 1965 gain amounted to 3.3 percent, identical with the 1964 gain. Consumption exceeded 100,000 tons in each month, except for the normal seasonal decline in July, and amounted to a daily average requirement of 3,401 tons of lead. Percentage increase was approximately equal for soft lead, antimonial lead, and lead in other alloys with soft lead representing 67 percent and antimonial lead 27 percent of the total, excluding direct use of scrap and lead in leaded zinc oxide and other nonspecified pigments. An increased requirement was also reported for these direct and unclassified uses and, in fact, the only decrease was as lead consumed in copper-base scrap products.

Total consumption of lead in metal products, after almost identical consumption in 1963–64, resumed the upward trend. The increase in recent years in use of lead in ammunition, brass-bronze, foil, solder, and storage batteries continued in 1965. A significant change was the increased amount used in cable covering and type metal which had previously shown a downward trend. The decline continued in calking lead and casting metals. Use in bearing metals, collapsible tubes, pipes and bends, and sheet lead decreased in 1965 after a slight recovery in demand in 1964.

Pigments required 109,000 tons, an increase of 5,200 tons, essentially all in the form of red lead and litharge and a small gain was reported for gasoline antiknock compounds. The use of lead in chemicals, essentially all for gasoline antiknock compounds, was 226,000 tons compared with a 169,000-ton average for the relatively stable period 1957–61. Miscellaneous and unclassified uses of lead increased slightly, with weights and ballast accounting for most of the enlarged need.

Storage batteries accounted for the largest quantity of lead, 455,300 tons compared with 429,300 tons in 1964, both in the form of soft lead and lead oxide. The Association of Battery Manufacturers, Inc., report-

Table 12.—Lead consumption in the United States, by products

(Short tons)

Product	1964	1965
Metal products:		
Ammunition	56,493	57,322
Bearing metals	22,754	21,600
Brass and bronze	23,328	23,699
Cable covering	56,225	59,645
Calking lead	73,628	66,584
Casting metals	6,961	5,046
Collapsible tubes	14,904	10,893
Foil	3,976	4,805
Pipes, traps, and bends	20,480	19,837
Sheet lead	29,605	27,569
Solder	71,186	77,819
Storage batteries:		
Battery grids, posts, etc.	221,594	235,641
Battery oxides	207,754	219,706
Terne metal	1,609	2,109
Type metal	25,374	33,416
Total	835,871	865,691
Pigments:		
White lead	8,802	8,414
Red lead and litharge	74,802	79,853
Pigment colors	11,921	12,553
Other [1]	8,111	8,063
Total	103,636	108,883
Chemicals:		
Gasoline antiknock additives	223,466	225,203
Miscellaneous chemicals	451	346
Total	223,917	225,549
Miscellaneous uses:		
Annealing	5,699	5,719
Galvanizing	1,592	1,775
Lead plating	179	240
Weights and ballast	12,760	14,135
Total	20,230	21,869
Other, unclassified uses	18,484	19,490
Grand total [2]	1,202,138	1,241,482

[1] Includes lead content of leaded zinc oxide and other pigments.
[2] Includes lead which went directly from scrap to fabricated products.

Table 13.—Lead consumption in the United States, by months

(Short tons)

Month	1964	1965
January	107,603	104,881
February	94,425	100,024
March	92,844	104,192
April	98,981	100,743
May	98,786	100,762
June	102,448	104,363
July	91,438	90,836
August	99,676	101,417
September	101,765	107,198
October	105,571	113,162
November	101,985	110,509
December	106,616	103,395
Total [1]	1,202,138	1,241,482

[1] Includes lead content of leaded zinc oxide and other pigments and lead which went directly from scrap to fabricated products.

Table 14.—Lead consumption in the United States in 1965, by class of products and types of material

(Short tons)

Product	Soft lead	Lead in antimonial lead	Lead in alloys	Lead in copper-base scrap	Total
Metal products	211,013	83,567	51,389	17,809	363,778
Storage batteries	227,134	228,213	-----	-----	455,347
Pigments	104,944	207	-----	-----	105,151
Chemicals	225,543	6	-----	-----	225,549
Miscellaneous	11,685	9,548	111	-----	21,344
Unclassified	15,869	2,474	703	-----	19,046
Total	796,188	324,015	52,203	17,809	[1] 1,190,215

[1] Excludes 47,535 tons of lead which went directly from scrap to fabricated products and 3,732 tons of lead contained in leaded zinc oxide and other nonspecified pigments.

Table 15.—Lead consumption in the United States in 1965, by States [1]

(Short tons)

State	Refined soft lead	Lead in antimonial lead	Lead in alloys	Lead in copper-base scrap	Total
California	80,839	25,483	6,940	1,247	114,509
Colorado	1,512	2,647	171	-----	4,330
Connecticut	13,038	13,117	89	1,211	27,455
District of Columbia	139	1	-----	-----	140
Florida	4,185	4,474	-----	-----	8,659
Georgia	32,859	10,313	2,566	11	45,749
Illinois	79,275	41,070	10,935	2,122	133,402
Indiana	74,558	44,990	2,084	1,365	122,997
Kansas	8,646	9,308	11	419	18,384
Kentucky	3,047	4,268	1	-----	7,316
Maryland	6,438	15,425	757	-----	22,620
Massachusetts	6,270	3,893	354	207	10,724
Michigan	21,243	19,165	1,910	620	42,938
Missouri	37,226	6,079	88	1,407	44,800
Nebraska	4,795	943	11	649	6,398
New Jersey	133,552	19,813	10,953	752	165,070
New York	39,867	3,084	8,030	839	51,820
Ohio	12,899	5,666	3,047	1,198	22,810
Pennsylvania	51,549	36,598	867	2,855	91,869
Rhode Island	1,808	506	24	-----	2,338
Tennessee	131	8,891	64	126	9,212
Virginia	2,197	1,244	605	981	5,027
Washington	6,731	405	291	-----	7,427
West Virginia	15,786	3,419	-----	-----	19,205
Wisconsin	1,767	3,343	107	153	5,370
Alabama and Mississippi	682	1,981	-----	707	3,370
Arkansas and Oklahoma	3,896	3,258	36	-----	7,190
Hawaii and Oregon	467	2,703	4	174	3,348
Iowa and Minnesota	4,566	8,176	293	147	13,182
Louisiana and Texas	131,608	15,258	1,940	385	149,191
Montana and Idaho	7,759	------	-----	-----	7,759
New Hampshire, Maine, Delaware	6,071	3,900	25	234	10,230
North and South Carolina	651	4,594	-----	-----	5,245
Utah, Nevada, Arizona	131	------	-----	-----	131
Total	796,188	324,015	52,203	17,809	1,190,215

[1] Excludes 47,535 tons of lead which went directly from scrap to fabricated products and 3,732 tons of lead contained in leaded zinc oxide and other nonspecified pigments.

ed shipments of S.L.I. type batteries (starting-lighting-ignition) of 41.7 million units, a record number exceeding the 41.1 million in 1963 and some 3 million more than in 1964. Of the batteries shipped, about 73 percent were designated as replacement batteries and 26 percent as original equipment. About 1 percent was for export.

While consumption of lead was reported in 44 States, the industry was concentrated in 14 States consuming 87 percent of the total; 10 of these States reported an increase. The increase in consumption in

Missouri was of interest because of its position as the leading producer.

Most of the increase in lead consumption was related to the sophisticated needs of modem society with respect to transport, communications, and nuclear power. Lead-acid batteries remained the most compact, economical source of packaged power for automotive starting, lighting, and ignition and continued progress was made in the employment of battery-powered vehicles in the industrial and recreational fields. The greater number of vehicles used in transportation and the increasing mileage per vehicle continued to raise the amount of lead required for batteries and gasoline additives. Expansion of the use of lead pigments for corrosion resistance and highway traffic marking paints was notable. In the nuclear area, the need for the radiation shielding properties of lead for reactors was also accompanied by a mounting need for lead in nuclear-fuel shipping casks and other special applications requiring space saving and portability, as well as temporary shielding achieved by use of lead shot and lead in brick form. The development of dispersion strengthening techniques using lead oxide as the dispersed phase for rolled or extruded lead products has enabled adoption of new fabrication techniques and manufacture of thinner, stronger lead sheaths for cables, lighter battery grids, and stronger sheet and tube. The ability of lead to maintain its competitive position in the transportation, communication, nuclear, and construction areas was thus further strengthened in 1965.

LEAD PIGMENTS

Production of lead pigments in the United States increased in all categories except white lead and consumed 321,200 tons of lead, 7 percent more than in 1964 and the fifth successive annual increase in use of lead for pigments. Requirements for black oxide, a mixture of litharge and metallic lead for battery plates, represented the largest increase in pig lead use, followed by litharge and red lead. Use in white lead and leaded zinc oxide continued to decline. Production of basic lead sulfate is not published and lead silicate for enamels and glazes derived from litharge is included with litharge.

White Lead.—The production of white lead, both dry and in oil, totaled 11,500 tons and continued its downward trend after a slight increase in 1964. The decline was especially reflected in the paint and ceramics industries. Other uses of white lead in various chemicals, greases, stabilizers, and plasticizers, however, increased significantly again in 1965.

Red Lead.—Requirements increased in 1965 thus continuing the upward trend of recent years. Only 46 percent was used in paints and the predominant requirement was by the oil and rubber industries along with many small industrial applications.

Litharge.—Shipments of litharge were 7 percent more than in 1964. An increase was registered in all categories except varnish which is predominantly reported as used in paints rather than varnish. To avoid disclosing company confidential data, a large percentage of the litharge shipped is designated "Other." Production of leaded litharge, known to the trade as "black oxide" and used by battery manufacturers, increased more than 8 percent and the 184,800 tons of lead consumed in production of this item compared with 133,600 tons in 1960.

Prices.—The quoted price of lead pigments was unchanged during the year in line with the stable domestic price of lead metal. The price of white lead in carload lots, freight allowed, was 20.5 cents per pound, established on November 2, 1964. The average value per ton of white lead at the plant was $425 for the dry type and $646 for the oil mixed in terms of weight of white lead. Red lead was quoted at 19.75 cents per pound, effective December 28, 1964, and the average value per ton at plant was $375. The price of litharge was 19.25 cents per pound, effective December 28, 1964, and the average value per ton at plant was $359. The value of the shipments of white lead, red lead, and litharge in 1965 was $56.3 million, 21 percent more than the 1964 value.

Foreign Trade.—The individual export classification of lead arsenate was discontinued beginning in calendar year 1965

Table 16.—Production and shipments of lead pigments [1] and oxides in the United States

Pigment	1964 Production (short tons)	1964 Shipments Short tons	1964 Shipments Value [2] Total	1964 Shipments Value [2] Average per ton	1965 Production (short tons)	1965 Shipments Short tons	1965 Shipments Value [2] Total	1965 Shipments Value [2] Average per ton
White lead:								
Dry	9,298	10,432	$3,997,056	$383	8,787	10,266	$4,358,293	$425
In oil [1, 3]	3,298	5,014	2,600,233	519	2,753	4,407	2,845,789	646
Total	12,596	15,446	6,597,289	427	11,540	14,673	7,204,082	491
Red lead	27,812	28,090	9,172,654	327	29,815	29,663	11,103,069	375
Litharge	100,230	99,393	30,653,873	308	105,634	105,892	37,963,871	359
Black oxide	178,038	-----	---------	----	192,655	------	---------	----

[1] Except for basic lead sulfate, figures withheld to avoid disclosing individual company confidential data.
[2] At plant, exclusive of container.
[3] Weight of white lead only, but value of paste.

Table 17.—Lead content of lead and zinc pigments [1] and lead oxides produced by domestic manufacturers, by sources

(Short tons)

Pigment	1964 Lead in pigments produced from— Ore Domestic	1964 Ore Foreign	1964 Pig lead	1964 Total lead in pigments	1965 Lead in pigments produced from— Ore Domestic	1965 Ore Foreign	1965 Pig lead	1965 Total lead in pigments
White lead	----	-----	10,077	10,077	----	-----	9,232	9,232
Red lead	----	-----	25,212	25,212	----	-----	27,027	27,027
Litharge	----	-----	93,214	93,214	----	-----	98,240	98,240
Black oxide	----	-----	170,394	170,394	----	-----	184,774	184,774
Leaded zinc oxide	1,398	593	------	1,991	1,345	561	------	1,906
Total	1,398	593	298,897	300,888	1,345	561	319,273	321,179

[1] Excludes lead in basic lead sulfate; figures withheld to avoid disclosing individual company confidential data.

Table 18.—Distribution of white lead (dry and in oil) shipments,[1] by industries

(Short tons)

Industry	1956–60 (average)	1961	1962	1963	1964	1965
Paints	16,824	12,086	12,054	11,358	10,534	9,185
Ceramics	406	141	137	138	143	133
Other	3,729	3,996	4,008	3,906	4,769	5,355
Total	20,959	16,223	16,199	15,402	15,446	14,673

[1] Excludes basic lead sulfate; figures withheld to avoid disclosing individual company confidential data.

Table 19.—Distribution of red lead shipments, by industries

(Short tons)

Industry	1956–60 (average)	1961	1962	1963	1964	1965
Paints	13,810	12,895	13,716	13,213	14,133	13,725
Storage batteries	W	W	W	W	W	W
Ceramics	W	W	637	W	W	W
Other	10,490	9,961	11,164	13,032	13,957	15,938
Total	24,300	22,856	25,517	26,245	28,090	29,663

W Withheld to avoid disclosing individual company confidential data; included with "Other."

Table 20.—Distribution of litharge shipments, by industries
(Short tons)

Industry	1956–60 (average)	1961	1962	1963	1964	1965
Ceramics	W	14,393	17,752	17,762	20,508	21,013
Chrome pigments	W	W	W	5,763	6,426	W
Floor covering	W	W	W	W	W	W
Insecticides	W	W	W	W	W	1,161
Oil refining	2,989	2,147	2,404	1,973	2,142	2,886
Rubber	1,598	1,243	1,792	1,702	1,978	2,153
Storage batteries	W	W	W	W	W	W
Varnish	3,644	3,394	4,083	4,240	4,004	3,763
Other	98,795	77,773	77,366	72,394	64,335	74,916
Total	107,026	98,950	103,397	103,834	99,393	105,892

W Withheld to avoid disclosing individual company confidential data; included with "Other."

Table 21.—U.S. exports of lead pigments and compounds

Kind	1964		1965	
	Short tons	Value (thousands)	Short tons	Value (thousands)
Lead pigments [1]	1,680	$608	2,286	$890
Lead arsenate	936	278	NA	NA
Total	2,616	886	2,286	890

NA Not available.
[1] Includes white lead, red lead, and litharge.

Table 22.—U.S. imports for consumption of lead pigments and compounds

Kind	1964		1965	
	Short tons	Value (thousands)	Short tons	Value (thousands)
White lead	2,674	$748	1,631	$581
Red lead	1,613	351	524	145
Litharge	19,763	4,001	22,208	5,375
Other lead pigments	5	13	5	15
Other lead compounds	195	61	203	67
Total	24,250	5,174	24,571	6,183

and this compound was to be included with pigments and oxides. Total exports thus declined 13 percent in tonnage, although the value increased slightly. The import of litharge, accounting for 90 percent of the total imports of lead pigments, oxides, and compounds, increased 12 percent in comparison to 1964 receipts while a substantial decrease occurred in deliveries of white lead and red lead. The total import tonnage in 1965 was, however, only 320 tons above the 1964 total. Value per ton of imports increased for each type of material and the total valuation of $6.2 million was almost 20 percent above the 1964 amount.

STOCKS

The continuing high level of demand for lead and limitation on imports of foreign concentrates until termination on October 22 resulted in a decline in producer stocks of refined and antimonial lead from 38,100 tons at the end of 1964 to a low of 24,300 tons at the end of September and only a small buildup thereafter to end the year at 25,200 tons. In comparison, producer stocks at the close of 1961 totaled 205,600 tons. Stocks of ore and base bullion for smelting and refining, amounting to 46,300 tons at the end of 1964, reached a low of 41,000 tons at the end of May and then gradually increased at yearend to 58,200 tons.

Stocks reported by the American Bureau of Metal Statistics indicate an additional 18,000 tons of lead in base bullion in process at refineries or in transit to refineries and about 30,300 tons of ore and matte in process at primary smelters. The total stocks of lead in metal, primary and secondary materials at primary plants was thus 131,700 tons at the end of 1965 compared with 141,900 tons at the close of 1964.

Consumer and secondary smelter stocks of lead in all forms—soft lead, antimonial lead, lead alloys, and copper-base scrap—declined from 113,400 tons to 109,200 tons. Soft lead stocks dropped to 56 percent of the total and antimonial lead increased to 33 percent compared with 61 percent and 31 percent, respectively, in 1964. As of December 31, 1965, government stocks of lead totaled 1,284,600 tons.

Table 23.—Stocks of lead at primary smelters and refineries in the United States, Dec. 31

(Short tons)

Stocks	1956–60 (average)	1961	1962	1963	1964	1965
Refined pig lead	107,325	195,200	136,544	48,780	34,100	17,524
Lead in antimonial lead	11,095	10,354	5,975	7.890	4,012	7,680
Lead in base bullion	13,669	16,978	10,392	14,947	13,218	10,735
Lead in ore and matte	47,205	39,570	43,750	49,219	33,068	47,504
Total	179,294	262,102	196,661	120,836	84,398	83,443

Table 24.—Consumer stocks of lead in the United States, Dec. 31, by types of material

(Short tons, lead content)

Year	Refined soft lead	Lead in antimonial lead	Lead in alloys	Lead in copper-base scrap	Total
1961	55,951	33,633	8,298	1,258	99,140
1962	51,121	34,389	6,817	1,169	93,496
1963	71,558	40,606	6,558	1,208	119,930
1964	69,361	35,163	7,933	987	113,444
1965	61,586	36,190	10,406	1,013	109,195

PRICES

The quoted New York price for common lead remained at 16 cents per pound, effective December 11, 1964, throughout the year. Government sales of stockpile-surplus lead in April were made at 15.75 cents per pound for common, corroding, and common desilverized lead and 15.85 cents per pound for chemical grade. Sales conducted in the fourth quarter were at a price of 15.5 cents per pound for common, corroding, and desilverized lead, 15.6 cents per pound for chemical grade lead, and 17.9 cents per pound for antimonial lead. The Government price was f.o.b. at the various stockpile depots.

Table 25.—Average monthly and yearly quoted prices of lead at St. Louis, New York and London [1]

(Cents per pound)

Month	1964			1965		
	St. Lous	New York	London [2]	St. Louis	New York	London [2]
January	12.80	13.00	9.87	15.80	16.00	15.73
February	12.80	13.00	10.11	15.80	16.00	17.64
March	12.80	13.00	10.14	15.80	16.00	17.88
April	12.80	13.00	10.29	15.80	16.00	15.99
May	12.80	13.00	11.05	15.80	16.00	13.72
June	12.80	13.00	11.15	15.80	16.00	12.61
July	12.80	13.00	12.25	15.80	16.00	12.28
August	13.04	13.24	13.58	15.80	16.00	12.30
September	13.80	14.00	13.87	15.80	16.00	13.11
October	14.32	14.52	14.96	15.80	16.00	13.93
November	14.80	15.00	16.47	15.80	16.00	13.59
December	15.46	15.66	17.34	15.80	16.00	13.66
Average	13.42	13.62	12.59	15.80	16.00	14.37

[1] St. Louis: Metal Statistics, 1966. New York: Metal Statistics. London: E&MJ Metal and Mineral Markets.
[2] Based on monthly rates of exchange by Federal Reserve Board.

Table 26.—U.S. exports of lead, by countries [1]

(Short tons)

Destination	1956–60 (average)	1961	1962	1963	1964	1965
Ore, matte, base bullion (lead content): [2]						
North America	621	3	------	4	------	------
South America	------	------	------	------	12	------
Europe	6	77	7	------	------	------
Asia	272	4,357	2,891	------	7	------
Total ore, matte, base bullion	899	4,437	2,898	4	19	------
Pigs, bars, anodes:						
North America:						
Canada	72	80	39	112	104	213
Mexico	22	24	25	23	10	128
Other	152	39	66	95	209	426
Total	246	143	130	230	323	767
South America	141	794	588	188	105	1,053
Europe	546	3	28	153	7,330	4,366
Africa	2	12	9	10	33	42
Asia:						
Japan	697	------	------	------	553	585
Philippines	313	227	81	26	130	129
Taiwan	849	874	950	------	575	73
Other	216	78	321	478	1,115	778
Total	2,075	1,179	1,352	504	2,373	1,565
Oceania	(3)	2	1	3	11	18
Total pigs, bars, anodes	3,010	2,133	2,108	1,088	10,175	7,811
Scrap:						
North America	249	54	37	14	400	243
South America	------	2	15	8	------	------
Europe:						
Belgium-Luxembourg	5	688	328	1,182	1,566	------
Germany, West	260	253	119	498	632	161
Italy	40	162	289	------	15	2,348
Netherlands	401	251	159	72	296	235
Spain	------	------	53	12	112	------
United Kingdom	485	1,167	786	519	1,293	83
Yugoslavia	------	------	------	------	2,943	584
Other	46	------	63	29	42	126
Total	1,237	2,521	1,797	2,312	6,899	3,537
Asia:						
Japan	65	2,579	593	85	5,847	12
Other	(3)	7	19	2	2	1
Total	65	2,586	612	87	5,849	13
Total scrap	1,551	5,163	2,461	2,421	13,148	3,793
Grand total	5,460	11,733	7,467	3,513	23,342	11,604

[1] In addition foreign lead was reexported as follows: Ore, matte, and base bullion, 1956–60 (average), 2 tons; 1961–64, none; 1965, class no longer separately classified. Pigs, bars, anodes, 1956–60 (average), 91 tons; 1961, 294 tons; 1962–63, none; 1964, 4,367 tons; 1965, 659 tons. Scrap, 1956–60 (average), 2 tons; 1961–64, none; 1965, 99 tons.

[2] Effective Jan. 1, 1965, no longer separately classified.

[3] Less than ½ unit.

Table 27.—U.S. imports [1] of lead, by countries

(Short tons)

Country	1956–60 (average)	1961	1962	1963	1964	1965
Ore, flue dust, and matte (lead content):						
North America:						
Canada	27,371	34,361	27,728	23,634	27,951	43,622
Guatemala	4,570	9,817	2,135	305	5	18
Honduras	3,610	5,512	4,965	6,809	6,375	8,712
Mexico	2,245	1,166	1,180	1,071	1,069	760
Other	1,127	------	------	------	------	------
Total	38,923	50,856	36,008	31,819	35,400	53,112
South America:						
Bolivia	14,091	11,370	8,242	9,791	6,073	5,096
Colombia	713	722	439	9	------	677
Peru	50,953	28,970	32,999	43,950	28,243	26,419
Other	696	610	------	------	------	------
Total	66,453	41,672	41,680	53,750	34,316	32,192
Europe	195	300	280	------	------	------

Table 27.—U.S. imports[1] of lead, by countries—Continued

Country	1956–60 (average)	1961	1962	1963	1964	1965
Ore, flue dust, and matte (lead content)—Continued						
Africa:						
Morocco	1,053	------	------	------	------	23
South Africa, Republic of	40,914	34,089	33,881	34,273	34,080	10,570
Total	41,967	34,089	33,881	34,273	34,080	10,593
Asia:						
Philippines	942	238	57	23	58	106
Other	303	------	181	244	117	------
Total	1,245	238	238	267	175	106
Oceania: Australia	27,428	20,031	26,544	27,633	19,286	26,658
Total ore, flue dust, and matte	176,211	147,186	138,631	147,742	123,257	122,661
Base bullion (lead content):						
North America	65	362	5	851	1,449	93
South America	124	60	2,080	2,647	603	25
Europe	------	(2)	------	2	------	(2)
Asia	(2)	------	------	------	------	------
Oceania	------	------	2,514	1,937	2,786	448
Total base bullion	189	422	4,599	5,437	4,838	566
Pigs and bars (lead content):						
North America:						
Canada	30,675	54,717	56,807	29,619	30,728	31,697
Mexico	91,933	81,328	65,892	74,466	71,728	73,546
Other	67	3	------	------	114	------
Total	122,675	136,048	122,699	104,085	102,570	105,243
South America:						
Peru	33,104	26,195	22,115	23,486	24,510	26,132
Other	349	------	------	36	------	38
Total	33,453	26,195	22,115	23,522	24,510	26,170
Europe:						
Belgium-Luxembourg	2,209	------	2,980	11,235	------	197
Denmark	------	------	------	------	700	514
Germany, West	1,656	842	914	277	5,017	1,653
Spain	7,513	8,529	4,104	7,694	949	243
United Kingdom	2,522	------	335	3,555	562	514
Yugoslavia	35,742	30,347	31,909	31,063	30,544	28,640
Other	2,629	------	12	------	834	531
Total	52,271	39,718	40,254	53,824	38,606	32,292
Africa	6,339	------	------	------	------	1,224
Asia: Japan	------	------	------	------	------	4,638
Oceania: Australia	70,229	54,891	72,133	45,596	42,158	51,105
Total pigs and bars	284,967	256,852	257,201	227,027	207,844	220,672
Reclaimed scrap, etc. (lead content):						
North America:						
Canada	3,335	1,441	1,279	3,243	1,959	2,919
Mexico	3,314	2,294	688	55	164	315
Other	605	45	186	162	46	10
Total	7,254	3,780	2,153	3,460	2,169	3,244
South America	151	------	------	------	------	------
Europe	420	2	17	13	------	6
Asia: Japan	9	------	2	------	------	42
Oceania: Australia	2,654	1,160	149	5,402	2,885	978
Total reclaimed scrap, etc.	10,488	4,942	2,321	8,875	5,054	4,270
Grand total	471,855	409,402	402,752	389,081	340,993	348,169

[1] Data are general imports; that is, they include lead imported for immediate consumption plus material entering the country under bond.
[2] Less than ½ unit.

Table 28.—U.S. Imports for consumption [1] of lead, by countries

(Short tons)

Country	1956–60 (average)	1961	1962	1963	1964	1965
Ore, flue dust, and matte (lead content):						
North America:						
Canada	29,001	31,439	29,523	30,937	27,973	33,637
Guatemala	4,872	5,527	4,691	387	5	18
Honduras	4,162	4,803	5,959	8,692	6,489	7,406
Mexico	2,834	1,060	1,899	1,850	458	577
Other	1,063	------	------	------	------	------
Total	41,932	42,829	42,072	41,866	34,925	41,638
South America:						
Bolivia	15,710	10,470	7,479	10,055	8,373	3,885
Colombia	740	514	480	95	------	439
Peru	54,668	32,318	32,327	32,140	32,314	30,732
Other	1,279	401	6	------	------	------
Total	72,397	43,703	40,292	42,290	40,687	35,056
Europe	30	------	220	------	------	------
Africa:						
Morocco	1,048	------	2	------	------	23
South Africa, Republic of	39,684	29,736	29,756	29,740	29,760	28,712
Other	369	------	------	------	------	------
Total	41,101	29,736	29,758	29,740	29,760	28,735
Asia:						
Philippines	938	380	111	31	86	96
Other	252	------	------	223	121	------
Total	1,190	380	111	254	207	96
Oceania:						
Australia	30,792	20,132	20,627	21,295	22,488	23,408
Other	32	------	------	------	------	------
Total	30,824	20,132	20,627	21,295	22,488	23,408
Total ore, flue dust, and matte	187,474	136,780	133,080	135,445	128,067	128,933
Base bullion (lead content):						
North America	65	134	5	964	3,094	93
South America	95	102	2,078	854	603	25
Europe	------	(2)	------	3	560	(2)
Oceania	------	------	------	1,937	2,786	448
Total base bullion	160	236	2,083	3,758	7,043	566
Pigs and bars (lead content):						
North America:						
Canada	30,677	54,902	56,807	29,674	30,777	31,697
Mexico	89,980	71,289	68,147	78,254	72,078	73,386
Other	58	6	-----	-----	45	69
Total	120,715	126,197	124,954	107,928	102,900	105,152
South America:						
Peru	33,116	26,195	22,103	22,224	23,114	27,484
Other	349	------	------	35	------	38
Total	33,465	26,195	22,103	22,259	23,114	27,522
Europe:						
Belgium-Luxembourg	2,193	41	1,685	4,366	4,375	422
Denmark	1,006	------	------	------	700	514
Germany, West	1,599	911	614	577	3,692	2,161
Spain	7,330	8,775	3,958	7,713	847	22
United Kingdom	2,501	16	------	1,462	1,697	425
Yugoslavia	35,697	30,230	32,240	31,063	30,544	28,639
Other	1,362	------	12	------	834	531
Total	51,688	39,973	38,509	45,181	42,689	32,714

Table 28.—U.S. Imports for consumption [1] of lead, by countries—Continued

(Short tons)

Country	1956–60 (average)	1961	1962	1963	1964	1965
Pigs and bars (lead content)—Continued						
Africa:						
Morocco	6,096	4	------	------	------	112
South Africa, Republic of	548	113	------	------	------	1,060
Other	------	------	------	------	------	112
Total	6,644	117	------	------	------	1,284
Asia: Japan	------	------	------	------	------	4,363
Oceania: Australia	69,818	54,945	72,300	45,030	42,437	50,484
Total pigs and bars	282,330	247,427	257,866	220,398	211,140	221,519
Reclaimed scrap, etc. (lead content):						
North America:						
Canada	3,335	1,441	1,240	3,218	1,716	3,127
Mexico	3,816	2,291	612	55	164	328
Other	648	91	58	288	26	55
Total	7,799	3,823	1,910	3,561	1,906	3,510
South America	202	------	------	903	------	15
Europe	512	2	17	12	1	22
Asia: Japan	9	1	2	------	------	42
Oceania: Australia	1,509	68	149	10,929	------	23
Total reclaimed scrap, etc.	10,031	3,894	2,078	15,405	1,907	3,612
Sheets, pipe, and shot:						
North America:						
Canada	231	114	49	35	78	83
Mexico	2,432	55	------	------	------	265
Other	4	------	------	------	------	------
Total	2,667	169	49	35	78	348
Europe	1,865	2,639	2,197	2,389	1,445	503
Asia	([2])	37	30	5	([2])	------
Oceania	------	------	------	------	------	29
Total sheets, pipe, and shot	4,532	2,845	2,276	2,429	1,523	880
Grand total	484,527	391,182	397,383	377,435	349,680	355,510

[1] Excludes imports for manufacture in bond and export, classified as "imports for consumption" by the Bureau of the Census.

[2] Less than ½ unit.

FOREIGN TRADE

Exports of lead material other than scrap decreased to 7,800 tons. Scrap exports amounted to only 3,800 tons compared with 13,100 tons in 1964 and only slightly more than the 3,500 tons of scrap imported for consumption in 1965.

General imports of lead in all materials amounted to 348,900 tons in 1965, a gain of 8,000 tons, although primary materials for domestic smelting and refining decreased 4,300 tons to 123,800 tons. A substantial decline in deliveries from the Republic of South Africa due to expanded operation of the new Tsumeb smelter and refinery and decreased deliveries of smelting materials from Bolivia, Mexico, and Peru more than offset substantial imports of Canadian ores for toll smelting and increased deliveries from Australia and Honduras. Receipts of lead bullion decreased significantly from all foreign suppliers. Metal imports from all of the producing areas listed increased with the exception of the European countries and total receipts of metal increased 13,000 tons in comparison with the prior year.

Imports for consumption of ores and metal, limited under the import quotas during the first three quarters of 1965, were 5,000 tons above the 1964 total. Termination of quotas in October for ore and in November for metal permitted entry for consumption of metal held in bond awaiting entry, especially from "other" countries not specifically alloted a quota. Notable changes were the decrease in ore from Bolivia, the decrease in bullion from all suppliers, and the decrease in metal deliveries from the European area.

Table 29.—U.S. imports for consumption of lead, by classes [1]

Year	Lead in ore, flue dust or fume, and matte, n.s.p.f. (lead content)		Lead in base bullion (lead content)		Pigs and bars (lead content)		Reclaimed scrap etc. (lead content)		Sheets, pipe, and shot			
	Short tons	Value (thousands)	Short tons	Value (thousands)	Short tons	Value (thousands)	Short tons	Valuc (thousands)	Short tons	Value (thousands)	Not otherwise specified value (thousands)	Total value (thousands)
1956–60 (average)	187,474	$43,706	160	$47	282,330	$66,800	10,031	$2,138	4,532	$1,107	$457	$114,255
1961	136,780	24,332	236	51	247,427	45,881	3,894	592	2,845	641	807	72,304
1962	133,080	21,003	2,083	710	257,866	41,570	2,078	269	2,276	474	978	65,004
1963	135,445	21,534	3,758	1,792	220,398	40,126	15,405	2,009	2,429	513	792	66,766
1964	128,067	21,789	7,043	2,058	211,140	45,790	1,907	350	1,523	369	713	71,069
1965	128,933	26,923	566	380	221,519	60,391	3,612	793	880	273	329	89,089

[1] Excludes imports for consumption in bond and export, classified as "imports for consumption" by the Bureau of the Census.

Table 30.—U.S. imports for consumption of miscellaneous products containing lead

Year	Babbitt metal, solder, white metal, and other combinations containing lead			Type metal and antimonial lead		
	Gross weight (short tons)	Lead content (short tons)	Value (thousands)	Gross weight (short tons)	Lead content (short tons)	Value (thousands)
1956–60 (average)	6,593	2,388	$8,790	6,032	5,364	$1,531
1961	7,930	1,409	14,207	6,430	5,765	1,340
1962	2,438	1,030	3,443	8,576	7,512	1,393
1963	2,535	1,246	3,207	[1]3,747	[1]3,196	[1]621
1964	r2,805	r1,228	r5,077	NA	NA	NA
1965	3,299	986	8,129	NA	NA	NA

r Revised. NA Not available.
[1] Due to changes in classification, effective Sept. 1, 1963, data no longer separately classified. January-August data tabulated.

WORLD REVIEW

The upward trend in world mine production in 1965 resulted in a record output approaching 3 million tons. Free world output of about 2.25 million tons was almost 8 percent above the 1964 total and reflected major increases in Canada, Japan, and Zambia, as well as additional output by several countries. Australia and Peru were the major suppliers recording a decrease in output. Smelter production also increased in the free world with major increases indicated for the Republic of South Africa, Canada, and Zambia and additional output recorded in several countries to more than offset the production declines in Australia, Spain, and a few other countries.

Lead consumption continued at the high level of 1964 with increases in Europe and North America offsetting an indicated decline in Japan and Australia. The strong demand for metal, plus a production curtailment in Australia in the first quarter of the year, provided an upward pressure on London Metal Exchange (LME) cash price for lead, which reached a post-Korean war high at the morning session of February 22 when £157 was bid, equivalent to 19⅞ cents per pound. The monthly average price on the LME ranged from £98.7 to £126.6, and the December average was £109.4 per long ton.

Producer stocks of lead, as published by the International Lead and Zinc Study Group, increased during the year from 173,000 tons to 187,000 tons. Of this total, the European area held 57,000 tons; the United States, 34,000 tons; and other countries, 96,000 tons.

NORTH AMERICA

Canada.—Mine production of lead increased almost 47 percent to a record level of 303,400 tons, lead content, in 1965; refinery output, all from the Consolidated Mining & Smelting Co. of Canada Ltd. (COMINCO), plant at Trail, British Columbia, was up 23 percent to 186,000 tons. The increase in production reflected primarily the initiation of production at the Pine Point mine in Northwest Territories from which regular shipments of ore were made during most of 1965 at a rate of 1,000 tons per day. In the first half of 1965, about 171,000 tons of ore was shipped averaging 22 percent lead, of which 150,000 tons was treated in COMINCO plants at Trail and Kimberley, British Columbia and 21,000 tons was treated by The Bunker Hill Co. at Kellogg, Idaho. Production of concentrates at the 5,000-ton-per-day concentrator began at the end of November with shipment to the Trail plant for smelting and refining. Reserves of ore at Pine Point were estimated at some 17.5 million tons averaging about 12 percent combined lead-zinc. The other major factor in the mine production increase was the first full year of operation of Brunswick Mining & Smelting Corp. Ltd., mines and concentrator near Bathurst, New Brunswick. The No. 12 mine and concentrator, which had reached rated capacity in July 1964, continued normal operations in 1965 with concentrates shipped to European smelters. During 1965, development of the No. 6 open pit mine was in progress along with expansion of capacity of the No. 12 mine concentrator and construction of an

Table 31.—World mine production of lead (content of ore) recoverable where indicated, by countries [1]

(Short tons)

Country	1961	1962	1963	1964	1965 p [2]
North America:					
Canada	182,557	211,321	198,988	206,359	303,405
Greenland	10,104	891	--------	--------	--------
Guatemala [3]	9,458	1,067	825	r, e 550	e 550
Honduras	6,762	6,522	r, e 9,100	r 8,250	10,642
Mexico	199,877	213,074	209,425	r 192,710	187,494
United States [3]	261,921	236,956	253,369	286,010	301,147
Total	670,679	669,831	r 671,707	r 693,879	803,238
South America:					
Argentina	31,306	32,606	r 29,173	r 28,576	33,619
Bolivia	r 20,874	r 20,375	r 20,989	r 18,180	19,219
Brazil e	15,400	16,800	19,200	r 16,200	16,200
Chile	2,252	1,603	957	1,230	1,399
Colombia	r 995	r, e 440	r 331	r 534	507
Ecuador	122	137	179	r 183	e 180
Peru [3]	150,353	141,290	r 162,268	r 166,089	162,150
Total	221,302	213,251	233,097	230,992	233,274
Europe:					
Austria [3]	6,051	5,855	5,504	5,727	5,553
Bulgaria	88,229	104,058	97,995	100,641	e 110,200
Czechoslovakia e	7,200	14,900	14,900	14,900	15,400
Finland	3,439	3,161	1,262	2,083	6,952
France	20,785	15,735	9,255	r 13,437	19,632
Germany:					
East e	7,700	r 7,700	r 11,000	r 11,000	11,000
West	r 54,802	r 54,925	r 58,243	r 53,944	53,434
Greece	12,787	14,110	e 14,600	15,873	9,315
Hungary	992	992	1,102	1,323	e 1,300
Ireland	279	--------	--------	1,300	2,853
Italy	52,216	45,463	36,266	36,333	39,104
Norway	2,524	r 3,153	r 3,297	3,968	4,553
Poland	42,108	41,778	42,659	42,329	51,037
Portugal	28	49	247	r 216	101
Rumania e, [4]	13,000	13,800	13,800	14,000	16,500
Spain	87,863	78,262	68,557	r 64,356	62,223
Sweden	70,518	74,721	r 78,665	r 74,406	73,304
U.S.S.R. e, [4]	390,000	390,000	390,000	400,000	410,000
United Kingdom	1,656	446	276	198	101
Yugoslavia	106,572	112,430	r 125,535	r 124,677	117,122
Total e	968,700	981,500	973,200	980,700	1,009,700
Africa:					
Algeria	10,337	r 9,965	r 9,038	10,525	11,514
Congo, Republic of (Brazzaville)	1,634	368	364	r 2,391	e 3,100
Morocco	97,299	99,323	81,540	r 78,584	85,000
Nigeria	7	--------	--------	--------	e 770
South Africa, Republic of	102	6	16	--------	53
South-West Africa [3]	r 77,683	r 83,081	r 83,220	104,045	96,790
Tanzania (exports)	387	--------	--------	--------	--------
Tunisia	19,123	14,936	15,697	r 13,713	17,514
United Arab Republic (Egypt) e	39	595	550	--------	NA
Zambia [4]	r 16,956	16,343	21,615	14,508	23,529
Total	223,567	224,617	212,040	223,766	238,270
Asia:					
Burma	18,519	22,377	r 22,064	20,889	e 21,800
China e	99,000	99,000	110,000	110,000	110,000
India	4,478	5,065	4,758	4,966	4,388
Iran e, [5]	16,500	11,000	11,000	r 18,500	e 18,700
Japan	51,015	58,924	58,110	r 59,604	60,601
Korea:					
North e	55,000	55,000	55,000	r 60,000	65,000
South	1,014	1,558	2,113	r 3,691	4,878
Philippines	111	90	78	114	116
Thailand	2,437	2,600	2,496	4,030	6,152
Turkey	3,538	4,299	2,811	1,792	1,854
Total e	251,600	259,900	268,400	283,600	293,500
Oceania: Australia	302,019	414,524	r 459,527	r 421,081	397,788
World total e	r 2,640,000	2,765,000	r 2,820,000	r 2,835,000	2,975,000

e Estimate. p Preliminary. r Revised. NA Not available.

[1] Data derived in part from International Lead and Zinc Study Group Monthly Bulletin, United Nations Statistical Yearbook, Yearbook of the American Bureau of Metal Statistics, annual issues of the Statistical Summary of the Mineral Industry (Overseas Geological Surveys, London), and Metal Statistics (Metallgesellschaft) Germany.

[2] Compiled mostly from data available August 1966.

[3] Recoverable.

[4] Smelter production.

[5] Year ended March 21 of year following that stated.

Table 32.—World smelter production of lead by countries [1]
(Short tons)

Country	1961	1962	1963	1964	1965 [p] [2]
North America:					
Canada (refined)	[r] 171,883	[r] 152,217	[r] 155,001	[r] 151,372	186,484
Guatemala	62	69	52	[r] 83	126
Mexico	194,476	208,447	205,217	183,758	181,117
United States (refined) [3]	449,486	376,024	394,732	449,429	418,249
Total	[r] 815,907	[r] 736,757	[r] 755,002	[r] 784,642	785,976
South America:					
Argentina	30,800	27,000	26,500	25,400	35,300
Bolivia (refined metal and solder)	4	138	[r] 280	[r] 508	1,032
Brazil	13,865	15,090	17,243	[r] 14,555	[e] 14,600
Chile	529	280	243	--------	--------
Peru	84,253	75,356	[r] 89,426	98,904	95,723
Total	129,451	117,864	[r] 133,692	[r] 139,367	146,655
Europe:					
Austria [4]	13,605	13,417	10,783	9,365	8,481
Belgium [4]	110,110	102,681	[r] 108,504	91,840	122,089
Bulgaria	45,099	48,200	56,584	96,500	[e] 100,000
Czechoslovakia [e]	10,000	15,400	15,400	15,400	16,000
France	78,052	77,787	[r] 85,569	[r] 98,976	108,419
Germany:					
East [e, 4]	27,500	[r] 27,600	[r] 27,600	[r] 27,600	27,600
West	[r] 138,363	[r] 140,407	[r] 121,515	[r] 118,502	114,674
Greece	3,267	[r] 4,896	3,900	5,500	[e] 5,700
Hungary	1,100	550	440	220	[e] 220
Italy	47,411	46,282	46,228	41,787	43,457
Norway	--------	--------	--------	4,400	1,900
Poland	43,874	44,842	42,895	[r] 45,747	46,116
Portugal	1,663	2,227	1,232	[r] 1,506	1,603
Rumania [e]	13,200	13,800	13,800	14,000	17,000
Spain	85,678	79,666	68,436	[r] 63,927	57,735
Sweden	42,745	42,737	[r] 44,939	44,800	45,000
U.S.S.R. [e, 4]	390,000	390,000	390,000	400,000	410,000
United Kingdom	1,178	614	297	195	99
Yugoslavia	99,650	107,945	114,832	111,427	111,889
Total [e]	[r] 1,152,500	[r] 1,159,100	[r] 1,153,000	[r] 1,191,700	1,238,000
Africa:					
Morocco	26,993	26,613	20,679	20,766	18,992
South-West Africa	--------	--------	1,997	52,685	72,791
Tunisia [5]	[r] 20,339	17,447	[r] 13,898	12,634	15,629
Zambia	[r] 16,956	16,343	21,615	14,508	23,529
Total	[r] 64,288	60,403	[r] 58,189	[r] 100,593	130,941
Asia:					
Burma	17,376	19,164	19,553	19,900	19,800
China, mainland [e]	95,000	95,000	99,000	110,000	110,000
India	4,039	3,140	3,899	3,995	3,202
Iran [6]	1,437	440	[e] 550	[r] 413	[e] 440
Japan	83,476	96,735	101,575	[r] 106,962	119,647
Korea: North [e]	45,000	45,000	45,000	[r] 50,000	55,000
Turkey	698	702	2,073	[r] 2,161	990
Total [e]	247,000	260,200	271,700	[r] 293,400	309,100
Oceania:					
Australia:					
Refined lead	181,736	212,941	251,558	[r] 227,473	216,504
Pb content of lead bullion (for export)	53,861	81,883	90,431	[r] 87,701	74,936
Total	235,597	294,824	341,989	[r] 315,174	291,440
World total [e]	[r] 2,645,000	[r] 2,630,000	[r] 2,715,000	[r] 2,825,000	2,905,000

[e] Estimate. [p] Preliminary. [r] Revised.
[1] Data derived in part from International Lead and Zinc Study Group Monthly Bulletin, United Nations Statistical Yearbook, Yearbook of the American Bureau of Metal Statistics, annual issues of Statistical Summary of the Mineral Industry (Overseas Geological Surveys, London), and Metal Statistics (Metallgesellschaft) Germany.
[2] Compiled mostly from data available August 1966.
[3] Figures cover lead refined from domestic and foreign ores; refined lead produced from foreign base bullion not included.
[4] Includes scrap.
[5] Lead bars only; does not include lead contained in antimonial lead or solder.
[6] Year ended March 21 of year following that stated.

Imperial Smelting process plant at Belledune Point, about 35 miles from the mines, with a rated capacity of 31,000 tons of lead and 30,000 tons of zinc annually. The expanded ore production facilities and smelting plant are expected to be in full production in mid-1966. Overall reserves of ore at the No. 6 and No. 12 mines were estimated at well over 50 million tons averaging over 10 percent combined lead-zinc.

Operation of the lead-zinc mines and concentrators which previously contributed to the Canadian lead output again contributed a substantial tonnage of lead. The Sullivan, H.B., and Bluebell of COMINCO, Canadian Exploration Ltd., Reeves MacDonald Mines Ltd., and Aetna Investment Corp, Ltd. (formerly Sheep Creek Mines, Ltd.), provided the output of British Columbia. United Keno Hill Mines Ltd., was the only Yukon producer. Hudson Bay Mining and Smelting Co. Ltd., produced lead at the Flin Flon-Snow Lake district mines of Manitoba-Saskatchewan. The zinc mines located in Ontario and Quebec produced a small tonnage of lead and the Heath Steele Mines Ltd., in New Brunswick and the Magnet Cove Barium Corp. Ltd., operations in Nova Scotia contributed a significant tonnage of lead in concentrates. Extensive exploration and development activity was carried on throughout Canada during the year.

Honduras.—The El Mochito mine of the New York and Honduras Rosario Mining Co. reported a production increase for the 11th consecutive year; output was 26 percent above that of 1964. A major expansion program initiated in 1964 was completed in mid-1965 increasing daily tonnage treated to 500 tons. In 1965 a total of 174,300 tons of ore containing 6.1 percent lead was treated to produce over 9,000 tons of lead in concentrates.[10] Compañia Minera "Los Angeles", S.A., produced some 1,300 tons of lead in concentrates.

Mexico.—The Mexicanization of the mines and plants of Compañia Minera Asarco, S.A., under the Mining Law of 1961, was completed in July with the formation of Asarco Mexicana, S.A., 51 percent owned by Mexican interests. Production of lead from company mines and purchased ores in the fiscal year ending June 30, 1965, was 81,819 tons, slightly higher than the prior year. Pending projects to increase ore production from operating units and expand related milling capacity about 24 percent were undertaken. These include mine and mill expansion at the Santa Bárbara, San Martin, and Taxco mines and mine development and construction of a 400-ton-per-day mill at the Plomosas mine.[11] The Nuestra Sěnora unit located in Cosalá, Sinaloa, was closed down and the 450-ton-per-day plant dismantled.

American Metal Climax, Inc. (Amax, Inc.), sold, on July 21, the remaining 49 percent interest in Metalúrgica Mexicana Penoles, S.A. (METMEX), to Mexican interests who had previously acquired the initial 51 percent ownership in 1961. Amax, Inc. will continue to provide technical assistance. Operation of mines and smelter controlled by METMEX were at the normal level during the year.

Compania Fresnillo, S.A., 49 percent owned by the Fresnillo Co. and 51 percent by METMEX, the operating company for the Fresnillo and Naica mines, acquired ownership of the mineral resources of these mines in order to fulfill requirements of the Mining Law of 1961. The Fresnillo unit, Naica unit, and Zimapan unit were operated at a slightly lower level of lead production. The Zimapan subsidiary acquired the Amaltea mine in Jalisco and Cia. Minera Sabinas, S.A., in Zacatecas, and will develop and expand these lead-zinc properties.[12]

SOUTH AMERICA

Argentina.—Cia. Minera Aguilar, S.A., a subsidiary of St. Joseph Lead Co., produced 27 percent more lead in concentrates than in 1964. The concentrates were exported for smelting, refining, and return to Argentina as metal for consumption. With the growing demand for metal within Argentina, an expansion program was underway which will increase productive capacity by at least 50 percent commencing in 1968.[13]

Bolivia.—Production of lead in 1965 was at about the same level as 1964 when 19,500 tons was exported. The nationalized

[10] New York and Honduras Rosario Mining Co. Annual Report. 1965, pp. 3–13.
[11] American Smelting and Refining Co. Annual Report. 1965, p. 14.
[12] The Fresnillo Co. Annual Report. June 30, 1965, p. 2.
[13] St. Joseph Lead Co. Annual Report. 1965, p. 6.

mines operated by Corporación Minera de Bolivia contributed about 7,100 tons (lead content) while small mines for which Banco Minero de Bolivia acts as agent contributed 9,700 tons and an additional 2,300 tons was individually exported by operating mines.

Peru.—Cerro de Pasco Corp., the operating subsidiary of Cerro Corp. in Peru, produced 95,400 tons of lead in 1965 compared with the record 98,600-ton output of 1964. Of the lead produced, 44 percent was from company mines and the remainder from ores purchased in Peru. The Yauricacha mine was in the process of conversion to production of a complex ore for concentration by flotation to produce a copper-lead concentrate and a zinc concentrate instead of the direct smelting copper ore previously mined. Progress was also made on major capital projects to increase lead-zinc ore production at the Cerro de Pasco mine and at the McCune open pit.[14]

Production of lead concentrate by the Compagnie des Mines de Huaron, a member of the large Mokta organization of France, was 19 percent more than in 1964, as mine production of copper-lead-zinc ore was expanded.

EUROPE

Bulgaria.—A lead-zinc ore body, claimed to be one of the largest found in Bulgaria, was being developed near Kyustendil in the foothills of the Ossogove Mountains. There will be several open pit mines and one underground mine and a flotation plant with an annual capacity of some 1.2 million tons. This is about four times the capacity of the Goroubsa mine in the Rhodope Mountains, one of the larger mines supplying the metallurgical works of the Plovdiv Non-ferrous Metals Combine.

Finland.—Production of lead concentrates in 1965 was some three times the 1964 output and amounted to about 10,600 tons containing over 65 percent lead and reflects the expansion of the Aijala mine concentrator and resumption of production at the Korsnas mine as well as from the increased production of zinc ores at the Pyhäsalmi and Vihanti mines.

France.—The French group of mines, controlled by the Société Minière et Métallurgique de Penarroya, were reported to have increased production of lead concentrate some 70 percent over the previous year, reflecting the contribution of the new lead-zinc mine at Largentiers in the south of France.

Ireland.—After more than 2 years of intensive effort, production at the Tynagh mine of Irish Base Metals Ltd., a wholly owned subsidiary of Northgate Exploration Ltd., Toronto, Canada, was initiated in November. The 2,000 ton-per-day concentrator, fed by open pit production of a complex ore, will produce a lead and a zinc concentrate for smelting and refining in British and West European smelters. The deposit reportedly contains about 4.5 million tons of open pit ore averaging 9.3 percent lead and 7.25 percent zinc and an underlying additional reserve of 3.5 million tons of ore averaging 4.76 percent lead and 4.27 percent zinc.

Mine development was in progress at the Silvermines property of Mogul of Ireland, Ltd., in Tipperary County. Under ownership of Consolidated Mogul Mines of Canada, Ltd. (75 percent), and Silvermines Lead and Zinc Co. Ltd., of Ireland (25 percent), the estimated reserve of 6.37 million tons of upper-zone ore averaging 10 percent zinc and 2.75 percent lead and an additional 4 million tons of lower grade ore will be mined by underground methods and concentrated in a proposed 3,000-ton-per-day plant.

United Kingdom.—The new Cavendish mill of Glebe Mines Ltd., at Eyam, Derbyshire, was completed in June 1965 with a production capacity of some 4,300 tons of lead annually. Ore from the company's fluorspar-barite-lead mines, formerly treated at the Glebe and Cupola plants, was all being handled by the new plant at the end of the year. The lead concentrates were shipped to smelters in Western Europe.

Yugoslavia.—Production of lead-zinc ore in 1965 amounted to 2.6 million tons averaging 6.5 percent lead and 3 percent zinc and production of refined primary lead was about 112,000 tons. The 5-percent increase in output of refined lead in 1965 was in accord with the gradual expansion under provisions of the 7-year plan (1964–70). Yugoslav discoveries of lead and zinc ore in 1964 and the first half of 1965 were reported to be some 11 million tons. Deposits were discovered at Blagodat, Stari Trg, Ajvalija Kiznica, and Nova Brdo.

[14] Cerro Corp. Annual Report. 1965, pp. 5–6.

AFRICA

Algeria.—A production increase of almost 10 percent in lead concentrates resulted from modernization and development efforts in 1965. The mines were operating at full capacity, and there was considerable exploration and capital investment in 1965 which was expected to further improve production. A deposit discovered at the El Abed in 1964 was being developed and two lead deposits were discovered at the Ouarsenis mine.

South-West Africa.—The Tsumeb mine of Tsumeb Corp. Ltd., produced, during fiscal year 1965, a total of 812,100 tons of ore assaying 3.98 percent copper, 13.08 percent lead, and 3.90 percent zinc, and the Kombat mill processed 343,000 tons of ore containing 4.31 percent copper and 1.6 percent lead. Various improvements made in the lead smelter and refinery resulted in lower costs and an increase in the production of refined lead at Tsumeb to 72,790 tons in 1965 compared with 52,660 tons in 1964. Some of the lead concentrates, as well as 58,400 tons of accumulated copper-lead slimes, were shipped to foreign custom smelters.[15]

The Berg Aukas mine of the South West Africa Co. Ltd. treating a complex lead-zinc-vanadium ore, continued to expand and improve mill recovery of the contained minerals in the ore mined. During fiscal year 1965, about 12,000 tons of lead-vanadate concentrate and 32,000 tons of lead-zinc sulfide concentrate was recovered. Mine development was expanded and assured reserves were estimated at 305,000 tons averaging 7 percent lead, 33 percent zinc, and 1.5 percent vanadium pentoxide.

Tunisia.—During the first half of 1965, an increase of 70 percent in lead ore production compared with the same period in 1964 was reported. The major producers were the Djebel and Sidi Bou Aouane mines. The two lead smelters, Djebel Hallouf and Megrine, produced, in the first half, 8,800 tons of lead compared with 5,800 tons during the same period in 1964. The Djebel Hallouf plant accounted for 93 percent of the metallic lead.

Zambia.—Zambia Broken Hill Development Corp. Ltd., substantially expanded output in 1965 with mine production of lead amounting to about 38,000 tons and refined lead output approximately 24,000 tons. The Imperial smelting process was used and metallurgical difficulties resulting from the high lead input to the smelter, which curtailed lead output in 1964, were smoothed out in 1965.

ASIA

India.—India's only lead producer, the Metal Corporation of India Ltd., was nationalized on October 22 in order to enable the Government to develop and exploit the lead and zinc deposits to the fullest possible extent with major emphasis on development and expansion of refinery capacity. The company has been producing about 4,000 tons of lead at the Zawar lead-zinc mines near the town of Vdaipur, Rajasthan, and refining the concentrates in its smelter and refinery at Tundoo, Bihar. The zinc concentrate was shipped to Japan for refining and return of metal to India.

Japan.—Mine production of ore and production of metal in Japan was relatively unchanged. Total rated capacity for refined lead, predominantly electrolytic, was approximately 130,000 tons annually. Proven ore reserves for the 24 lead-zinc mines totaled 39 million tons containing 427,000 tons of lead and 2 million tons of zinc and there was an additional 35 million tons of probable and inferred ore. Mitsubishi Cominco Smelting Co. Ltd., in which COMINCO has a 45-percent interest, continued construction of a 40,000-ton-annual-capacity lead smelter at Naoshima scheduled for completion in mid-1966.[16]

OCEANIA

Australia.—The production of lead ore and refined lead was substantially below the record level of 1963 and also the 1964 production. The lengthy strike at Mount Isa and a labor situation at the Broken Hill mines contributed to the decline. Mine production was about 398,000 tons and refined lead output 216,000 tons. Production at Mount Isa Mines Ltd. curtailed by a labor strike initiated in the fourth quarter of 1964, was not resumed until

[15] Newmont Mining Corp. Annual Report. 1965, p. 6.
[16] Consolidated Mining & Smelting Co. of Canada, Ltd. Annual Report. 1965, p. 9.

February 17 and operations did not regain normal levels until the second quarter. In fiscal year 1965, production of lead amounted to 58,900 tons compared with 71,600 tons in fiscal year 1964. The planned expansion of concentrator capacity was also delayed.[17]

North Broken Hill Ltd., mined a slightly larger tonnage of ore in 1965, with 44 percent of the ore from the new No. 3 shaft area, and ore reserves increased slightly. Production of lead concentrates decreased about 7 percent as the grade of ore declined. Recovery of 97.4 percent of the lead in ore was achieved by improvements in milling.[18] New Broken Hill Consolidated Ltd., completed the first stage of an expansion program to increase annual mill capacity to 1 million tons of ore by the end of 1967. Amount of ore milled in 1965 was 7 percent above the 1964 total while lead production was up only 2 percent due to decreased ore grade.[19] Production of ore at Broken Hill South Ltd., decreased about 7 percent during fiscal year 1965 and lead recovered in concentrates decreased 5 percent as improvement in ore grade offset slightly the reduced tonnage treated.[20] Production of ore by The Zinc Corp. Ltd., increased about 13 percent to a new high and the lead in concentrates increased 4 percent.[21] Active exploration and development programs at the Broken Hill mines continued to maintain a satisfactory year-end reserve ore position. The Broken Hill Associated Smelters Pty. Ltd., produced approximately 229,000 short tons of lead metal, 4 percent less than in 1964.

The efficiency of the Imperial smelting furnace of the Sulphide Corp. Pty. Ltd., at Cockle Creek, New South Wales, was further improved in 1965. The 14.5-percent increase in production of slab zinc was, however, contrasted with a 5-percent decline in lead bullion output due to a reduction in lead content of the feed concentrate.

Production from the West Coast mines of EZ Industries Ltd., during fiscal year 1965, was about the same as in fiscal 1964. The lead content of ore milled averaged 5.5 percent, slightly above the 1963–64 average. Ore reserves at the Rosebery, Hercules, and Farrel mines comprising the West Coast operations were increased by 1.5 million tons to 5.5 million tons.[22]

TECHNOLOGY

The physical, chemical and electrical properties of lead, one of the oldest metals used by man, have been continuously explored and utilized to meet developing needs. Many of the technological discoveries and advances made in the field of atomic energy have been possible only through accompanying advances in the technique of radiation shielding with lead. This field of nucleonics is continuing to receive major research attention. The subject of dispersion strengthening of lead has only recently been explored,[23] but commercial usage in cable sheaths, battery grids, and sound attenuating panels offer research and development incentives. The successful application of evaporated lead-oxide layers as photosensitive was described as a breakthrough in color broadcasting,[24] and was the incentive for a published study of the properties of lead monoxide.[25] The advantages of lead-platinum anodes for a seawater anticorrosive system were demonstrated,[26] and lead dioxide-coated graphite anodes now make possible electrolysis of sodium perchlorate without use of the previously required platinum anodes.[27] The use of lead pellets as an anode in the manufacture of tetraethyllead and tetra-

[17] American Smelting and Refining Co. Annual Report. 1965, p. 16.

[18] North Broken Hill Ltd. Annual Report. 1965, p. 4.

[19] New Broken Hill Consolidated Ltd. Annual Report. 1965, p. 11.

[20] Broken Hill South Ltd. Annual Report. 1965, p. 5.

[21] Rio Tinto-Zinc Corp. Annual Report. 1965, p. 34.

[22] E.Z. Industries, Ltd. Annual Report. 1965, p. 5.

[23] Light Metals and Metal Industry (London). Improving the Mechanical Properties of Lead by Dispersion Strengthening. V. 28, No. 330, November 1965, pp. 71–72.

[24] Lead Industries Association, Inc. Lead Information Bulletin. No. 160, Nov. 23, 1965, pp. 1–2.

[25] van den Broek, J. Contact Barriers in Red Lead Monoxide. Philips Research Reports (Eindhoven, Netherlands), v. 20, No. 6, December 1965, pp. 674–683.

[26] Lead Industries Association, Inc. Lead Information Bulletin. No. 159, Oct. 8, 1965, p. 1.

[27] Lead Industries Association, Inc. PbO_2/Graphite, a Tough, New Electrochemical Anode. V. 29, No. 4, 1965, p. 7.

methyllead was reported.[28] Investigation of electrochemical characteristics of crystal growth was reported for the lead fluoride-lead oxide system,[29] and for electrodeposited lead dendrites.[30] The technologic aspects of recovery and refining of lead continued to receive industrial attention as plants were expanded and new plants designed. The difficult metallurgy of treating the mixed oxide-sulfide ores of Sardinia, Italy, was reported,[31] and the flotation flowsheet of the Parc mill near Llanrwst, Wales, United Kingdom, was described.[32] A progress report on the Imperial smelting process in the various operating installations through 1964 was published,[33] and process changes in the electrolytic refining of lead in Sardinia to compensate for increasing bismuth content of concentrates was described.[34] The use of oxygen to increase production and recovery of lead in blast furnace was an active area in metallurgical research.[35]

The Second International Conference on Lead was held October 4–7 in Arnhem, Netherlands. This conference, sponsored by the European Lead Development Committee, presented 32 papers[36] relative to technical developments in lead material and products. Worldwide coordination of lead and zinc research and development was announced at the International Lead and Zinc Study Group meeting in Tokyo, November 1–5, by incorporation of the International Lead and Zinc Research Organization sponsored by a group of leading companies located in Australia, Canada, Italy, Japan, Mexico, Peru, South-West Africa, the United Kingdom, and the United States.

U.S. patents were issued for a process of recovering lead from byproduct materials by mixing with sodium hydroxide and treating in a reverberatory furnace[37] and for a process for preparing elemental fluorine and a sodium-lead alloy simultaneously.[38]

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[28] Chemical Engineering. Electrolysis: New Route to Alkyl Lead Compounds. V. 72, No. 13, June 21, 1965, pp. 102–104.
Chemical Engineering. NALCO Achievement. V. 72, No. 23, Nov. 8, 1965, pp. 249–250.

[29] Oliver, C. B. The Viscosity of Some Molten Lead Compounds. J. Electrochem. Soc., v. 112, No. 6, June 1965, pp. 629–631.

[30] Ogburn, F., C. Bechtoldt, J. B. Morris, and A. de Koranyi. Structure of Electrodeposited Lead Dendrites. J. Electrochem. Soc., v. 112, No. 6, June 1965, pp. 574–577.

[31] World Mining. Milling Four Types of Oxidized Lead-Zinc Ores at Monteponi. V. 18, No. 9, August 1965, pp. 32–35.

[32] South African Mining and Engineering Journal (Johannesburg). Process Variables in Flotation. V. 76, No. 3789, Sept. 3, 1965, pp. 2059–2062.

[33] Woods, S. E., and D. A. Temple. The Present Status of the Imperial Smelting Process. Bull. Institution of Min. and Metall., v. 74, No. 703, pt. 9, June 1965, pp. 564–570.

[34] Freni, Elio R. Electrolytic Lead Refining in Sardinia. J. Metals, v. 17, No. 11, November 1965, pp. 1206–1214.

[35] Hase, E. A. Oxygen Enriched Blast at Asarco's Lead Smelter. J. Metals, v. 17, No. 12, December 1965, pp. 1334–1337.

[36] Metal Bulletin (London). No. 5036, Oct. 5, 1965, pp. 21–28.

[37] Mattison, Edwin L., and Richard Wolfe (assigned to E. I. du Pont de Nemours & Co., Inc., Wilmington, Del.). Process for Recovering Lead From Byproduct Lead Materials. U.S. Pat. 3,188,199, June 8, 1965.

[38] Mastrangelo, Sebastian V. R. (assigned to E. I. du Pont de Nemours & Co., Inc., Wilmington, Del.). Process for Producing Fluorine and Sodium-Lead Alloy. U.S. Pat. 3,196,091, July 20, 1965.

Lime

By Paul L. Allsman [1]

Lime production in 1965 was a record 16.8 million tons, 4 percent more than in 1964. Lime for use in basic-oxygen-furnace steelmaking was again the most rapidly expanding market, and the trend promised to continue for the next several years.

Table 1.—Salient lime statistics in the United States
(Thousand short tons and thousand dollars)

	1956–60 (average)	1961	1962	1963	1964	1965
Number of active open-market plants	151	220	215	208	210	212
Sold or used by producers						
Quicklime	6,693	8,998	9,509	10,128	11,370	12,009
Hydrated Lime	2,352	2,269	2,386	2,444	2,551	2,609
Dead-burned dolomite	2,054	1,982	1,858	1,949	2,168	2,176
Total [1]	11,099	13,249	13,753	14,521	16,089	16,794
Value [2]	$145,777	$177,463	$186,754	$199,389	r $223,149	$232,939
Average value per ton	$13.13	$13.39	$13.58	$13.73	$13.87	$13.87
Open-market	8,299	8,072	8,145	8,889	9,802	10,449
Captive	[3] 2,800	5,177	5,608	5,632	6,287	6,345
Imports for consumption	37	37	78	101	123	276
Exports	62	30	20	17	30	40

r Revised.
[1] Data may not add to totals shown because of rounding.
[2] Selling value, f.o.b. plant, excluding cost of containers.
[3] Incomplete figures. Before 1961 the coverage of captive plants was only partial.

DOMESTIC PRODUCTION

The Warner Co. of Bellefonte, Pa. added 200 tons of daily capacity to its lime plant for basic-oxygen-furnace steelmaking. The plant produces Bell-Mine pebble lime. The company also opened a 1,000-ton distribution center in the Pittsburgh area.

The Detroit Lime Co., a subsidiary of Edward C. Levy Co., erected a 600-ton-per-day vertical lime kiln, said to be the largest of its kind. Also being installed was a 500-ton-per-day rotary kiln. A major portion of the lime production was to go to the basic-oxygen-furnace plant of Great Lakes Steel Corp. in Ecorse, Mich.[2]

Bethlehem Steel Corp. was building a 600 ton-per-day lime-burning plant for basic-oxygen-steelmaking furnaces at its Lackawanna, N.Y. plant. The plant will be composed of three 200-ton-per-day kilns. The company also awarded a contract for a similar 600-ton-per-day calcimatic plant at its Hanover limestone quarry near York, Pa.

Texas Lime Co. announced plans to build a new 200-ton-per-day lime plant 12 miles west of Cleburne, Tex. The firm already has a 300-ton-per-day plant south of Cleburne. Dixie Lime & Stone Co. announced addition of a new calcimatic kiln at its Coleman No. 2 mine, Sumterville, Fla.

Chemstone Corp., a subsidiary of Minerals and Chemicals Philipp Corp., was in-

[1] Commodity specialist, Division of Minerals.
[2] Iron and Steel Engineer. Vertical Lime Kiln Will Produce 600 Tons Per Day for BOF Plant. V. 42, No. 4, April 1965, pp. 177–178.

Table 2.—Primary lime sold or used by producers in the United States, by States

State	Sold			Used			Total		
	Active plants	Short tons	Value	Active plants	Short tons	Value	Active plants	Short tons	Value
1964:									
Alabama	5	W	W	4	W	W	6	599,147	$7,118,369
Arizona	3	W	W	3	W	W	6	176,769	2,920,053
Arkansas	1	W	W	4	W	W	5	188,522	2,814,479
California	5	160,347	r $2,874,860	13	416,521	r $7,419,212	16	576,868	r 10,294,072
Colorado	3	W	W	13	W	W	15	138,066	2,193,139
Connecticut	1	30,413	564,278	1	8,161	124,455	1	38,574	688,733
Florida	2	W	W	1	W	W	3	116,841	1,813,617
Hawaii	2	W	W	1	W	W	2	8,737	320,790
Louisiana	2	W	W	3	W	W	5	724,553	8,311,972
Maryland	3	W	W	—	—	—	3	W	W
Massachusetts	3	W	W	2	W	W	3	171,398	2,703,276
Michigan	3	W	W	8	W	W	9	1,429,724	19,245,883
Missouri	4	W	W	1	W	W	4	1,218,695	14,327,617
Montana	1	W	W	5	W	W	6	135,880	1,384,524
New Mexico	—	—	—	1	25,346	352,309	1	25,346	352,309
Ohio	18	2,364,426	37,665,532	9	1,299,979	15,642,338	22	3,664,405	53,307,870
Oklahoma	1	W	W	—	—	—	1	W	W
Oregon	2	W	W	2	W	W	4	95,250	1,917,956
Pennsylvania	18	1,440,285	20,656,024	—	—	—	18	1,440,285	20,656,024
Texas	10	634,348	7,559,611	7	716,017	9,641,467	13	1,350,365	17,201,078
Utah	3	W	W	4	W	W	7	163,240	2,917,207
Virginia	8	W	W	1	W	W	9	780,290	9,780,920
Wisconsin	6	W	W	1	W	W	6	W	W
New Jersey, New York, Vermont, West Virginia	7	172,332	2,253,358	4	928,316	8,878,312	8	1,100,648	11,131,670
Illinois, Iowa, Minnesota, Nebraska, South Dakota, Wyoming	9	1,035,434	16,929,956	14	107,539	2,015,821	23	1,142,973	18,945,777
Mississippi, Tennessee	2	W	W	3	W	W	4	109,741	1,756,344
Idaho, Nevada, Washington	4	W	W	6	W	W	10	381,417	6,647,163
Undistributed		3,963,819	54,887,944		2,785,589	35,683,293		311,138	4,397,928
Total [1]	126	9,801,000	143,392,000	111	6,287,000	79,757,000	210	16,089,000	223,149,000
Puerto Rico	1	17,825	573,925	—	—	—	1	17,825	573,925

Table 2.—Primary lime sold or used by producers in the United States, by States—Continued

State	Sold			Used			Total		
	Active plants	Short tons	Value	Active plants	Short tons	Value	Active plants	Short tons	Value
1965:									
Alabama	5	W	W	3	W	W	6	653,237	$7,905,255
Arizona	4	W	W	3	W	W	6	204,228	3,542,593
Arkansas	1	W	W	4	W	W	5	192,439	2,775,684
California	5	173,611	$3,342,451	12	428,296	$7,730,896	16	601,907	11,073,347
Colorado	2	W	W	13	W	W	15	118,380	2,074,407
Connecticut	1	W	W	1	W	W	1	W	W
Florida	2	W	W	1	W	W	3	W	W
Hawaii	2	W	W	1	W	W	2	8,820	305,463
Louisiana	2	W	W	2	W	W	4	841,769	9,979,570
Maryland	3	37,294	480,682	—	—	—	3	37,294	480,682
Massachusetts	3	W	W	2	W	W	3	169,784	2,779,055
Michigan	4	W	W	8	W	W	10	1,094,684	13,057,347
Missouri	4	1,442,260	16,781,702	—	—	—	4	1,442,260	16,781,702
Montana	1	3,392	71,599	5	155,382	1,440,322	6	158,774	1,511,921
New Mexico	—	—	—	1	33,427	464,635	1	33,427	464,635
Ohio	18	2,430,244	37,588,820	9	1,400,262	15,618,913	22	3,830,506	53,207,733
Oklahoma	1	W	W	—	—	—	1	W	W
Oregon	2	W	W	2	W	W	4	98,243	1,853,229
Pennsylvania	18	1,568,492	22,495,848	—	—	—	18	1,568,492	22,495,848
Texas	10	672,407	7,950,997	7	665,544	11,712,493	14	1,337,951	19,663,490
Utah	3	W	W	4	W	W	7	189,290	3,470,081
Virginia	9	W	W	1	W	W	10	847,196	10,583,984
Wisconsin	5	W	W	1	W	W	6	197,187	3,075,801
New Jersey, New York, Vermont, West Virginia	7	238,934	2,966,850	4	937,531	8,901,459	9	1,176,465	11,868,309
Illinois, Iowa, Minnesota, Nebraska, North Dakota, South Dakota, Wyoming	10	1,162,821	17,983,645	13	100,716	2,151,668	23	1,263,537	20,135,313
Mississippi, Tennessee	2	W	W	2	W	W	3	114,145	3,433,557
Idaho, Nevada, Washington	4	W	W	6	W	W	10	378,704	6,873,000
Undistributed		2,718,921	40,156,860		2,624,007	35,099,456		284,922	3,547,290
Total[1]	128	10,448,000	149,819,000	105	6,345,000	83,120,000	212	16,794,000	232,939,000
Puerto Rico	1	27,276	867,018	—	—	—	1	27,276	867,018

[r] Revised. W Withheld to avoid disclosing individual company confidential data; included with "Undistributed."
[1] Data may not add to total shown because of rounding.

Table 3.—Regenerated quicklime produced in the United States

State	1964 Short tons	1964 Value	1965 Short tons	1965 Value
Alabama	312,410	$4,290,108	316,318	$4,493,682
Arkansas	153,421	3,146,503	146,821	2,796,589
California	42,531	1,007,432	48,238	1,166,065
Florida	419,873	6,226,300	425,001	6,523,600
Georgia	335,428	6,489,272	351,512	6,697,200
Kentucky	217,748	2,754,500	W	W
Louisiana [1]	300,787	5,600,485	946,307	17,741,004
Maine	32,711	489,029	39,398	589,000
Maryland	W	W	41,234	651,745
Michigan [1]	56,642	594,985	44,874	523,376
North Carolina	318,429	3,808,000	324,327	4,112,470
Ohio	93,001	1,113,410	93,610	1,123,320
Oregon	137,000	3,388,000	136,800	3,353,000
Pennsylvania	23,088	384,415	22,805	379,703
South Carolina	278,125	3,525,518	310,925	3,478,009
Tennessee	121,166	1,901,406	125,848	2,057,009
Virginia	83,447	1,168,258	20,225	283,150
Washington [1]	354,386	7,585,411	362,082	7,606,902
Wisconsin	6,683	116,618	25,332	442,043
Undistributed [2]	r 382,520	r 6,031,793	550,055	7,859,485
Total [3]	r 3,669,000	r 59,621,000	4,332,000	71,877,000

r Revised. W Withheld to avoid disclosing individual company confidential data; included with "Undistributed."
[1] Includes hydrated lime to avoid disclosing individual company confidential data.
[2] Includes Idaho, Mississippi, New York, Texas, and States indicated by symbol W.
[3] Data may not add to totals shown because of rounding.

Table 4.—Number and production of domestic lime plants, by size of operation [1]

Annual production (short tons)	1964 Number of plants	1964 Production (thousand short tons)	1964 Percent of total	1965 Number of plants	1965 Production (thousand short tons)	1965 Percent of total
Less than 10,000	30	228	1	26	172	1
10,000 to less than 25,000	33	684	4	20	356	2
25,000 to less than 50,000	44	1,512	10	59	2,022	12
50,000 to less than 100,000	43	3,464	22	53	4,437	27
100,000 to less than 200,000	54	8,070	50	44	6,579	39
200,000 and over	6	2,131	13	10	3,228	19
Total	210	16,089	100	212	16,794	100

[1] Includes captive tonnage.

creasing the capacity of its pebble lime plant at Strasburg, Va. by 50 percent. Mercer Lime & Stone Co. announced plans for a new lime manufacturing plant at Burgettstown, Pa. Total lime available for steel manufacturing, including the company's Branchton, Pa. plant, will be 1,500 tons daily.

A lime sludge reburning kiln, 320 feet long and reportedly the world's largest, was being installed in Beryl, West Va. Facilities will be leased to the West Virginia Pulp & Paper Co. Groundbreaking ceremonies for construction of a lime hydrating and handling plant for the U.S. Lime division of The Flintkote Co. were held in Richmond, Calif.

The Ohio Lime Co. began production at its new $1.5 million lime plant at Woodville, Ohio. The plant produces chemical and metallurgical dolomitic quicklime.[3] The Brazos Lime Co. new plant at Blum, Tex., went into production. The plant was designed to produce 600 tons per day of chemical lime and an additional 800 tons per shift of byproduct stone.[4]

The milk-of-lime plant, used for the San Manuel Div., Magma Copper Co.'s copper milling operation at San Manuel, Ariz., was described. The mill handles 40,000 tons per day of copper ore, and the lime plant has a capacity of 100 tons per day, used for grinding and flotation.[5]

[3] Iron and Steel Engineer. New Lime Plant Begins Production. V. 42, No. 12, December 1965, p. 162.
[4] Trauffer, W. E. Newest Texas Lime Plant. Pit and Quarry, v. 58, No. 1, July 1965, pp. 90–98.
[5] Engineering and Mining Journal. How San Manuel Prepares Lime Products for Mill. V. 166, No. 12, December 1965, p. 104.

Table 5.—Lime sold or used by producers in the United States, by uses
(Short tons)

Use	1964 Open market	1964 Captive	1964 Total	1965 Open market	1965 Captive	1965 Total
Agriculture	200,000	[1]	200,000	217,000	[1]	217,000
Construction:						
Finishing lime	441,143	W	441,143	364,958	W	364,958
Mason's lime	466,370	W	466,370	443,634	W	443,634
Soil stabilization	449,621	W	449,621	509,048	—	509,048
Other	19,822	W	19,822	75,532	—	75,532
Total [2]	1,377,000	104,000	1,481,000	1,393,000	84,000	1,477,000
Chemical and other industrial:						
Alkalies (ammonium, potassium, and sodium compounds)	13,191	3,368,705	3,381,896	15,364	3,490,961	3,506,325
Brick, sand-lime, slag, and silica	42,471	—	42,471	22,639	—	22,639
Calcium carbide	602,785	355,868	958.653	597,328	W	597,328
Glass	301,534	—	301,534	300,812	—	300,812
Other chemical uses [3]	594,977	1,039,564	1,634,541	673,668	1,337,326	2,010,994
Metallurgical uses:						
Aluminum	93,016	W	93,016	114,068	W	114,068
Copper smelting	122,897	207,418	330,315	125,918	236,495	362,413
Magnesium	19,183	W	19,183	W	113,192	113,192
Ore concentration [4]	92,897	W	92,897	54,861	W	54,861
Steel flux	2,108,212	157,838	2,266,050	2,351,751	158,048	2,509,799
Other metallurgy uses [5]	217,293	293,762	511,055	389,484	199,133	588,617
Paper and pulp	795,076	48,048	843,124	856,229	31,943	888,172
Sewage and trade-wastes treatment	186,213	14,415	200,628	237,859	28,951	266,810
Sugar	29,713	624,819	654,532	37,398	587,102	624,500
Water softening and treatment	909,267	337	909,604	962,372	1,208	963,580
Total [2]	6,129,000	6,111,000	12,239,000	6,740,000	6,184,000	12,924,000
Refractory lime (dead-burned dolomite)	2,096,000	72,000	2,168,000	2,099,000	77,000	2,176,000
Grand total	9,802,000	6,287,000	16,089,000	10,449,000	6,345,000	16,794,000

W Withheld to avoid disclosing individual company confidential data.
[1] Included with open-market agricultural lime to avoid disclosing confidential data.
[2] Data may not add to totals shown because of rounding.
[3] Includes alcohol, calcium carbonate (precipitated), coke and gas, food and food byproducts, insecticides, medicine, and drugs, explosives, oil-well drilling, paint, petrochemicals, petroleum refining, rubber, tanning, salt, miscellaneous, and unspecified uses.
[4] Includes flotation, cyanidation, bauxite purification, and magnesia manufacture.
[5] Includes wire drawing and various metallurgical uses; and items indicated by symbol W.

CONSUMPTION AND USES

Continued growth in the use of lime in basic-oxygen-furnace steelmaking continued to be a major factor behind the growing demand for lime. The basic-oxygen-furnace process uses an average of 125 pounds of lime per ton of steel, as contrasted with the 28 pounds of lime per ton of steel used in the open-hearth furnace. Some estimates place 1970 consumption of lime by the steel industry at nearly 10 times the 1965 level.[6]

The National Lime Association held its 63d Annual Convention in June at Lake Placid, N.Y. Research and product promotion were keynotes of the meeting. Safety, which had fallen off in 1964, was also stressed.[7]

Water and sewage treatment were the subjects of a paper on lime usage. These plants continue to be big users of pebble lime, alum, soda ash, ferric sulfate, ferrous sulfate, and ferric chloride.[8] Soil stabiliza-

[6] Rock Products. Lime Continues to Set Records. V. 68, No. 1, January 1965, p. 63.
[7] Rock Products. Research and Promotion Top NLA List for Survival. V. 68, No. 8, August 1965, pp. 90–91, 102.
[8] Chemical Engineering. How Four Municipalities Cut Water Treatment Costs. V. 72, No. 26, Dec. 20, 1965, pp. 30–31.

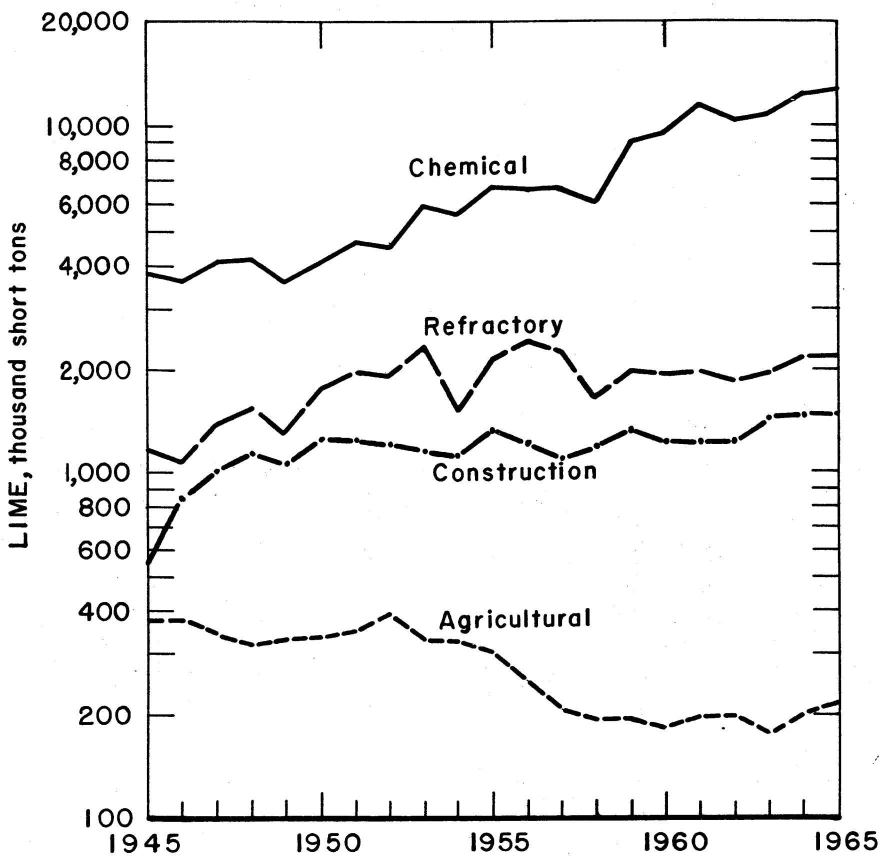

Figure 1.—Trends in major uses of lime.

tion techniques were described for road building and foundation conditioning. A new pulverizer-mixer, called a Metrodon, has been developed for spreading a layer of lime stabilized soil on the road bed.[9] The use of lime for soil stabilization is becoming increasingly popular as several State highway departments showed interest in the technique. Lime has been applied to highway soil stabilization in Texas, California, Wisconsin, and the Dakotas.

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[9] Pit and Quarry. Lime Builds New Bases and Rejuvenates Old Ones. V. 57, No. 12, June 1965, pp. 73–74, 79.

Table 6.—Destination of shipments of primary open-market lime sold in the United States, by States
(Short tons)

State	1964 Quicklime	1964 Hydrated lime	1964 Total	1965 Quicklime	1965 Hydrated lime	1965 Total
Alabama	229,056	12,540	241,596	265,995	16,572	282,567
Alaska	W	W	1,570	W	W	1,861
Arizona	W	W	93,780	W	W	105,718
Arkansas	32,601	15,207	47,808	10,985	19,443	30,428
California	222,796	137,358	360,154	239,680	118,669	358,349
Colorado	35,115	22,902	58,017	50,567	23,718	74,285
Connecticut	55,812	24,860	80,672	51,015	27,852	78,867
Delaware	37,415	11,090	48,505	41,753	10,753	52,506
District of Columbia	W	W	6,832	W	W	5,200
Florida	127,013	63,227	190,240	157,390	57,690	215,080
Georgia	73,906	19,044	92,950	81,161	17,609	98,770
Hawaii	--	W	W	--	W	W
Idaho	W	W	W	W	W	9,611
Illinois	520,769	137,948	658,717	593,258	149,966	743,224
Indiana	668,054	43,926	711,980	631,744	50,483	682,227
Iowa	W	W	80,458	83,924	20,650	104,574
Kansas	35,072	23,538	58,610	36,741	14,265	51,006
Kentucky	457,819	17,534	475,353	481,426	17,612	499,038
Louisiana	131,994	45,360	177,354	202,808	57,189	259,997
Maine	43,162	10,723	53,885	44,225	11,006	55,231
Maryland	211,636	19,684	231,320	232,418	19,246	251,664
Massachusetts	W	W	40,122	W	W	36,312
Michigan	663,124	59,242	722,366	654,686	66,058	720,744
Minnesota	104,376	19,888	124,264	103,924	18,238	122,162
Mississippi	56,405	9,873	66,278	23,819	22,396	46,215
Missouri	W	W	166,412	131,038	55,723	186,761
Montana	8,759	4,233	12,992	7,011	3,849	10,860
Nebraska	W	W	23,742	W	W	21,020
Nevada	W	W	32,933	W	W	W
New Hampshire	W	W	10,400	6,769	3,157	9,926
New Jersey	46,066	80,893	126,959	67,203	79,963	147,166
New Mexico	W	W	20,366	581	26,510	27,091
New York	155,447	143,351	298,798	203,513	150,820	354,333
North Carolina	34,649	30,661	65,310	50,002	29,744	79,746
North Dakota	W	W	16,759	W	W	16,575
Ohio	1,026,257	132,635	1,158,892	1,026,668	157,501	1,184,169
Oklahoma	W	W	82,825	W	W	W
Oregon	49,453	16,415	65,868	52,072	18,020	70,092
Pennsylvania	1,388,100	197,409	1,585,509	1,514,576	198,062	1,712,638
Rhode Island	W	W	15,499	5,865	7,512	13,377
South Carolina	21,839	8,585	30,424	17,481	8,162	25,643
South Dakota	11,483	25,569	37,052	10,593	30,532	41,125
Tennessee	49,417	30,807	80,224	68,376	29,566	97,942
Texas	290,970	388,750	679,720	295,824	396,535	692,359
Utah	W	W	67,916	W	W	75,761
Vermont	W	W	1,238	W	W	2,761
Virginia	104,180	43,774	147,954	102,645	42,148	144,793
Washington	57,739	15,456	73,195	62,307	16,396	78,703
West Virginia	113,513	14,147	127,660	119,073	15,608	134,681
Wisconsin	82,816	67,233	150,049	84,594	57,414	142,008
Wyoming	W	W	3,820	W	W	4,129
Undistributed	429,221	249,626	14,175	323,112	149,895	194,060
Total [1]	7,576,000	2,143,000	9,720,000	8,137,000	2,217,000	10,353,000

W Withheld to avoid disclosing individual company confidential data; included with "Undistributed."
[1] Data may not add to totals shown because of rounding.

PRICES

Quotations in the Engineering News-Record for delivered hydrated finishing lime in 1965 ranged from $52.00 per ton in Minneapolis and Seattle to $27.00 per ton in Los Angeles. The average price reported for 20 major cities was $38.17 per ton. Prices for pulverized quicklime ranged from $60.00 per ton in Boston to $24.00 per ton in Pittsburgh and averaged $35.30 per ton for 13 cities. The average delivered price for common hydrated lime, as reported from 20 selected cities, was $31.86 per ton.

The average value of lime sold or used by producers, f.o.b. plant, excluding the cost of containers, was $13.87 per ton, the same as in 1964.

FOREIGN TRADE

In 1965, Canada received 68 percent of U.S. lime exports, and Mexico received 8 percent.

Imports from Canada represented 78 percent of the combined import total for all types of lime.

Table 7.—U.S. exports of lime

Year	Short tons	Value
1956–60 (average)	61,522	$1,182,824
1961	29,969	920,668
1962	19,512	660,408
1963	17,463	565,299
1964	29,858	777,359
1965	40,036	941,849

Table 8.—U.S. imports for consumption of lime

Year	Hydrated lime		Other lime		Dead-burned dolomite [1]		Total	
	Short tons [2]	Value	Short tons [2]	Value	Short tons [2]	Value	Short tons [2]	Value
1956–60 (average)	642	$12,301	26,909	$473,317	9,307	$519,040	36,858	$1,004,658
1961	950	21,710	31,418	491,352	4,256	233,271	36,624	746,333
1962	1,141	18,755	71,970	939,226	4,456	244,788	77,567	1,202,769
1963	692	12,226	90,676	1,004,920	9,389	454,721	100,757	1,471,867
1964	843	10,475	93,420	1,112,129	28,876	1,165,306	123,139	2,287,910
1965	532	10,032	215,816	2,589,561	59,519	2,385,032	275,867	4,984,625

[1] Dead-burned basic refractory material consisting chiefly of magnesia and lime.
[2] Includes weight of immediate container.

WORLD REVIEW

Mexico.—A new $3.5 million water softening and treatment plant was completed at Merida, Yucatan. The plant contains a cold-lime-alum softening plant and a lime recovery unit. Seven more of these plants are under construction in Yucatan.[10]

Nigeria.—The Israeli firm, Cideco Ltd., announced plans for a substantial lime industry in Nigeria. A 30,000-ton plant was planned, at a cost of $1.4 million. Limestone deposits were being surveyed at Ewokeri and at Yandev.

Puerto Rico.—Puerto Rican Cement Co. Inc. announced that the first white lime plant in Puerto Rico, a 250,000-barrel plant at Ponce, would cost $2.3 million.

United Kingdom.—Beswicks Lime Works, near Buxton, ordered three 100-to-120 ton-per-day lime kilns. The International Symposium on Autoclaved Calcium Silicate Building Products was held at the School of Pharmacy in the University of London during May. There were 42 papers, covering all kinds of products, manufacturing, chemical research, and design of structures.[11]

TECHNOLOGY

Research on soil stabilization in Great Britain included studies of the reaction between hydrated lime and the clay present in the soil and studies of stabilization of sandy soils with lime and fuel ash mixtures. All the ashes were shown to possess pozzolanic properties, with the activity related to the surface area and the unburnt carbon content of the ash.[12]

A highly automated sand-lime brick plant in England has reduced the labor requirement to the very low level of 3 man-hours per 1,000 bricks. The capital expenditure is 40 percent of that needed for a clay brick factory.[13]

A process for burning limestone, using naphtha instead of coal, was used at the

[10] Engineering News-Record. Joint Plans Speed Construction. V. 175, No. 23, Dec. 2, 1965, pp. 35–36.
[11] Cement, Lime and Gravel (London). International Symposium on Autoclaved Calcium Silicate Building Products. V. 40, No. 7, July 1965, pp. 248–252.
[12] Cement, Lime and Gravel (London). Lime & Pulverized Fuel Ash as Soil-Stabilizing Agents. V. 40 No. 7, July 1965, p. 261.
[13] Cement, Lime and Gravel (London). Automation in the Manufacture of Sand-Lime Bricks. V. 40, No. 6, June 1965, pp. 203–206.

Table 9.—World production of quicklime, hydrated lime, and dead-burned dolomite [1]

(Thousand short tons)

Country	1961	1962	1963	1964	1965 [p] [2]
North America:					
Canada	1,415	1,424	1,451	1,541	1,517
Costa Rica [e]	4	4	6	7	13
Guatemala	NA	NA	31	29	30
Nicaragua	28	29	4	18	27
Puerto Rico	1	1	14,521	16,089	16,794
United States (sold or used by producers)	13,249	13,753	3	NA	NA
West Indies:					
Bahamas	3	2	[r] 5	[r] 3	4
Barbados (exports)	[r] 16	NA	—	—	—
Dominican Republic	7	8			
Haiti [e]	180	180	180	180	180
South America:					
Argentina	1,100	NA	NA	NA	NA
Brazil	1,410	1,308	1,332	[r] 1,585	NA
Colombia	90	94	107	[r] 110	117
Paraguay	[r] 19	[r] 19	[r] 19	20	20
Peru	77	88	94	102	NA
Uruguay [e]	36	36	33	[r] 46	66
Venezuela	38	49	[r] 55	[r] 75	[e] 72
Europe:					
Austria	784	740	759	[r] 805	753
Belgium	2,120	2,245	[r] 2,223	[r] 2,534	2,526
Bulgaria	698	766	830	913	NA
Czechoslovakia	2,598	2,611	2,485	2,587	2,743
Denmark	162	162	167	176	176
Finland	245	246	229	265	270
France	3,248	3,078	2,919	[r] 3,216	2,999
Germany:					
East	3,116	3,686	3,811	[r] 4,049	[e] 4,100
West	10,939	10,690	10,775	[r] 11,920	11,714
Hungary	676	685	685	807	782
Ireland	32	[r] 33	[r] 36	47	46
Luxembourg	13	—	—	—	—
Malta	45	39	18	NA	43
Norway	NA	NA	NA	121	140
Poland	2,071	2,186	2,209	2,326	[e] 2,425
Rumania	725	746	806	[r] 896	[e] 1,000
Spain	160	203	234	[r] 283	NA
Sweden	983	798	[r] 853	[r] 1,071	NA
Switzerland	205	212	203	221	NA
U.S.S.R.	[r] 19,025	[r] 18,239	17,651	[r] 17,855	[e] 18,700
Yugoslavia	800	847	947	999	1,226
Africa:					
Congo, Republic of the (Léopoldville)	NA	52	74	75	72
Ethiopia (including Eritrea) [3]	5	6	5	[e] 7	[e] 4
Kenya	NA	NA	NA	[r] 5	16
Libya [e]	18	19	NA	NA	NA
Mozambique	8	7	NA	NA	NA
South Africa, Republic of (sales)	748	726	719	771	823
South-West Africa	4	3	3	4	4
Tanzania (sales and exports)	4	3	1	2	2
Tunisia	133	142	[r] 146	193	[e] 185
Uganda	16	18	12	[r] 13	22
Zambia	NA	NA	NA	NA	85
Asia:					
Cyprus	45	50	65	[e] 44	NA
Indonesia	114	NA	NA	NA	NA
Japan	[r] 1,255	[r] 1,373	1,527	1,798	1,865
Kuwait	—	—	—	13	1
Lebanon	8	[e] 10	39	29	44
Mongolia [e]	14	23	28	33	39
Philippines	28	[e] 47	35	[r] 32	26
Ryukyu Islands	3	1	[e] 1	NA	NA
Saudi Arabia	NA	NA	7	NA	33
Taiwan	84	83	88	101	113
Oceania:					
Australia [4]	124	139	[r] 130	[r] 144	NA
Fiji Islands	4	3	6	4	20

[e] Estimate. [p] Preliminary. [r] Revised. NA Not available.

[1] Lime is also produced in Burundi, Cape Verde Islands, Chile, China, Ecuador, El Salvador, Greece, Honduras, India, Iran, Israel, Italy, South Korea, Mexico, Morocco, New Zealand, Pakistan, Ruanda, Southern Rhodesia, Syrian Arab Republic, and Viet-Nam, but production data are not available. In addition Bermuda, Guadeloupe, Netherlands Antilles, Sarawak and St. Thomas and Principe Islands produce less than 1,000 tons.

[2] Compiled mostly from data available July 1966.

[3] Year ended September 10 of year stated.

[4] Year ended June 30 of year stated.

Hylla Lime Works in Inderoy, Norway. The process was developed in cooperation with the Esso Research Centre at Abingdon, Oxfordshire, England.[14]

A method of testing soundness in plaster was developed as a test of unsoundness in limes. This method is called the LeChatelier test, it measures the expansion in a specimen compact.[15]

A new vertical shaft kiln has overcome many of the defects of vertical kilns, especially channeling. A pilot model has been built and has proved the following principles: Heat can be perfectly distributed, giving complete combustion; overburning can be avoided; and complete temperature control is possible.[16]

In the preparation of a dry, highly plastic hydrated lime, the quicklime is contacted with a gaseous reactant to form a dry reaction film on the particles, and the resulting slaked particles dried to form a powder.[17]

The Berlin Symposium on lime was described. The papers discussed included underground mining, crushing, limestone dressing, quarry equipment, quality control, limestone calcination, lime quality requirements, oil-fired lime shaft kilns, and plasticized binders.[18]

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[14] Minerals Processing. Naptha for Burning Limestone. V. 6, No. 8, August 1965, p. 6.

[15] Ramachandra, V. S., R. F. Feldman, and P. J. Sereda. An Unsoundness Test for Limes Without Cement. Mat. and Res. Standards. V. 5, No. 10, October 1965, pp. 510–516.

[16] Pit and Quarry. Pilot Model of New Vertical Shaft Lime Kiln Proves Design Principles. V. 58, No. 3, September 1965, pp. 132-136.

[17] Corson, B. L. (assigned to G. & W. H. Corson). British Pat. 976,085, Nov. 25, 1964.

[18] Cement, Lime, and Gravel (London). International Symposium on Lime, Berlin, September 1965. Part 1: The Symposium. V. 40, No. 11, November 1965, pp. 385–390. And Part II: The Study Tour. V. 40, No. 12, December 1965, pp. 421–426.

Lithium

By Donald E. Eilertsen [1]

Production of domestic lithium mineral source materials was noticeably larger in 1965 than in 1964, but imports of lithium minerals from Southern Rhodesia declined sharply.

Legislation and Government Program.— In August 1965 the Atomic Energy Commission transferred 6,497 tons of Lithium hydroxide, monohydrate, to the custody of the General Services Administration. The transfer was made under provisions of the Federal Property and Administrative Services Act of 1949.

DOMESTIC PRODUCTION

There was a moderate increase in the output of spodumene, a moderate decrease in the output of lithium carbonate from brines, a decline in amblygonite production, and no change in lepidolite production in 1965 compared to 1964.

Foote Mineral Co. mined spodumene ore from pegmatite and produced spodumene flotation concentrate at Kings Mountain, N. C.; American Potash & Chemical Corp. recovered lithium carbonate from Searles Lake brines at Trona, Calif.; and in Pennington County, S. Dak., L. W. Judson produced 75 tons of amblygonite from the Hugo mine, and Keystone Chemical Corp. produced 25 tons of amblygonite and 50 tons of lepidolite from the Ingersoll mine. Production data on spodumene flotation concentrate and lithium carbonate are not disclosed, as they are company confidential.

The consumers of lithium mineral source materials for the production of lithium chemicals were Foote Mineral Co., at Sunbright, Va., Lithium Corporation of America, Inc. at Bessemer City, N.C.; and American Potash & Chemical Corp., at Trona, Calif. No production figures were available for publication.

Foote Mineral Co. continued to prepare its new facility at Silver Peak, Nev., for the mining of brines containing lithium, potassium, and magnesium from a dry lake bed. Full scale output is expected in 1966.

CONSUMPTION AND USES

Figures on the consumption of lithium mineral source materials for chemical production are withheld to avoid disclosing company confidential information. Figures on the consumption of lithium minerals in the ceramic and glass industries were obtained, but the data were too incomplete for publication. Quantitative data on the consumption of lithium metal, alloys, and compounds were not available.

The largest use of spodumene was in the production of lithium chemicals. Lepidolite, petalite, and spodumene, and some amblygonite were used as sources of lithium in the glass and ceramic industries. Lithium chemicals had many applications, such as in greases, storage batteries, bleaches, air conditioning, refrigeration, welding and brazing fluxes, and in ceramics and glass. On a company basis, gains were reported in the usage of lithium bromide in refrigeration, lithium hydroxide in lubricants, lithium hypochlorite as dry bleach for laundries and swimming pool sanitation, and lithium metal in alloys, especially lithium-magnesium alloy.

[1] **Commodity specialist, Division of Minerals.**

PRICES

Lithium metal, 99.5-percent pure, was quoted at $9 to $11 per pound throughout 1965.[2] Prices for various compounds are shown in table 1.

Table 1.—Prices of selected lithium compounds in 1965
(Per pound)

Compound	1965
Lithium aluminum hydride, lump, drums, works [1]	$33.00–$39.00
Lithium carbonate:	
Drums, ton lots [2]	.46
Technical, drums, ton lots [3]	.45
Lithium chloride:	
Chemically pure, anhydrous, drums, ton lots	1.235
Technical, anhydrous, drums, carlots, truckloads, delivered or works, freight allowed	.87
Technical, anhydrous, drums, less than carlots, freight allowed	.88–.92
Lithium fluoride:	
Barrels, ton lots and more, delivered	1.55
Barrels, less ton lots, delivered	1.65
Lithium hydride, powder, drums, 500-pound lots or more, works	9.50
Lithium hydroxide:	
Monohydrate, granular, drums, carlots, truckloads, freight allowed	.54
Monohydrate, drums, less than carlots, freight allowed	.58
Lithium manganite, drums, works [1]	1.35–1.45
Lithium nitrate, technical, drums, 100-pound lots	1.15–1.25
Lithium silicate, drums, works [1]	1.25–1.50
Lithium stearate:	
Drums, carlots, works	.475
Drums, ton lots, works	.485
Drums, less than ton lots, works	.535
Lithium sulfate, drums, 100-pound lots	1.15–1.25
Lithium titanate, drums, works [1]	1.50–2.00

[1] Price not quoted after Nov. 22, 1965.
[2] Price through Nov. 1, 1965, was $0.58 per pound.
[3] Price through Nov. 1, 1965, was $0.50 per pound.

Source: Oil, Paint and Drug Reporter.

FOREIGN TRADE

Imports of lithium minerals were mostly for the glass and ceramic industries; the imports of lithium minerals from Southern Rhodesia were the smallest for many years. Imports for consumption of lithium minerals are shown in table 2.

Imports of lithium compounds for consumption were as follows: 1,337,300 pounds valued at $573,235 from Canada, 8 pounds valued at $2,005 from the United Kingdom, and 22 pounds valued at $1,349 from West Germany.

Table 2.—U.S. imports for consumption of lithium minerals, by country of origin and U.S. customs district

Country of origin and U.S. customs district	1964 r Short tons	1964 r Value	1965 Short tons	1965 Value
Africa:				
Mozambique: Maryland	-----	------	1,122	$39,148
Zambia, Southern Rhodesia, and Malawi: Maryland	27,033	$851,861	7,868	247,302
Total	27,033	851,861	8,990	286,450

r Revised.

WORLD REVIEW

South-West Africa.—All of the lepidolite and petalite and half of the amblygonite production in South-West Africa in 1964 was from the Helicon, Rubicon, and Aurora mines of S.W.A. Lithium Mines (Pty.) Ltd., which are located southeast of Karibib.

[2] E&MJ Metal & Mineral Markets. V. 36, Nos. 1–52, January–December 1965.

United Kingdom.—In trade controls affecting Southern Rhodesia, imports of lithium mineral were prohibited as of December 6.

The United Kingdom revoked its antidumping duty on Canadian lithium carbonate in August; the duty came into effect November 30, 1962.

Table 3.—Free world production of lithium minerals, by countries

(Short tons)

Country	Mineral produced	1961	1962	1963	1964	1965 p
North America: [1] Canada	Spodumene (Li_2O content)	268	250	322	r 528	518
South America:						
Argentina	Lithium minerals	443	496	r 1,583	r 799	NA
Brazil	Spodumene (exports)	----	165	28	----	NA
Surinam	Amblygonite (exports)	475	827	568	NA	NA
Europe: Spain	Amblygonite	19	----	----	----	----
Africa:						
Mozambique	Lepidolite	170	302	115	----	----
Rhodesia, Southern	Eucryptite	1,879	866	1,164	806	e 705
	Amblygonite	86	35	52	----	----
	Lepidolite	24,037	21,244	16,157	22,943	e 17,700
	Petalite	27,698	21,704	29,946	36,449	e 29,900
	Spodumene	1,627	1,496	2,235	6,965	e 15,300
Rwanda	Amblygonite	1,854	359	406	325	NA
South Africa, Republic of	Lithium minerals	260	1,263	417	r 179	e 1,025
South-West Africa	Amblygonite	136	141	128	r 12	39
	Lepidolite	1,418	1,781	86	r 407	298
	Petalite	2,540	1,008	865	r 798	1,332
Uganda	Amblygonite	25	22	53	r 22	----
Oceania: Australia	Petalite	108	94	437	233	e 510
	Amblygonite	26	31	22	----	
	Spodumene	6	26	24	58	

r Revised. e Estimate. NA Not available. p Preliminary.

[1] U.S. figure withheld to avoid disclosing individual company confidential data.

Table 4.—South-West Africa: Exports of lithium mineral concentrates, by country of destination

Year and country of destination	Amblygonite		Lepidolite		Petalite	
	Short tons	Value [1]	Short tons	Value [1]	Short tons	Value [1]
1964:						
Japan	----	----	----	----	392	$9,867
Netherlands	----	----	330	$7,650	323	8,035
United Kingdom	----	----	212	4,561	436	8,523
Total	----	----	542	12,211	1,151	26,426
1965: Total [2]	669	NA	170	NA	1,110	22,721

[1] Converted to U.S. currency at the rate of 1 rand equals US$1.3909 (1964) and U.S.$1.327 (1965).

[2] No data available on countries of destination.

Table 5.—Southern Rhodesia: Exports of lithium mineral concentrates, by country of destination

Country of destination	1963		1964	
	Short tons	Value [1]	Short tons	Value [1]
Belgium	4,304	$76,180	14,513	$267,866
Germany, West	51	2,856	----	----
Italy	714	4,665	904	10,096
Japan	3,499	98,140	7,429	206,822
Netherlands	3,403	78,954	4,327	95,423
South Africa, Republic of	189	2,965	409	5,822
United Kingdom	3,827	56,784	10,688	160,422
United States	24,256	507,366	36,014	770,698
Total	40,243	827,910	74,284	1,517,149

[1] Converted to U.S. currency at the rate of £1 equals US$2.80 (1963) and US$2.7921 (1964).

TECHNOLOGY

Bureau of Mines metallurgists worked on the beneficiation of lithium minerals and the thermodynamic properties of spodumene and various lithium compounds. At 298.15° K the heat of formation of lithium chloride was found to be —98.38 ± 0.54 kcal/mole and that for lithium oxalate was —329.02 ± 0.79 kcal/mole, using graphite as a standard state for carbon.[3] A procedure was reported for devitrifying cast rolled shapes of glass containing about 17 percent lithia and 82 percent silica.[4] The devitrification of lithium silicate glasses was investigated for the effect of annealing temperature, composition, and additives on nucleation and crystallization.[5]

Corrosion studies were made on a number of alloys in connection with the use of lithium as heat-transfer medium in proposed advanced power plants.[6]

The lightest structural metals available commercially are reported to be magnesium-lithium alloys. One of the alloys which is 22 percent lighter than magnesium and 27 percent lighter than beryllium has limited uses in the aerospace industry. The technical and economic aspects of magnesium-lithium alloys were reported.[7] A comprehensive review of the use of lithium and its compounds as catalysts in industrial polymerization was published.[8]

Three methods were developed for producing single-domain crystals of lithium metaniobate, a material having unusual electrical, optical, and acoustical properties, for potential uses in a variety of electrical devices.[9]

Numerous patents on lithium were issued.[10]

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[4] Harris, Henry M., John E. Kelley, and Hal J. Kelly. Devitrification of Lithium Disilicate Glass. BuMines Rept. on Inv. 6711, 1965, 14 pp.

[5] Paige, Jack I., Henry M. Harris, and Hal J. Kelly. Devitrification of Vacuum-Melted Glasses of the Lithium Metasilicate-Silica Compositional Series. BuMines Rept. of Inv. 6651, 1965, 15 pp.

[6] Materials for Space-Power Liquid Metals Service. Defense Metals Inf. Center, Battelle Memorial Inst., DMIC Memorandum 209, Oct. 5, 1965, 9 pp.

[7] Frost, Paul D. (Battelle Memorial Inst.). Technical and Economic Status of Magnesium-Lithium Alloys—A Technology Utilization Report. National Aeronautics and Space Administration, NASA SP-5028, August 1965, 45 pp. Supt. of Documents, U.S. Govt. Printing Office, Washington, D.C.

[8] Kamienski, C. W. Lithium Catalysis in Industrial Polymerization. Ind. and Eng. Chem., v. 57, No. 1, January 1965, pp. 38–55.

[9] Chemical & Engineering News. Three Techniques Give Single-Domain $LiNbO_3$. V. 43, No. 33, Aug. 16, 1965, pp. 38–39.

[10] Bach, Ricardo O., and William W. Boardman (assigned to Lithium Corporation of America, Inc., New York). Preparation of Anhydrous Lithium Peroxide. U.S. Pat. 3,185,546, May 25, 1965.

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Orazem, Gerald J., Ruben B. Ellestad, and Joseph R. Nelli (assigned to Lithium Corporation of America, Inc., New York). Preparation of Dry Lithium Hypochlorite Compositions. U.S. Pat. 3,171,814, Mar. 2, 1965.

Magnesium

By Lloyd R. Williams [1]

Although the production of magnesium in 1965 increased only 2 percent, inventories were considerably reduced by a 15-percent increase in shipments. The domestic output of primary metal was slightly more than 81,000 tons, the largest since 1953.

One company was developing a process to recover magnesium from the Great Salt Lake in Utah. Five other companies have secured leases to exploit the resources of the lake after March 8, 1969, when present exclusive rights terminate.

The Magnesium Association reorganized and issued new by-laws to members.

LEGISLATION AND GOVERNMENT PROGRAMS

The national stockpile objective established by the Office of Emergency Planning remained at 144,687 short tons. At yearend the stockpile contained 168,119 tons or an excess of 23,432 tons. On August 16, 1965, the House of Representatives passed the Concurrent Resolution 453 with the Senate concurring for the disposal of approximately 21,500 short tons of magnesium contained in primary pigs and alloys. Of this quantity about 5,000 tons will be offered in 1966.

During 1965 about 4,200 tons of magnesium was offered for sale on a competitive bid basis from the national stockpile. Of this 2,650 tons was sold at an acceptable price bringing the total utilized by a Government agency or sold since March 1962 to 10,685 tons.

Table 1.—Salient magnesium statistics

(Short tons)

	1956–60 (average)	1961	1962	1963	1964	1965
United States:						
Production:						
Primary magnesium	50,162	40,745	68,955	75,845	79,488	81,361
Secondary magnesium	10,066	8,125	9,610	9,225	11,790	13,617
Shipments: Primary	50,174	55,515	69,410	72,255	74,580	85,796
Imports for consumption	629	1,005	2,359	1,850	2,227	2,551
Exports	2,176	6,160	6,426	15,484	15,949	17,836
Consumption	42,411	45,533	47,320	51,240	54,748	69,622
Price per pound cents	34.98	35.25	35.25	35.25	35.25	35.25
World: Primary production	101,260	115,800	147,200	159,900	166,172	174,000

DOMESTIC PRODUCTION

Production of 81,361 short tons of primary magnesium in the United States was 2 percent more than in 1964. Alamet Division of Calumet and Hecla, Inc., producer of magnesium metal in Selma, Ala., increased plant capacity to 7,000 tons per year by technological improvements; Chas. Pfizer & Co., Inc., produced magnesium ingot and continued supplying magnesium in the form of crown for final usage by the Atomic Energy Commission (AEC); The Dow Chemical Co. operated plants at

[1] Commodity specialist, Division of Minerals.

Freeport and Velasco, Tex., and planned to increase capacity to 120,000 tons. Dow also announced future plans to produce electrolytic metal from magnesium chloride to be supplied by a joint venture of Lithium Corporation of America, Inc. and Salzdetfurth of Hanover, West Germany, organized to exploit the resources of the Great Salt Lake in Utah, after March 8, 1969. Titanium Metals Corp. of America, Henderson, Nev., owned jointly by Allegheny Ludlum Steel Corp. and the National Lead Co., recovered and recycled magnesium for use in titanium production. National Lead Co., Hogle-Kearns Co., and Hooker Chemical Corp. were jointly developing a method to produce magnesium from magnesium chloride recovered from the Great Salt Lake.

The plans, announced in 1963, by Kaiser Aluminum & Chemical Corp. and Harvey Aluminum, Inc., to build primary magnesium plants in the Pacific Northwest did not materialize. Both companies together with others that included Signal Oil and Gas, Los Angeles, Calif., and Quintana Petroleum Corp., Houston, Tex., secured leases to exploit resources of the Great Salt Lake. Interest in magnesium plants in the northwest was reactivated by the search for low cost power to produce metal from magnesium chloride recovered from the lake.

The Products Engineering Company, Portland, Oreg., expanded facilities to include magnesium die casting.

A magnesium powder plant built in 1963 at Essex, Conn., by Metallurgical Processing Co., was in full operation. The company made contracts to supply magnesium powder valued at $2.2 million for military uses.

Table 2.—Magnesium recovered from scrap processed in the United States, by kinds of scrap and forms of recovery

(Short tons)

	1956–60 (average)	1961	1962	1963	1964	1965
Kind of scrap:						
New scrap:						
Magnesium-base	2,998	1,905	4,700	4,183	4,505	6,306
Aluminum-base	2,178	1,500	1,770	2,848	3,177	3,643
Total	5,176	3,405	6,470	7,031	7,682	9,949
Old scrap:						
Magnesium-base	4,172	4,260	2,620	1,150	2,998	2,232
Aluminum-base	718	460	520	1,044	1,110	1,436
Total	4,890	4,720	3,140	2,194	4,108	3,668
Grand total	10,066	8,125	9,610	9,225	11,790	13,617
Form of recovery:						
Magnesium alloy ingot [1]	3,791	1,090	1,110	2,227	2,875	2,138
Magnesium alloy castings (gross weight)	136	360	650	404	37	14
Magnesium alloy shapes	3	350	195	75	50	58
Aluminum alloys	3,197	1,910	1,850	3,839	4,468	7,947
Zinc and other alloys	42	1,095	560	435	23	23
Chemical and other dissipative uses	190	1,350	260	754	588	542
Cathodic protection	2,707	1,970	4,985	1,491	3,749	2,895
Total	10,066	8,125	9,610	9,225	11,790	13,617

[1] Figures include secondary magnesium content of both secondary and primary magnesium alloy ingot.

CONSUMPTION AND USES

Magnesium consumption was more than 20 percent above the 1964 level. Use in printing plates and in the production of nodular iron expanded.

Magnesium die castings were used in the products of three major power mower manufacturers and in eight racing cars built for the 500-mile Memorial Day race in Indianapolis. Castings made from magnesium are two-thirds of the weight of aluminum and require only two-thirds of the time for heat release from the die. Magnesium die castings were used for holding glass portals of welding helmets and replaced magnesium extrusions in luggage frames, because extrusions were difficult to bend to the desired angle.

Magnesium-lithium alloy that costs $25

per pound was being used for the structure of the guidance computer for the *Saturn V* moon rocket. The high cost is a minor factor when excess weight in space vehicles is considered to impose a $10,000 per pound penalty. The alloy is half the weight of aluminum and three-fourth the weight of magnesium. It has exceptional tensile strength, thermal properties, and damping characteristics. It is the most efficient material based on the stiffness-to-weight ratio except for beryllium.

Table 3.—Consumption of primary magnesium (ingot equivalent and magnesium content of magnesium-base alloys), in the United States by uses

(Short tons)

Use	1956–60 (average)	1961	1962	1963	1964	1965
For structural products:						
Castings:						
Sand	5,117	2,408	3,464	3,280	2,229	2,959
Die [1]	1,675	1,328	3,660	5,580	4,757	5,599
Permanent mold	844	464	901	1,400	732	814
Wrought products						
Sheet and plate	4,943	4,434	6,352	5,650	4,897	4,937
Extrusions (structural shapes, tubing)	3,916	3,990	6,240	3,370	4,419	[2] 5,995
Forgings	685	767	415	220	293	*W*
Total	17,180	13,391	21,032	19,500	17,327	20,304
For distributive or sacrificial purposes:						
Powder	509	244	465	1,175	*W*	*W*
Aluminum alloys	12,519	19,754	18,405	21,780	21,880	26,266
Zinc alloys	([3])	27	100	70	99	136
Other alloys	478	1,017	896	1,420	1,705	2,216
Scavenger and deoxidizer	704	344	1,120	150	141	170
Chemical	233	297	430	470	2,684	3,806
Cathodic protection (anodes)	2,866	2,406	2,024	2,985	4,983	4,597
Reducing agent for titanium, zirconium, halfnium, uranium, and beryllium [4]	7,821	7,950	2,843	3,070	3,764	8,467
Other [5]	101	103	5	620	2,165	3,660
Total	25,231	32,142	26,288	31,740	37,421	49,318
Grand total	42,411	45,533	47,320	51,240	54,748	69,622

W Withheld to avoid disclosing individual company confidential data.
[1] Includes primary metal to produce small quantities of investment castings.
[2] Includes "Forgings."
[3] Before 1961, included with "Other alloys,"
[4] Quantity used for reduction of uranium not included in 1964.
[5] Includes primary metal for experimental purposes, debismuthizing lead, and producing modular iron, and secondary magnesium alloys and powder.

The Minerals Pigments & Metals Division of Chas. Pfizer & Co., Inc. were awarded a contract to deliver 1,500 to 2,500 tons of magnesium to AEC between July 1, 1965, and June 30, 1966, for an amount in excess of $1 million.

PRICES

The quoted base price of primary magnesium, 42-pound slabs, remained at 35.25 cents per pound f.o.b. U.S. plants. The declining price scale initiated by The Dow Chemical Co. to aluminum smelters and alloyers places the price at 33.25 cents in 1965. During 1965 GSA accepted bids as low as 32 cents per pound for grade-A magnesium from the national stockpile. The highest bid received was 32.45 cents per pound. In Canada magnesium was sold for 31 cents per pound and in West Germany 25 cents per pound.

Prices, which were quoted in the American Metal Market for magnesium-ferrosilicon alloy used for nodular iron, ranged during the year between 19 cents in January, 17.9 cents in June, and 19.5 cents in December for alloy containing 9 percent magnesium. For the same magnesium content with 0.5 percent cerium, prices ranged between 21.5 cents in January, 19.9 cents in June, and 22 cents in December. Prices for 5-percent-magnesium-content alloy remained at 15.6 cents during the year.

STOCKS

On December 31, 1965, producer and consumer stocks were 12,800 tons of primary magnesium and 2,700 tons of primary magnesium alloy ingot. Stocks at the beginning of 1965 were 17,400 tons of primary magnesium and 4,100 tons of primary magnesium alloy ingot.

Table 4.—Stocks and consumption of new and old magnesium scrap in the United States in 1965

(Short tons)

Scrap item	Stocks, Jan. 1	Receipts	Consumption: New scrap	Consumption: Old scrap	Consumption: Total	Stocks Dec. 31
Cast scrap	227	3,001	114	2,726	2,840	388
Solid wrought scrap	r 374	3,756	3,633	----	3,633	497
Borings, turnings, drosses, etc.	r 169	4,046	3,954	----	3,954	261
Total	r 770	10,803	7,701	2,726	10,427	1,146

r Revised.

FOREIGN TRADE

The imports of 2,981 tons (magnesium content) came from 21 countries as follows: 1,521 tons from Canada; 281 tons from Norway; 256 from Belgium and Luxembourg; 231 tons from the United Kingdom; 207 tons from Netherlands; 117 tons from West Germany; 92 tons from Sweden; 67 tons from Denmark; and 47 tons each from Japan and Republic of South Africa. The remainder came from Dominican Republic, Australia, Malaysia, Spain, Hong Kong, Taiwan, Kuwait, Portugal, Iran, Bermuda, Southern Rhodesia, and Malawi.

The duty on magnesium and scrap remained at 40 percent ad valorem; alloys (magnesium content) were 16 cents per pound plus 8 percent ad valorem; and wrought magnesium was 13.5 cents per pound plus 7 percent ad valorem. Duty on metal waste and scrap was temporarily suspended through June 30, 1966.

Table 5.—U.S. imports for consumption and exports of magnesium

Year	Imports: Metallic and scrap: Short tons	Imports: Metallic and scrap: Value	Imports: Alloys (magnesium content): Short tons	Imports: Alloys (magnesium content): Value	Imports: Powder, sheets, tubing, ribbons, wire, and other forms (magnesium content): Short tons	Imports: Powder, sheets, tubing, ribbons, wire, and other forms (magnesium content): Value
1956-60 (average)	629	$313,830	24	$193,312	11	$60,823
1961	1,005	482,907	31	170,304	5	80,419
1962	2,359	1,079,819	53	106,242	35	83,399
1963	1,850	733,248	485	660,135	18	112,146
1964	2,227	889,908	474	710,299	40	70,176
1965	2,551	1,100,539	327	760,425	103	127,666

Year	Exports: Metal and alloys in crude form and scrap: Short tons	Exports: Metal and alloys in crude form and scrap: Value	Exports: Semifabricated forms, n.e.c.: Short tons	Exports: Semifabricated forms, n.e.c.: Value	Exports: Powder: Short tons	Exports: Powder: Value
1956-60 (average)	2,176	$1,425,451	622	$981,386	22	$41,767
1961	6,160	3,639,669	488	878,815	33	78,297
1962	6,426	3,656,316	594	1,002,977	21	52,980
1963	15,484	8,599,260	690	1,187,912	33	87,075
1964	15,949	8,848,490	862	1,354,014	8	29,491
1965	17,836	10,265,192	484	1,259,743	(1)	(1)

1 Beginning Jan. 1, 1965 no longer separately classified, included with semifabricated forms, n.e.c.

Table 6.—U.S. exports of magnesium, by classes and countries

(Short tons)

Destination	1964 Primary metal, alloys, and scrap	1964 Semifabricated forms, n.e.c. including powder	1965 Primary metal, alloys, and scrap	1965 Semifabricated forms, n.e.c. including powder
North America:				
Canada	1,726	355	1,747	188
Mexico	269	67	477	2
Other	----	5	3	8
Total	1,995	427	2,227	198
South America:				
Brazil	896	(1)	811	1
Venezuela	----	19	11	15
Other	32	24	132	38
Total	928	43	954	54
Europe:				
Belgium-Luxembourg	6	16	90	8
France	450	32	190	21
Germany, West	10,663	93	12,009	84
Italy	45	18	63	19
Netherlands	51	8	160	4
Spain	33	----	163	----
Switzerland	121	9	34	4
United Kingdom	400	21	424	19
Yugoslavia	301	----	597	----
Other	28	40	95	32
Total	12,098	237	13,825	191
Africa	55	23	49	(1)
Asia:				
India	24	2	63	----
Israel	23	6	8	6
Japan	552	101	334	4
Other	3	26	47	11
Total	602	135	452	21
Oceania	271	5	329	20
Grand total	15,949	870	17,836	484

[1] Less than ½ unit.

WORLD REVIEW

There are indications that Volkswagenwerk A. G. will be joined by other European automakers as substantial users of magnesium. As world prices of aluminum and zinc increase, the competitive status of the lighter weight magnesium metal is enhanced.

The quotas for duty-free magnesium imports entering member countries of the European Economic Community from other countries were increased in 1965 to 39,000 short tons for West Germany, 176 tons for the Netherlands, and 495 tons for Belgium-Luxembourg.

Canada.—The value of magnesium exported from January to September was about 9 percent above that of the same period in 1964. The United Kingdom received 42 percent, West Germany 34 percent, and France and Australia each about 6 percent. The United States probably received nearly all of the remainder. In addition to the magnesium ingot for defense purposes, the United States received magnesium scrap which is free of the 40-percent duty on commercial magnesium ingot.

Dominion Magnesium Ltd., the only magnesium producer in Canada, is installing 2 additional gas-fired reduction furnaces at Haley, Ontario, bringing the total to 16 furnaces and increasing the capacity from 10,000 to 11,500 tons per year.

Table 7.—World production of primary magnesium, by countries [1]
(Short tons)

Country	1961	1962	1963	1964	1965 p
Canada	7,635	8,816	8,907	9,353	11,133
China [2]	1,000	1,000	1,000	1,000	1,000
France	2,287	2,337	1,921	1,100	3,131
Germany, West [3]	440	550	550	550	550
Italy	6,365	6,288	6,092	6,645	e 6,600
Japan	[4] 2,477	[4] 2,301	[4] 2,689	[4] 3,237	e 3,700
Norway	16,018	16,400	22,700	24,300	e 25,000
U.S.S.R. e	33,000	35,000	35,000	35,000	36,000
United Kingdom [5]	5,824	5,559	5,219	5,499	e 5,500
United States	40,745	68,955	75,845	79,488	81,361
World total (estimate) [1]	115,800	147,200	159,900	166,200	174,000

e Estimate. p Preliminary.
[1] This table incorporates some revisions. Data do not add exactly to totals shown because of rounding where estimated figures are included in the detail.
[2] Conjectural, denoting an order of magnitude.
[3] Estimate according to the 52nd Annual issue of Metal Statistics (Metallgesellschaft), except for 1965.
[4] In addition, the following amounts of secondary magnesium were produced: 1961, 3,060; 1962, 2,130; 1963, 1,556; and 1964, 2,478 metric tons.
[5] Primary metal and remelt alloys.

Germany, West.—Estimates of magnesium consumption in 1965 were reported as 53,000 tons including use in aluminum alloys and other outlets.[2] Of this about 42,000 tons was used by Volkswagenwerk A. G., based on estimated vehicle production.

January to May imports indicate a potential yearend increase of 16 percent. Norway accounted for 41 percent of the imports and the United States 36 percent compared with 52 percent and 30 percent, respectively, in 1964.

India.—Plans were announced for the installation of a 250-ton pilot plant for magnesium production at the National Metallurgical Laboratory, Jamshedpur, India. Current requirements for the country are estimated at 200 tons per year.

Japan.—The Magnesium Commission of the Japan Light Metals Society released a survey predicting expansion of the magnesium industry at a rate of 17.8 percent each year. The demand for magnesium in 1968 was estimated at 14,300 tons. Estimates for 1965 primary and secondary magnesium are 9,350 tons. About 60 percent of the magnesium output is secondary and is used as a reducing agent in the production of titanium sponge.

Norway.—Norsk-Hydro Elektrisk A/S, the largest magnesium producer in Europe established a subsidiary company, A/S Rjukan Maskiner at Rjukan, to manufacture 1,500 tons per year of magnesium extrusions. The Norsk-Hydro smelter at Herya was to supply the magnesium.

U.S.S.R.—Production of magnesium and titanium was reported from the new Ust-Kamenogorsk plant near the Mongolian-Chinese border, a low-cost hydroelectric power region. The magnesium ore is obtained from carnalite deposits in the Ural Mountains.

United Kingdom.—Imports of magnesium alloys amounted to 3,148 short tons during 1964 and about 4,850 tons in 1965. Exports totaled 2,237 tons.

[2] Metal Bulletin (London). Rising German Magnesium Use, No. 5022, Aug. 13, 1965, p. 21.

TECHNOLOGY

Research was conducted to develop new sources of magnesium and increase the efficiency of present methods. Studies were directed toward fuller utilization of magnesium by a better understanding and knowledge of the properties and characteristics of the metal and its alloys.

The three-company combination of Hooker Chemical Co., Hogle-Kearns Co., and National Lead Co., started a three-stage research program at Utah's Great Salt Lake to (1) determine the feasibility of evaporation ponds in the Stansbury Basin at the lake's southwest edge by testing the porosity and stability of the basin bottom, (2) establish a process scheme in a pilot plant to fractionate various salts obtained from the lake involving solar evaporation, in-plant evaporation spray drying, and finally dehydration to bone-dry magnesium chloride, and (3) improve a magnesium-producing electrolytic cell for converting magnesium chloride into magnesium and chlorine.[3]

The Bureau of Mines released two reports on research directed toward fuller utilization of light metals. In the first the Bureau obtained basic metallurgical information on the magnesium-zirconium alloy system.[4]

The second report, a study on the ability of magnesium to absorb or damp out mechanical vibration, presented results of measurements made on single crystals of pure magnesium to determine the effects of crystal orientation on the vibration-damping properties. The internal friction of eight single crystals of magnesium with orientation ranging from 10° to 84° was measured at 33.5 kilocycles and 272° C.[5]

The first report of a series of three summarizing practices and cost evaluations of major known magnesium production methods was released. This report was on the metallothermic method. The second and third reports will evaluate carbothermic and electrolytic methods. Costs and requirements of raw materials, energy, and major equipment were estimated for a hypothetical plant designed to produce 12,000 tons of magnesium per year from a suitable type of dolomite using ferrosilicon as a reductant.[6]

Magnesium and certain other metals, notably cerium, added to cast iron cause excess carbon to crystalize in a spheroidal or nodular graphite structure giving the iron the strength and ductility of steel with the castability and economy of gray cast iron. Free carbon in the form of thin flakes of graphite reduces the strength of ordinary gray cast iron. Heating white cast iron produces either white heart malleable cast iron by substantially removing the carbon or black heart malleable cast iron by precipitating the carbon as free graphite in the form of discrete agglomerations increasing the strength and ductility of the iron.

Magnesium is the most economical of the metals suitable for the formation of nodular graphite structure in cast iron. The composition of unalloyed nodular iron, which is usually made in a cupola furnace, is essentially the same as gray iron. The formation of the nodular structure may be hindered by the presence of trace elements such as titanium and lead, unless they are neutralized by including small amounts of cerium. Sulfur is also detrimental, and proportional increased amounts of magnesium or cerium are needed for the formation of the graphite nodules.

Because of the violent reaction that occurs when magnesium is added to molten iron as a primary metal, little or none of the magnesium is retained to help deoxidize and desulfurize the iron. Three general systems have been developed to counteract this violent reaction: (1) dilution of the magnesium by alloying with less reactive carrier metals such as magnesium-ferrosilicon and nickel-magnesium-silicon, (2) introduction of magnesium as the primary metal in a treatment ladle at a pressure higher than the vapor pressure of magnesium at the temperature of the cast iron under treatment, (3) injection of magnesium powder or chips below the surface of the molten iron through graphite tubes with nitrogen or argon as a carrier.

Various techniques for adding magnesium to produce ductile iron are employed; such as plunging a bell loaded with a can of magnesium alloy into a ladle of molten iron at a temperature of 2,700° F within 1 or 2 inches of the ladle bottom. Holes in the plunging bell allow magnesium vapor to escape. They also permit all of the alloying material to leave the bell, thereby causing total solution of the magnesium and preventing dross buildup inside the bell.[7]

The carrier additives currently in use are nickel-magnesium, iron-silicon-magnesium, nickel-iron-silicon-magnesium, iron-silicon-magnesium-cerium, magnesium-impregnated coke, magnesium ingot wire and shapes, and magnesium chips or turnings bonded into briquet form.

Unless nickel is desired in the end product, the use of nickel-magnesium alloys ranging from 40 to 85 percent nickel is

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[3] Chemical & Engineering News. Hooker Joins National Lead, H-K in Salt Lake Venture. V. 43, No. 13, Mar. 29, 1965, p. 30.
Chemical & Engineering News. Magnesium Recovery Project Moves Ahead. V. 43, No. 33, Aug. 16, 1965, p. 40.

[4] Crosby, R. L., and K. A. Fowler. Determination of a Part of the Magnesium-Zirconium Liquidus. BuMines Rept. of Inv. 6673, 1965, 19 pp.

[5] Nothdurft, R. R., and A. E. Schwaneke. Internal Friction as a Function of Orientation in Magnesium Single Crystals. BuMines Rept. of Inv. 6642, 1965, 18 pp.

[6] Dean, K. C., D. A. Elkins, and S. J. Hussey. An Economic and Technical Evaluation of Magnesium Production Methods (In Three Parts) 1. Metallothermic. BuMines Rept. of Inv. 6656, 1965, 76 pp.

[7] Foundry. Magnesium Plunging Practice. V. 93, No. 2, February 1965, p. 132.

relatively expensive. About half of the magnesium is lost by burning when a nickel-magnesium alloy with an 85/15 content ratio, respectively is added to molten iron at 2,640° F. Part of the remainder reacts with the sulfur to form magnesium sulfide slag. In order to maintain a residual content of about 0.06 percent magnesium in the iron, the amount of alloy required is 0.8 percent plus 10 times the sulfur content in the iron.

The magnesium content in the iron-silicon magnesium alloys ranges from 5 to 50 percent. Cerium content may range from 0.5 to 1.5 percent when included.

A series of tests was run to determine the effect on magnesium recovery in the iron by varying the magnesium content of the nodulizing alloy. From preliminary tests an alloy containing 5 percent magnesium, 47 percent silicon, and 0.5 percent cerium was selected as the one with the greatest commercial merit for further study in comparison with the regular cerium-bearing 9-percent-magnesium alloy. Tests showed that both the amount of magnesium recovered in the iron and the nodular graphite structure were similar when 0.11 percent magnesium was added using the 5-percent-magnesium alloy and when 0.16-percent-magnesium was added using the 9-percent magnesium alloy. With the 5-percent-magnesium alloy 36.2 percent of the magnesium was recovered compared with 27.7 percent of the magnesium when using the 9-percent-magnesium alloy.[8]

Ductile iron is formed also by adding magnesium-impregnated coke containing 43 percent magnesium and 57 percent coke to molten cast iron. Plunging of the magnesium-impregnated coke in molten iron results in a slow controlled evolution of magnesium vapor from the pores of the coke into the iron where it effectively removes dissolved gases, entrained slags, and sulfur, and reacts in the iron as a nodulizing agent.[9]

A pressure ladle method is generally used for adding alloys containing more than 50 percent magnesium or pure magnesium. Nodular iron was produced experimentally in the U.S.S.R. by using magnesium chloride and calcium silicide at 2.1 and 2.4 weight-percent, respectively, of the iron. About one-third of the calcium chloride was placed on the bottom of the ladle and covered with the magnesium chloride followed by the remaining calcium chloride.[10]

Recognition of the technical advantages of nodular iron formed by the use of magnesium is shown by the rapid increase of shipments compared with those for standard and pearlitic malleable iron.

The magnesium-lithium alloy group has been expanded to include several experimental alloys. Mg-14Li-5Zn-3Ag-2Si alloy is being used for three spherical gimbals in a prototype inertial guidance system. Problems have arisen in selecting suitable coating to prevent absorption and reaction of a hydrocarbon fluid in which the gimbals float. Mg-14Li-1.5A1-0.08 Mn alloy is being used in the developmental M113 armored vehicles; however, the alloy presents some difficulties.[11]

Magnesium alloys ZK61, QE22, and experimental ZQ64 (Z-zinc, K-zirconium, E-rare-earth, Q-silver) qualified for a redesigned military mortar base that was 10 percent lighter, 30 percent higher strength, and 100 percent more rigid than the standard aluminum forgings.[12]

A silver-magnesium alloy was designed for blades in electrical relays and contactors to retain good spring qualities and high conductivity at elevated temperatures permitting contact-point brazing without loss of blade tensile strength. The higher conductivity of the silver-magnesium blade than that of the replaced bronze-copper blade permitted design of lighter and shorter contact blades.[13]

An alloy containing 17 to 40 percent magnesium, 35 to 60 percent silicon, and the remainder iron with fine calcium cyanamide in suspension was patented.[14]

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[8] Clark, Ralph A., and T. K. McCluhan. Low Magnesium Alloy Improves Magnesium Recovery. Foundry, v. 93, No. 6, June 1965, pp. 172–174, 177.

[9] Snow, William E. Ductile Iron Is Made With Magnesium-Impregnated Coke. Foundry, v. 92, No. 11, November 1964, pp. 99–100, 103.

[10] Bremer, Edwin, ed. Nodular Iron. Foundry, v. 93, No. 11, November 1965, p. 157.

[11] Materials in Design Engineering. Magnesium-Lithium Alloys Combine Lightness and Stiffness. V. 62, No. 6, November 1965, pp. 98–101, 194, 196.

[12] Meier, J. W., and B. Lagowski. Magnesium Casting Out-Performs Aluminum Forging in Mortar Base. Modern Metals, v. 21, No. 5, June 1965, pp. 54–55.

[13] American Metal Market. Silver-Magnesium Alloy Replaces Bronze in Electrical Contractors. V. 72, No. 143, July 28, 1965, p. 14.

[14] Kaess, Franz, Traunstein and Erich Pfluger, and Lothar Strassberger (assigned to Suddeutsche Kalkstickstoff-Werke Aktiengesellschaft und Metallgesellschaft Aktiengesellschaft). Alloy Containing Magnesium, Silicon, and Calcium. U.S. Pat. 3,177,072, Apr. 6, 1965.

A process for the manufacture of iron-silicon-magnesium prealloys by slowly adding solid ferrosilicon to molten magnesium while increasing the temperature from 650° to 1100° C was patented.[15]

Two magnesium-base alloys containing 10 to 12 percent lithium and lesser amounts of thorium were patented. One also included small amounts of aluminum and yttrium.[16]

Another magnesium-base alloy containing 9 to 15 percent zinc, 0.1 to 10 percent zirconium, and 1 to 8 percent rare-earth metals was also patented.[17]

A high-drain primary battery which comprises a plurality of individual nodules, each containing a magnesium-base plate-like anode was patented.[18]

A patent was filed for a method that increases the modulus of elasticity and decreases the coefficient of thermal expansion in a magnesium-base alloy by vacuum heating compact slug of metal borides and powdered magnesium-base material at a temperature at which the magnesium material melts with minimum vaporization and below the melting temperature of the borides. The slug was cooled below the freezing temperature of the magnesium material.[19]

A structural member with a magnesium core and at least one surface of aluminum was patented whereby the aluminum had the characteristic of being polarized when subject to a cathodic current density of less than 0.5 milliampere per square inch of cathode area.[20]

A method for the introduction of magnesium into a galvanizing bath by precleaning in a pickling solution was patented.[21]

A thermic method to produce magnesium by controlling, with the use of vacuum pumps, the pressure in the condensing zones in retorts to maintain the flow and condensation of magnesium vapor at temperatures below the melting point of magnesium was patented.[22]

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[15] Ebert, Hans, and Klaus Frank (assigned to Knapsack-Griesheim). Process for the Manufacture of Iron-Silicon-Magnesium Prealloys. U.S. Pat. 3,177,071, Apr. 6, 1965.

[16] Frost, Paul D., and Thomas G. Byrer (assigned to U.S. Army). Magnesium-Lithium-Thorium Alloys. U.S. Pat. 3,189,441, June 15, 1965.

Frost, Paul D., and Thomas G. Byrer. Magnesium-Lithium-Yttrium Alloys. U.S. Pat. 3,189,-442, June 15, 1965.

[17] Foerster, George S. (assigned to The Dow Chemical Co.). Magnesium-Base Alloy. U.S. Pat. 3,183,083, June 15, 1965.

[18] Kirk, Roy C., and Richard E. Carr (assigned to The Dow Chemical Co.). High Power Output Magnesium Primary Battery. U.S. Pat. 3,185,-592, May 25, 1965.

[19] Conant, Louis A. (assigned to Union Carbide Corporation). Magnesium-Base Alloys. U.S. Pat. 3,166,415, Jan. 19, 1965.

[20] Bothwell, Marvin R. (assigned to The Dow Chemical Co.). Composite Body of Magnesium and Aluminum and Method of Making Same. U.S. Pat. 3,179,504, Apr. 20, 1965.

[21] Heath, John A. (assigned to The Dow Chemical Co.). Method of Introducing Magnesium Into Galvanizing Baths. U. S. Pat. 3,164,-464, Jan. 5, 1965.

[22] Peplinski, Desmond M. (assigned to Dominion Magnesium Ltd.). Method of Producing Magnesium. U.S. Pat. 3,189,439, June 15, 1965.

Magnesium Compounds

By Lloyd R. Williams [1]

World production of magnesite was about 7 percent above that of 1964. The Soviet Union continued as principal producer of magnesite and accounted for 30 percent of the world total. Production of magnesite in the United States increased. U.S. exports of dead-burned magnesite and magnesia decreased 10 percent below that of 1964. The value of exported magnesite and magnesia, other than dead-burned, decreased about 1 percent.

Legislation and Government Programs.—U.S. Internal Revenue Service reported that saline minerals in the Great Salt Lake do not qualify for depletion since the saline content is increased continuously each year from dissolved salts carried into the lake by streams. The saline content is, therefore, an inexhaustible source.

Table 1.—Salient magnesium compounds statistics

(Thousand short tons and thousand dollars)

	1956-60 (average)	1961	1962	1963	1964	1965
United States:						
Caustic-calcined magnesia:						
Shipments:						
Quantity	52	80	63	[1] 64	[1] 77	[1] 83
Value	$3,212	$5,004	$3,857	[1] $4,513	[1] $5,183	[1] $5,781
Imports for consumption:						
Value	$241	$226	$395	$500	$493	$592
Exports:						
Value	$1,033	$535	$427	$678	$1,654	$1,637
Refractory magnesia:						
Shipments:						
Quantity	468	599	576	713	842	897
Value	$26,936	$35,408	$35,186	$44,378	$49,025	$56,111
Imports:						
Value	$6,481	$3,611	$5,520	$4,593	$3,180	$4,214
Exports:						
Value	$3,175	$7,988	$5,363	$5,620	$5,554	$5,912
Dead-burned dolomite:						
Sold or used by producers:						
Quantity	2,054	1,983	1,857	1,949	2,168	2,137
Value	$33,306	$32,513	$31,059	$33,058	$37,961	$38,974
Imports:						
Value	$519	$233	$245	$455	$1,165	$2,385
World: Crude magnesite: Production: Quantity	6,200	8,300	8,750	9,200	10,025	10,700

[1] Excludes caustic-calcined magnesia used in production of refractory magnesia.

DOMESTIC PRODUCTION

Nevada and Washington supplied all of the crude magnesite produced in 1965. Northwest Magnesite Co., a subsidiary of Harbison-Walker Refractories Co., was the sole producer of crude magnesite in Washington and Basic Inc. was the sole producer in Nevada. Basic Inc. also reported production of brucite in Nevada. Agro Minerals, Inc., did not report production of epsomite in Washington.

Approximately 87 percent of the dead-burned dolomite was produced in Ohio, Illinois, Pennsylvania, and Missouri. Washington and North Carolina accounted for the production of crude olivine. This year's

[1] Commodity specialist, Division of Minerals.

production was 20 percent greater than the production in 1964.

Production of hydrous magnesium sulfate increased 6 percent and magnesium trisilicate increased 3 percent.

Small quantities of magnesium nitrate, magnesium phosphate, magnesium acetate, and anhydrous magnesium sulfate were also produced.

Michigan led in the production of refractory magnesia from well brines, sea water, and dolomite. Refractory magnesia from the same sources was also produced in California, Florida, Mississippi, New Jersey, and Texas. Nevada led in the production of refractory magnesia from magnesite and brucite; Washington was second.

Several companies are planning to exploit the resources of the Great Salt Lake in Utah to recover magnesium salts. A combination of three firms with exclusive rights to extract magnesium chloride from the lake until March 8, 1969, organized the venture, Magnesium Project, to recover magnesium chloride by stages of evaporation. National Lead Co. and Hooker Chemical Co. each had a 44.5 percent interest in the project and Hogle Kearns Co. held the remaining 11 percent. Lithium Corporation of America Inc. in conjunction with Salzdetfurth, A.G. of Hanover, West Germany, executed an agreement with the Utah State Land Board to extract magnesium salts and derivatives from the lake after March 8, 1969. Others seeking mineral rights include Kaiser Aluminum & Chemical Corp., Signal Oil and Gas Co., Quintana Petroleum Corp., and Solar Salt Co.

The A. P. Green Refractories Co. announced plans to build a $3.5 million plant at Freeport, Tex. to produce periclase (refractory magnesia) from magnesium hydroxide purchased from The Dow Chemical Co. who recovered the hydroxide from sea water primarily for the production of magnesium metal. Kaiser announced plans for a $1.7 million plant addition to expand production of periclase at Moss Landing, Calif. Harbison-Walker Refractories Co. plans include expansion of its periclase plant at Ludington, Mich. and other refractory plants at Baltimore, Md., Hammond, Ind., and Windham, Ohio. Harbison-Walker developed a new magnesia-chrome refractory, trade-named "Guidon", with a density of 203 to 208 pounds per cubic foot. Harbison-Carborundum Corp., jointly owned by Harbison-Walker Refractories Co. and The Carborundum Co., producers of fused cast-alumina refractories for the glass industry, announced plans to build a plant at New Carlisle, Ind. to produce basic chrome-magnesia refractory products.

CONSUMPTION AND USES

Consumption of olivine increased over that of 1964. Consumption of crude magnesite and brucite also increased.

Consumption of hydrous magnesium sulfate increased 6 percent; magnesium trisilicate increased 33 percent. Consumption of anhydrous magnesium chloride principally for the production of magnesium metal increased less than one percent and hydrous magnesium chloride decreased 15 percent.

About 1.7 million short tons of magnesium hydroxide was estimated as produced and consumed in processing of other magnesium compounds including magnesium chloride used in the production of magnesium metal. It was used either in the originating plant or transported to another plant to continue the process. About 67,000 tons of magnesium hydroxide was shipped outside industry, an increase of 62 percent above 1964.

Consumption of refractory magnesia, both single-burned and double-burned, amounted to 897,000 tons, an increase of 7 percent. About 83,000 tons of caustic-calcined magnesia, an increase of 8 percent, was consumed for uses excluding consumption as an intermediate material in processing of refractory magnesia.

Basic, Inc., marketed a magnesium oxide compound reported suitable for uses such as the following: A liming agent in sugar production, an acceptor during rubber vulcanization, a precipitate for magnesium diurinate in uranium ore processing, an ingredient in magnesium oxycements, an extender-filler in inks and paints, a source of magnesium in the preparation of magnesium salts, and an additive for fertilizer.

Allegheny Industrial Chemical Co., a division of Amerace Corp., Butler, N.J., announced production of a magnesium silicate absorbent suitable for use as a retention agent of aromatic products, as a base carrier for catalysts, and as a preventative of caking caused by selective adsorption. The price ranges from 16 to 29 cents per pound, depending on quantity.

Table 2.—Dead-burned dolomite sold in and imported into the United States

Year	Sales of domestic product		Imports [1]	
	Short tons	Value (thousands)	Short tons [2]	Value (thousands)
1956–60 (average)	2,054,310	$33,306	9,307	$519
1961	1,982,759	32,513	4,256	233
1962	1,857,438	31,059	4,456	245
1963	1,948,953	33,058	8,890	455
1964	2,167,523	37,961	28,876	1,165
1965	2,137,329	38,974	NA	2,385

NA Not available.
[1] Dead-burned basic-refractory material comprising chiefly magnesium and lime.
[2] Includes weight of immediate container.

Table 3.—Magnesium compounds produced and shipped in the United States

Year and product	Plants	Produced (short tons)	Shipped	
			Short tons	Value (thousands)
1964:				
Refractory magnesia [1]	12	---	842,013	$49,220
Caustic-calcined magnesia [2]	6	---	77,048	5,183
Specified magnesias, U.S.P. and technical	4	7,737	7,045	3,373
Magnesium hydroxide (100 percent $Mg(OH)_2$)[2]	8	---	41,544	1,740
Magnesium chlorides [3]	7	305,602	305,848	25,025
Precipitated magnesium carbonate [2]	5	---	7,294	---
1965:				
Refractory magnesia [1]	11	---	897,336	56,111
Caustic-calcined magnesia [2]	6	---	83,272	5,781
Specified magnesias, U.S.P. and technical	4	6,697	6,742	3,382
Magnesium hydroxide (100 percent $Mg(OH)_2$)[2]	8	---	67,324	2,691
Magnesium chlorides [3]	7	305,990	305,789	25,023
Precipitated magnesium carbonate [2]	5	---	8,219	---

[1] Includes both single-burned and double-burned.
[2] Excludes material produced as an intermediate step in the manufacture of other magnesium compounds.
[3] Includes magnesium chloride used in production of magnesium metal.

Table 4.—Domestic consumption of caustic-calcined magnesia and specified magnesias by uses

(Percent)

Use	1964	1965
Chemical processing	5	6
Fertilizer	2	5
85-percent MgO insulation	4	3
Oxychloride and oxysulfate cements	23	23
Pulp and paper	22	20
Rayon	13	14
Rubber	9	8
Other: Electrical, medicinal, flux, ceramic, glass, sugar, animal feed, fuel additive, water treatment, and uranium processing	22	21

PRICES

In January the price of magnesium silicofluoride in drums increased from 11.25 to 12.75 to 12 to 13.5 cents per pound according to Oil, Paint and Drug Reporter. U.S.P. grade magnesium carbonate in carlots, equalized freight, increased from 14.0 to 14.5 cents per pound during November. In the last half of December technical-grade calcined magnesia in bags in carlots f.o.b., Lunning, Nev., increased as follows: 90 percent—$49.50 to $53; 93 percent—$52.50 to $56; and 95 percent—$57.50 to $61.

FOREIGN TRADE

Exports of dead-burned magnesite and magnesia decreased about 10 percent. Increased deliveries to Canada, Argentina, Chile, Venezuela, Spain, and Nansei and Nanpo Islands were more than offset by decreases in deliveries to Australia, United Kingdom, Japan, and West Germany. The latter two, after several years of decreases, have become minor recipients. Mexico remained the principal recipient.

All categories of crude and processed magnesite imports for consumption showed increases in 1965. Imports of lump or ground caustic-calcined magnesia continued to increase, reaching a new high of 11,900 tons about 27 percent over that of 1964.

Imports for consumption of dead-burned grain magnesia and periclase increased 20 percent; magnesium carbonate (precipitated) increased 12 percent; and magnesium sulfate (epsom salt) decreased about 30 percent.

Table 5.—U.S. exports of magnesite and magnesia, by countries

Destination	Magnesite and magnesia, dead-burned				Magnesite and magnesia (except dead-burned) and manufactures [1]	
	1964		1965		1964	1965
	Short tons	Value	Short tons	Value	Value	Value
North America:						
Canada	17,886	$1,384,324	21,217	$1,908,055	$200,534	$116,080
Costa Rica	---	---	---	---	62,296	37,808
Mexico	25,131	1,704,430	24,800	1,778,274	74,370	52,905
Other	85	13,114	69	42,720	30,768	23,486
South America:						
Argentina	592	75,254	4,934	354,660	2,354	7,029
Brazil	1	594	6	3,767	595	2,407
Chile	1,188	91,703	2,964	218,310	76,427	3,185
Colombia	---	---	---	---	2,993	16,033
Peru	1,104	69,555	1,323	103,048	11,852	4,430
Venezuela	1,847	125,692	4,906	359,963	10,193	40,220
Other	1	470	---	---	1,231	---
Europe:						
Belgium-Luxembourg	19	14,041	---	---	16,363	29,971
Denmark	---	---	5	3,097	21,288	25,446
France	524	248,314	15	4,767	1,915	53,869
Germany, West	1,370	240,119	193	75,262	326,725	266,246
Italy	267	44,413	228	25,744	19,617	68,540
Netherlands	706	57,187	1,135	76,250	724	40,747
Portugal	---	---	---	---	432	778
Spain	42	3,223	1,519	124,535	45,681	13,498
Sweden	68	35,655	101	53,474	33,427	18,689
Switzerland	33	12,176	---	---	10,032	18,960
United Kingdom	6,291	212,096	700	148,627	390,033	522,581
Other	36	12,683	48	12,789	4,437	25,692
Africa:						
Malagasy Republic		---	127	16,572	---	---
South Africa, Republic of	56	24,128	88	43,775	28,094	53,979
Other	2	820	22	3,010	24,306	10,004
Asia:						
Bahrain	---	---	22	2,716	---	---
India	---	---	---	---	---	16,349
Israel	---	---	---	---	---	3,484
Japan	5,123	301,772	77	29,367	37,412	814
Korea, South	1,219	68,050	---	---	---	---
Nansei and Nanpo Islands	---	---	16	2,259	---	---
Philippines	3	1,600	4	894	3,197	4,467
Other	11	1,851	12	2,936	50,346	2,180
Oceania:						
Australia	15,715	810,618	7,103	508,314	119,841	120,614
New Zealand	---	---	15	9,188	46,086	36,908
Total	79,320	5,553,882	71,649	5,912,373	1,653,569	1,637,399

[1] Not elsewhere classified.

Table 6.—U.S. imports for consumption of crude and processed magnesite by countries

Country	1964 Short tons	1964 Value	1965 Short tons	1965 Value
Crude magnesite:				
North America: Canada	---	---	33	$497
Europe: Austria	2	$490	---	---
Asia: India	---	---	17	715
Total	2	490	50	1,212
Lump or ground caustic-calcined magnesia:				
Europe:				
Austria	700	25,519	756	26,462
Belgium Luxembourg	---	---	162	11,835
Greece	65	4,814	225	18,176
Netherlands	430	30,467	282	16,719
Switzerland	---	---	1	290
Yugoslavia	330	13,872	663	28,908
Africa: Tanzania	144	7,376	26	1,398
Asia:				
India	6,867	325,128	8,894	404,051
Japan	1	390	---	---
Pakistan	76	4,186	---	---
Turkey	---	---	193	14,000
Oceania: Australia	771	81,159	698	69,920
Total	9,384	492,911	11,900	591,759
Dead-burned and grain magnesia and periclase:				
North America: Canada	39	4,042	52	3,540
Europe:				
Austria	22,369	1,198,340	46,589	2,554,283
Greece	14,009	886,018	10,559	704,750
Italy	1,747	76,458	---	---
United Kingdom	28	3,055	---	---
Yugoslavia	21,904	1,011,875	6,040	323,487
Asia: Japan	---	---	8,732	627,960
Total	60,096	3,179,788	71,972	4,214,020

Table 7.—U.S. imports for consumption of magnesium compounds

Year	Oxide or calcined magnesia		Magnesium carbonate (precipitated)		Magnesium chloride (anhydrous) [1]		Magnesium sulfate (epsom salt)		Magnesium salts and compounds [1 2]		Manufactures of carbonate of magnesia	
	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value
1956-60 (average)	301	$93,477	319	$73,408	718	$26,260	10,810	$257,267	1,702	$70,896	11	$2,777
1961	248	61,208	342	73,602	1,012	31,375	10,031	231,022	3,796	117,393	6	3,155
1962	182	47,766	398	94,421	1,474	127,090	9,297	209,787	3,505	106,729	4	2,823
1963	93	39,436	623	118,895	668	22,611	8,543	186,997	3,625	128,111	---	---
1964	127	50,249	1,112	210,081	752	24,487	9,549	212,380	1,051	58,406	---	---
1965	148	46,931	1,250	224,944	366	11,198	6,640	126,500	3,599	133,885	5	2,085

[1] Not specifically provided for.
[2] Includes magnesium silicofluoride or fluosilicate and calcined magnesia.

WORLD REVIEW

Argentina.—A $2 million basic refractory plant was completed at San Nicolas. The plant is part of a wholly owned subsidiary of General Refractories Co.

Austria.—Mechanization by introduction of a belt loader and a diesel-powered scoopmobile at the Trieben magnesite mine of Vietscher Magnesit A.G. increased production from 8.5 tons per man-shift in 1962 to 40 tons per man-shift in 1965.

Output of magnesite in short tons for 1963 and 1964 was a follows:

Magnesite	*1963*	*1964*
Crude	1,446,692	1,825,546
Caustic-calcined	[1] 187,750	[2] 211,270
Dead-burned	453,022	575,244

[1] Includes 42,235 tons of fly ash.
[2] Includes 61,954 tons of fly ash.

Table 8.—World production of magnesite by countries [1]
(Short tons)

Country	1961	1962	1963	1964	1965 p [2]
North America: United States	603,656	492,471	527,655	W	W
South America:					
Brazil	84,549	103,348	99,536	r 103,331	e 105,000
Colombia	110	110	276	r 243	209
Europe:					
Austria	1,982,704	1,771,863	1,447,099	1,826,058	2,001,363
Czechoslovakia e	550,000	580,000	580,000	580,000	610,000
Greece	163,573	299,789	e 275,000	e 220,000	e 385,000
Italy	7,478	9,275	7,512	6,954	3,898
Poland	29,873	37,589	29,321	(3)	(3)
Spain	91,702	78,691	93,315	r 102,874	e 103,000
U.S.S.R. e	2,760,000	2,760,000	2,980,000	3,090,000	3,200,000
Yugoslavia	301,002	411,561	454,107	548,311	579,254
Africa:					
Kenya	1,930	---	288	187	74
Rhodesia, Southern	13,880	11,619	12,077	42,410	e 40,000
South Africa, Republic of	67,732	102,352	108,309	93,443	95,789
Tanzania (exports)	46	---	94	546	1,260
Asia:					
China, mainland e	770,000	880,000	990,000	1,100,000	1,100,000
India	231,203	234,669	258,564	228,985	263,128
Korea, North e	220,000	550,000	880,000	990,000	990,000
Pakistan	180	336	968	680	577
Turkey	2,414	10,736	19,750	43,065	83,320
Oceania:					
Australia	110,651	69,654	63,780	r 35,001	e 28,000
New Zealand	650	711	875	676	937
World total e	8,300,000	8,750,000	9,200,000	r 10,025,000	10,700,000

e Estimate. p Preliminary. r Revised. W Withheld to avoid disclosing individual company confidential data.
[1] Quantities in this table represent crude magnesite mined. Magnesite is also produced in Bulgaria and Canada, but data on production are not available; estimates by author of chapter included in total.
[2] Compiled mostly from data available June 1966.
[3] Data not available; estimate by author of chapter included in total.

Belgium.—Kaiser Refractories Division of Kaiser Aluminum & Chemical Corp. announced formation of a subsidiary company, Kaiser Refractories S. A., with headquarters at Liege, Belgium, to distribute and sell Kaiser refractory products in Europe.

Canada.—Canadian Refractories Ltd. completed two new 1,000-ton storage silos at its Marelan, Quebec, plant, increasing the storage capacity to 10,000 tons. Each silo is divided into four sections. This gives greater quality control for processing various kinds of refractory products. Magnesite ore mined near Kilmar is stored in the silos at Marelan prior to drying and processing.

Greece.—The Societe Financiere de Grèce (Scalistiri) has plans to increase productive capacity of dead-burned magnesite to 100,000 tons per year towards the middle of 1966 with the operation of a third kiln. A second kiln was put in operation by the end of 1965.

Deposits of high-grade magnesite in the Khalkidiki area southeast of Thessaloniki in northern Greece were exploited by several companies, largest of which is Magnomin, A.G., a wholly owned subsidiary of General Refractories Co. The company operates the Vavdos mine. About 80 percent of Magnomin's output of dead-burned magnesite is shipped to the United States. Most of the remainder is exported to General Refractories subsidiaries in Austria and Italy. The company exported 32,000 tons of dead-burned magnesite in 1964 at an average price of $60 per ton, f.o.b., Thessaloniki.

General Mining Enterprises, S.A., controlled by Fried. Krupp Industriebau obtained Greek Government approval to borrow $150,000 to expand the Ploygyros Magnesite mine to produce about 22,000 tons per year of calcined magnesite.

Under Legislative Decree 4231/1962, the Government of Greece granted exporters of crude magnesite a 3-percent deduction from gross export earnings subject to tax.

India.—Current output of dead-burned magnesite in India was about 70,000 tons per year. Plans were announced for building a new dead-burned magnesite plant near Someshwar, Almora district, Uttar Pradesh, with an annual capacity of 36,000 tons.

Table 9.—Austria: Exports of magnesia and magnesite brick by countries

(Short tons)

Destination	Magnesia				Magnesite brick	
	Caustic-calcined		Refractory			
	1964	1965	1964	1965	1964	1965
North America: United States	701	953	48,012	85,058	1	139
South America:						
Argentina	63	15	2,962	9,559	3,024	2,484
Chile	3	---	1,035	1,683	907	3,046
Europe:						
Belgium-Luxembourg	176	153	1,394	1,558	5,506	8,328
Czechoslovakia	591	---	---	---	1,115	---
Denmark	2,382	3,131	138	667	4,049	4,119
Finland	3	17	1,005	815	2,943	2,812
France	1,382	1,961	18,039	19,406	23,576	23,852
Germany, West	93,255	88,938	114,328	127,332	26,215	25,061
Greece	---	---	423	601	1,829	1,937
Hungary	2,234	3,614	11,310	10,466	---	---
Italy	4,473	4,267	10,890	13,103	6,129	5,196
Netherlands	910	440	229	100	565	1,596
Norway	31	17	694	374	3,723	2,211
Poland	---	---	109	---	1,435	2,243
Portugal	40	25	61	184	1,162	538
Rumania	---	---	1,675	2,363	450	5,383
Spain	18	44	621	799	2,393	5,101
Sweden	1,276	965	2,018	2,637	11,830	19,839
Switzerland	3,926	3,545	887	571	2,182	1,970
United Kingdom	238	778	33,986	23,134	15,167	25,990
Africa:						
Rhodesia, Southern	---	---	246	---	4,359	228
South Africa, Republic of	---	---	222	109	2,327	1,986
Tunisia	---	---	---	87	---	1,293
Zambia	---	---	---	74	---	2,098
Asia:						
India	---	---	822	4	1,903	16
Israel	---	---	409	726	640	273
Turkey	---	---	599	551	3,578	4,592
Oceania:						
Australia	---	---	7,405	62	3,921	1,501
New Caledonia	---	---	---	98	---	2,189
Other countries	[r] 146	733	[r] 1,691	1,303	[r] 5,016	3,566
Total	111,848	109,596	261,210	303,424	135,945	159,587

[r] Revised.

Table 10.—Greece: Exports of magnesite and calcined magnesia, by countries

(Short tons)

Destination	Crude magnesite		Calcined magnesia	
	1964	1965 [e]	1964	1965 [e]
Canada	---	---	2,425	---
France	---	---	1,919	2,900
Germany, West	645	480	31,568	34,130
Italy	15,192	14,420	---	---
Netherlands	2,650	2,800	31,321	25,800
Poland	471	---	---	---
United Kingdom	4,115	3,230	13,530	15,300
United States	---	---	15,922	17,850
Other countries	2	250	8,654	25,400
Total	23,075	21,180	105,339	121,380

[e] Estimate.

Mexico.—A plant capable of producing 55,000 tons of refractory and chemically active magnesia from sea water, is under construction at Cuidad Madero near Tampico, Tamaulipas, Mexico. This plant is being built for Quimica del Mar, S.A., partly owned by General Refractories Co.

Cia. Minera Penoles, a Mexican mining corporation, joined wtih Harbison-Walker-Flir to construct a plant at Laguna del Rey, Coahuila, Mexico, capable of producing 55,000 tons of magnesium oxide per year. Harbison-Walker-Flir is owned by Harbison-Walker Refractories Co., Pittsburgh, Pa. and Fundidora de Monterrey, one of Mexico's largest steel companies.

Table 11.—Netherlands: Exports of refractory magnesia, by countries
(Short tons)

Destination	1964	1965
Belgium-Luxembourg	1,155	1,367
France	607	142
Germany, West	9,023	9,114
Italy	55	60
Other countries	30,768	24,074
Total	41,608	34,757

Rhodesia, Southern, and Republic of South Africa.—Plans to exploit a magnesite deposit, 20 miles east of Beit Bridge by a joint venture of two South African companies were announced. Also included was a proposed 80,000-ton-per-year treatment plant with arrangements for shipment of the graded magnesite to Transvaal, Republic of South Africa for calcining. Other deposits of magnesite were found in the Nuanetsi and Belingwe areas.

Turkey.—Continental Magnesit Ltd. Sirketi, a subsidiary of Continental Ore Corp. announced plans to expand facilities near Kutahra to permit exportation of 40,000 to 60,000 tons of dead-burned magnesite per year and about 15,000 tons of caustic calcined magnesia.

Venezuela.—Magnesite deposits on the Island of Margarita are being investigated for exploitation.

TECHNOLOGY

Extraction of magnesium compounds and new uses for magnesium-bearing ores were studied or developed. Applied research on methods to produce basic refractories to meet industries' demands for high-life heat-resistant furnace linings, especially for use in basic oxygen furnaces, continued.

A paper was published [2] on the use of olivine in the shell molding process. Properties of olivine sand, beneficial in the shell process are as follows: low uniform expansion (0.83 percent compared to 1.8 percent for silica), high initial chill of casting skin at the metal-mold interface, and excellent thermal conductivity and heat capacity.

Pulverized serpentine is a source of magnesium fertilizer in agriculture. When serpentine is exposed to moisture, the surface of the crystal ionizes to form hydroxyl and magnesium ions. Magnesium is released at a slow sustained rate making serpentine an effective and efficient source of magnesium for soil. The low calcium content creates a favorable calcium-magnesium ratio. The chromium and nickel content is well below the toxic limits and may be beneficial.[3]

The Kaiser Aluminum & Chemical Corp.'s integrated complex for producing magnesium refractories and other products from dolomite and sea water at Natividad and Moss Landing, Calif., was described. The dolomite is mined and processed at a quarry near Natividad. After the dolomite is loaded and transported to jaw crushers and scrubbers it is benefiiciated by heavy-media separation. Ferrosilicon and magnetite are used as the media. About 68 to 70 percent of the original ore is recovered as dolomite. More than 90 percent goes to the kilns. The remaining raw dolomite is sized for landscaping and metallurgical stone, glass manufacture, plastic floor tile, asphaltic-concrete filler, and soil conditioning.

About 150 tons per day of dead-burned dolomite is produced for the steel industry as fettling material and tar-bonded refractory grains. The dolomite traverses the kiln in 4 hours; 1,200°F at the feed to 3,200°F at the exit. About 8-million B.t.u. of natural gas is required for each ton. Electrostatic precipitators recover material for soil conditioner and various fillers from the exhaust gas containing about 10 percent of the kiln feed.

About 250 tons per day of calcined dolomite is produced in kilns at 2,000°F requiring 6.75-million B.t.u. per ton. It is used in the Kaiser Moss Landing sea water plant.

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[2] Blomberg, Stan. Use of Olivine Sand in Shell Cores and Molds. Foundry, v. 93, No. 1, January 1965, pp. 117–125.

[3] Burns, A. F., and A. M. Smith. Pulverized Serpentine As a Source of Available Magnesium. Agricultural Chem., v. 20, No. 9, September 1965, pp. 23–26, 168.

However, some is reserved for hydrated-lime production.[4]

At the Kaiser Moss Landing Calif. plant, basic refractories and other magnesium compounds are produced from sea water containing about 0.017 pounds of MgO equivalent per gallon and calcined dolomite containing 38 to 40 percent MgO from the Natividad quarry, 15 miles away. One ton of MgO is produced from 1 ton of dolomite and 72,000 gallons of sea water.

The recovery of magnesia or magnesium from sea water is based on the solubility of calcium hydroxide and the insolubility of magnesium hydroxide, but complications are caused by impurities.

After screening to remove undesirable sea life and debris, the sea water is pretreated with calcined dolomite to remove objectionable bicarbonates.

A solution containing 1.5 pounds of 97 to 98 percent (ignited basis) MgO per gallon in the form of magnesium hydroxide, suspended as milk of magnesia, is formed by recirculating a calculated mixture of treated sea water and calcined dolomite through two reactors and a rake classifier, and removing silica ferric oxide and other solids before feeding into three thickners. The whole operation takes 3 weeks. Five rotary filters are used to recover a filter cake containing 50 percent magnesium hydroxide.

About 85 percent of the magnesium hydroxide is used to produce single-burned refractory magnesia with a density of 115 to 130 pounds per cubic foot. Additives such as alumina, silica, iron oxides, and calcium lower the sintering temperature and permit fluxing and shrinking of grains at 3,300°F during a residence of 2.5 to 4 hours in the kilns.

About 10 percent is calcined to high-purity MgO of which one-fourth is sold as light-burned active magnesia, ground to 99-percent minus 325 mesh for production of rayon, paper, and sugar. The other three-fourths is pressed into briquettes and dead-burned in a rotary kiln for 2 hours producing double-burned magnesia with a density of 125 to 140 pounds per cubic foot.

The remaining 5 percent of the magnesium hydroxide is sold to the paper industry.[5]

The principal constituents in the production of basic refractories at the Kaiser Moss Landing plant are periclase, a refractory magnesia produced locally, and chromite ore from the Philippine Islands. The magnesia provides resistance to chemical attack and ability to withstand pressure at high temperature. The chromite adds resistance to spalling and flaking under cyclical temperatures.

About 100 carloads per month of dry blends are sacked for gunning and ramming mixes and for mortar. The wet mix is pressed into bricks and dried in tunnels at 350°F for 8 hours. They are chemically bonded and will withstand pressures up to 13,000 pounds per square inch. Heating at 2,500°F produces ceramic-bonded bricks and heating at 3,200°F produces direct-bonded bricks. Bonding agents are alkali silicates or low-temperature organic binders that are destroyed and replaced by ceramic or sintered bonds during firing.

A substantial amount of the bricks are encased in cold-rolled steel jackets which oxidizes at high temperature and fuses to hold the bricks in a monolithic mass in the hearths.[6]

Microscopic examination of direct-bonded magnesite-chrome bricks showed that intercrystallization eliminated the usually weak silicate bond. These bricks are not equal in performance to the fusion-cast magnesite-chrome refractories which must give double life in most applications to warrant their expense.[7] Using refractories of higher MgO content the linings of Linz-Donawitz basic oxygen furnaces, wear rates may drop to between 1 and 2 millimeters per cast; and with tar-impregnated magnesite bricks to as low as 3/4 millimeter per cast. Special magnesite brick, containing over 90 percent MgO and impregnated after firing, showed excellent volume stability when used with high phosphorous iron.

After experimenting with several types of refractory linings it was found that the use of tar-impregnated burned MgO bricks in a basic oxygen furnace resulted in as

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[4] Havighorst, C. R., and S. L. Swift. Dolomite Purification and Calcining. Chem. Eng., v. 72, No. 15, July 19, 1965, pp. 150–152.

[5] Havighorst, C. R., and S. L. Swift. Magnesia Extraction From Seawater. Chem. Eng., v. 72, No. 16, Aug. 2, 1965, pp. 85–86.

[6] Havighorst, C. R., and S. L. Swift. The Manufacture of Basic Refractories. Chem. Eng., v. 72, No. 17, Aug. 16, 1965, pp. 98–100.

[7] Iron Age. British Steel Producers Foresee Change in Refractory Types. V. 196, No. 13, Sept. 23, 1965, pp. 84–86.

much as 529 heats per lining or 5.8 pounds of brick per ton of steel.[8]

A method of making dead-burned basic refractory grain in a vertical kiln was patented, whereby briquettes of at least one material of the group consisting of magnesia, dolomite, and lime were charged at the upper end and dead-burned briquettes were withdrawn at the lower end. Temperature ranged up to at least 3,000°F. The briquettes are heated at a rate not exceeding 200°F per minute until they reach 2,000°F.[9]

An investigation of water-activated magnesium-silver chloride batteries showed two types of serious clogging; gray clogging, a result of intercell shorts; and black clogging, a result of the inability of the normal flow of electrolyte to flush out adherent reaction products because of physical changes.[10]

Magnesium nitride was made by treating magnesium chips with commercial ammonia and nitrogen in porcelain boats in a silica reactor. The nitrogen was freed from all traces of oxygen and moisture before entering the reactor. Nitriding was tried at 200°C to 1,000°C for periods ranging from 15 minutes to 4 hours. Reaction began when the nitrogen was passed over magnesium for 30 minutes at 250°C.[11]

A process to produce magnesium hydroxide from sea water was patented. It stated that after the first precipitation of magnesium hydroxide, the calcium carbide waste fraction was reacted with sea water. This reaction resulted in a second magnesium hydroxide precipitate which was mechanically fractionated into pure and crude magnesium hydroxide.[12]

A process to produce magnesium hydroxide by precipitation in a two-vessel closed circuit was patented wherein magnesium chloride reacts with ammonia to form magnesium hydroxide and ammonia chloride which in turn reacts with calcium hydroxide to form ammonia and calcium chloride for discharge.[13]

A method was patented to produce a hydrated magnesium carbonate ($4MgO \cdot 3CO_2 \cdot 11H_2O$) by contacting magnesium hydroxide slurry with carbon dioxide until the pH is between 8.0 and 8.6 and dries at less than 75°C.[14]

A process for the manufacture of a product, consisting of a mixture of anhydrous magnesium orthophosphate and a minor part of calcium orthophosphate, by reacting rock phosphate containing calcium with a mixture of anhydrous magnesium chloride and other chlorides was patented.[15]

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[8] Yoxall, John. Burned High Magnesia and Cast Magnesia as Working Linings of Basic Oxygen Furnaces. J. Metals, v. 17, No. 8, August 1965, pp. 910–912.

[9] Leatham, Earl, and Albert H. Pack (assigned to Harbison-Walker Refractories Co.). Production of Dead Burned Magnesia in a Shaft Kiln. U.S. Pat. 3,221,082, Nov. 30, 1965.

[10] Faletti, Duane W., and Larry F. Nelson. An investigation of Clogging in High-Drain, Water-Activated Magnesium-Silver Chloride Batteries. Electrochem. Tech., v. 3, No. 3–4, March-April 1965, pp. 98–106.

[11] Dubovik, T. V., V. S. Polishchuk, and G. V. Samsonov. (Preparation of Magnesium Nitride.) J. Applied Chem. (U.S.S.R.), v. 37, No. 8, August 1964, pp. 1828–1830.

[12] Kato, Tsuneo (assigned to Asahi Kasei Kogyo Kabushiki Kaisha, Kita-ku, Osaka, Japan). Process for Simultaneously Producing Pure and Crude Magnesium Hydroxide From Sea Water. U.S. Pat. 3,197,282, July 27, 1965.

[13] Ben-Ari, Carmela, and Warren J. Fuchs (assigned to Negev Phosphates Ltd., Hakirya, Israel). Manufacture of Magnesium Hydroxide. U.S. Pat. 3,170,762, Feb. 23, 1965.

[14] Pond, Richard L., and Leo F. Heneghan (assigned to Merck & Co., Inc., Rahway, N.J.). Method of Preparing a Hydrated Magnesium Carbonate. U.S. Pat. 3,169,826, Feb. 16, 1965.

[15] Baniel, Avraham M., Simon Lavie, and Hugo C. Heimann (assigned to Israel Mining Industries-Institute for Research and Development). Process for the Manufacture of Magnesium Phosphates or of Salt Mixtures Containing Magnesium Phosphates. U.S. Pat. 3,194,632, July 13, 1965.

Manganese

By Gilbert L. DeHuff [1]

The strong demand for manganese ferroalloys continued in 1965, resulting in ferromanganese production and manganese ore consumption well above that of 1964. Manganese ore imports increased 25 percent, with consumers and importers taking advantage of the duty suspension which carried over from the previous year. Shipments of domestic manganese ore—ore, concentrate, and nodules, containing 35 percent or more manganese—were approximately the same as in 1964 and were small in terms of consumption.

Table 1.—Salient manganese statistics in the United States

	1956–60 (average)	1961	1962	1963	1964	1965
Manganese ore (35 percent or more Mn):						
Production (shipments):						
Metallurgical....short tons....	265,379	39,246	19,007	7,402	19,126	22,871
Battery..............do......	[1] 4,136	6,832	5,729	3,220	6,932	6,387
Miscellaneous........do......	5	10	22	---	---	---
Total..............do......	269,520	46,088	24,758	10,622	26,058	29,258
Imports, general..........do......	2,547,593	2,098,438	1,970,152	2,093,473	2,064,990	2,575,229
Consumption............do......	1,935,018	1,701,756	1,865,272	1,841,725	2,241,756	2,866,079
Manganiferous ore (5 to 35 percent Mn):						
Production (shipments)...do......	639,087	225,004	338,501	543,125	238,776	332,763
Ferromanganese:						
Production..............do......	799,137	732,813	781,112	751,198	929,486	1,148,011
Imports for consumption..do......	154,500	221,936	126,716	148,630	212,629	257,339
Exports.................do......	2,549	469	4,114	678	3,903	3,273
Consumption............do......	822,218	778,003	805,441	892,884	1,007,623	1,040,502

[1] Battery ore included in metallurgical in 1958.

Legislation and Government Programs.—In May, General Services Administration (GSA) announced a long-range plan for disposal of approximately 1.8 million short tons of manganese ore held in Defense Production Act inventory: 945,000 tons of low-grade ore at Deming, N. Mex., Wenden, Ariz., and Butte, Mont., would be offered for immediate sale; the remaining 804,000 tons—metallurgical ore, sinter, and nodules, containing less than 46 percent manganese for the most part—would be released over a period of approximately 5 to 8 years beginning with 100,000 tons the first year. Bids for 313,000 tons of the low-grade ore at Deming and 392,000 tons at Wenden were opened on June 23, but no acceptable offers were obtained. Bids for 100,000 tons of the higher-grade ore, sinter, and nodules were opened August 23 with similar results.

Late in November, the U.S. Department of Agriculture invited U.S. firms to submit offers for the delivery of $215,000 worth of manganese dioxide to South Viet-Nam under its barter program of procurements for the Agency for International Development. The successful firms were to receive payment in surplus agricultural commodities owned by the Commodity Credit Corporation and vegetable oils from private stocks, with the agricultural commodities exported to eligible destinations according to the rules of the program.

DOMESTIC PRODUCTION

The Philipsburg, Mont., properties of Taylor-Knapp Co., Trout Mining Co., and Contact Mining Co. were consolidated to form one group with all work under the direction of Taylor-Knapp Co. A 1-year program of exploration and development was begun with the expectation that this

[1] Commodity specialist, Division of Minerals.

would result in production of manganese and silver-lead-zinc ores at a rate of 300 to 350 tons per day. Taylor-Knapp Co. continued to be the only domestic producer of natural battery-grade ore. Its reported production of battery ore included some ore which was used as a chemical ore.

Although shipments were made of Montana metallurgical oxide nodules, made previously from Montana carbonate ore, no ore, concentrate, or nodules of metallurgical grade was actually produced in Montana in 1965. Manganese ore or concentrate, containing 35 percent or more manganese, continued to be produced in New Mexico; it was not used for metallurgical purposes.

Low-grade manganese ores (ferruginous manganese ores, middlings, and concentrates) containing 10 to 35 percent manganese were shipped from Minnesota, Montana, and New Mexico. Manganiferous iron ore and concentrate containing 5 to 10 percent manganese also was shipped from Minnesota. All Minnesota shipments were from the Cuyuna range. Manganiferous zinc residuum was produced from New Jersey zinc ores.

Table 2.—Manganese materials in Government inventories as of December 31, 1965
(Thousand short tons, dry equivalent)

Type of material	National stockpile	DPA inventory	CCC and supplemental stockpile	Total
Stockpile grade:				
Battery:				
Natural ore	144	---------	148	292
Synthetic dioxide	21	4	--------	25
Chemical:				
Type A ore	29	---------	118	147
Type B ore	2	---------	99	101
Metallurgical ore	5,086	1,938	2,250	9,274
(Ferromanganese, standard high carbon) [1]	(143)	---------	(919)	(1,062)
(Manganese metal, electrolytic) [1]	(1.7)	(5.3)	(5.8)	(12.8)
Nonstockpile grade: [2]				
Battery ore, natural	---------	---------	5	5
Metallurgical ore	476	1,030	--------	1,506

[1] Gross weight of upgraded forms of manganese. Equivalent ore quantities are included in the stockpile grade metallurgical ore figures.
[2] 584 short tons of nonstockpile grade high carbon ferromanganese in supplemental stockpile, also.

Table 3.—Manganese and manganiferous ore shipped [1] in the United States, by States
(Short tons)

Type and State	1964 Gross weight	1964 Manganese content	1965 Gross weight	1965 Manganese content
Manganese ore (35 percent or more Mn, natural): [2]				
Montana	20,264	10,171	23,621	12,014
New Mexico	5,794	2,746	5,637	2,631
Total	26,058	12,917	29,258	14,645
Manganiferous ore:				
Ferruginous manganese ore (10 to 35 percent Mn, natural):				
Minnesota	157,429	19,485	243,818	31,078
Montana	3,638	1,058	1,968	540
New Mexico	46,657	5,412	50,090	5,560
Total	207,724	25,955	295,876	37,178
Manganiferous iron ore (5 to 10 percent Mn, natural): Minnesota	31,052	3,006	36,887	2,684
Total manganiferous ore	238,776	28,961	332,763	39,862
Value manganese and manganiferous ore	$3,024,268	---------	$4,049,513	--------

[1] Shipments are used as the measure of manganese production for compiling U.S. mineral production value. They are taken at the point at which the material is considered to be in marketable form for the consumer. Besides direct-shipping ore, they include, without duplication, concentrate and nodules made from domestic ores.
[2] All metallurgical except 6,387 short tons of battery ore (concentrate) containing 2,415 tons of manganese shipped from Montana in 1965, and 6,932 tons of battery ore (concentrate) containing 2,662 tons of manganese shipped from Montana in 1964.

CONSUMPTION, USES, AND STOCKS

Consumption of manganese ore in the United States continued to increase, with that from domestic sources still approximating only 1 percent of the total. Of the natural battery-grade ore consumed in the manufacture of dry cells, however, 14 percent was of domestic origin, compared with 17 percent in 1964. Industrial ore stocks at yearend were somewhat lower than inventory at the start of the year, and were little more than a half-year's supply at the 1965 consumption rate.

In the production of steel ingots, consumption of manganese as ferroalloys, metal, and direct-charged ore per short ton of open-hearth, bessemer, basic oxygen process, and electric steel produced was 13.8 pounds, the same as in 1964. Of the 13.8 pounds in 1965, 11.7 pounds was ferromanganese; 1.7 pounds, silicomanganese; 0.1 pound, spiegeleisen; and 0.3 pound, manganese metal.

In January, Union Carbide Corp. announced that it had formed a new Mining and Metals Division, and that the activities previously conducted by its metals and ore divisions would henceforth be the responsibility of the new division.

Electrolytic Manganese and Manganese Metal.—Although consumption of manganese metal increased, the change was small. Consumption for production of stainless steel and for carbon steel actually decreased. It can be assumed that, except for possibly a few pounds, all the manganese metal consumed, produced, and imported was electrolytic metal. American Potash & Chemical Corp. at Hamilton (Aberdeen), Miss.; Foote Mineral Co., with two plants at Knoxville, Tenn.; and Union Carbide Corp. at Marietta, Ohio, continued to be the only domestic producers. American Potash & Chemical Corp. modified and expanded its plant with a resultant increase in capacity to 7,500 tons per year. In October, Foote Mineral Co. announced that it would augment production from its Knoxville plants by constructing a $9 million electrolytic manganese plant at New

Table 4.—Consumption and stocks of manganese ore [1] in the United States
(Short tons)

Use and ore source	Consumption 1964	Consumption 1965	Stocks Dec. 31, 1965 [2] (including bonded warehouses)
Manganese alloys and manganese metal:			
Domestic ore	10,371	12,067	169
Foreign ore	2,082,074	2,685,649	1,436,914
Total	2,092,445	2,697,716	1,437,083
Steel ingots: Foreign ore	725	100	------
Steel castings: Foreign ore	96	46	160
Pig iron:			
Domestic ore	------	2,063	------
Foreign ore	18,706	25,709	36,328
Total	18,706	27,772	36,328
Dry cells:			
Domestic ore	5,270	4,738	620
Foreign ore	24,844	29,127	19,678
Total	30,114	33,865	20,298
Chemicals and miscellaneous:			
Domestic ore	4,246	5,476	860
Foreign ore	95,424	101,104	44,988
Total	99,670	106,580	45,848
Grand total:			
Domestic ore	19,887	24,344	1,649
Foreign ore	2,221,869	2,841,735	1,538,068
Total	2,241,756	2,866,079	[3] 1,539,717

[1] Containing 35 percent or more manganese (natural).
[2] Excluding Government stocks.
[3] Excludes small tonnages of dealers' stocks.

Johnsonville, Tenn., to be on stream in 1967.

Ferromanganese.—Demand for ferromanganese continued and production exceeded 1 million tons for the first time. Production was by the same companies producing at the end of 1964 except for Shenango, Inc., and Vanadium Corporation of America. Manganese Chemicals Corp. continued its production of low-carbon ferromanganese by fused-salt electrolysis at Kingwood, W. Va. The quantity of ferromanganese made in blast furnaces was more than twice that made in electric furnaces. Shipments of ferromanganese totaled 1,141,000 tons valued at $167 million, compared with 942,000 tons valued at $135 million in 1964. In 1965, 10 companies used 18 plants to produce ferromanganese.

Silicomanganese.—Production of silicomanganese in the United States was 241,000 tons, compared with 203,000 tons in 1964. For the 1965 output, 6 companies used 11 plants. Shipments from furnaces were 215,000 tons ($32 million), compared with 214,000 tons ($30 million) in 1964. Consumption of silicomanganese relative to that of ferromanganese continued its

Table 5.—Consumption, by end uses, and stocks of manganese ferroalloys and metal in the United States in 1965

(Short tons)

Use	Ferromanganese		Silicomanganese	Spiegeleisen	Manganese metal [1]	Briquets
	High carbon	Medium and low carbon				
Steel ingots:						
Stainless steel	835	3,132	7,757	42	8,739	---
Other alloy steel	196,966	29,012	55,343	4,633	3,133	58
Carbon steel	712,151	50,126	102,339	15,367	7,448	1,049
Other	439	127	454	---	88	---
Total	910,391	82,397	165,893	20,042	19,408	1,107
Steel castings:						
Stainless steel	399	346	602	---	141	---
Other alloy steel	10,453	1,838	7,238	192	37	67
Carbon steel	6,912	1,437	13,602	978	21	172
Other	3,558	211	566	18	1	---
Total	21,322	3,832	22,008	1,188	200	239
Steel mill rolls	1,870	260	753	829	---	2
Gray and malleable castings	9,738	1,085	2,133	10,490	7	11,589
Alloys (includes welding rods)	7,642	1,140	1,494	---	6,233	10
Other	669	156	---	---	436	---
Grand total	951,632	88,870	192,281	32,549	26,284	12,947
Stocks, Dec. 31: [2] Consumer	136,233	9,959	14,733	4,903	3,514	1,315

[1] Virtually all electrolytic.
[2] Including bonded warehouses. Producer stocks of ferromanganese, silicomanganese, spiegeleisen, manganese metal, and briquets totaled 169,000 tons. Excluding Government stocks.

Table 6.—Ferromanganese produced in the United States and metalliferous materials [1] consumed in its manufacture

Year	Ferromanganese produced			Materials consumed			Manganese ore used per ton of ferromanganese [2] made (short tons)
	Gross weight (short tons)	Manganese content		Manganese ore (35 percent or more Mn natural)		Iron and manganiferous iron ores (short tons)	
		Percent	Short tons	Foreign (short tons)	Domestic (short tons)		
1956-60 (average)	799,137	77.3	617,933	[2] 1,679,463	[2] 32,792	1,527	2.1
1961	732,813	77.3	566,432	[3] 1,577,519	[3] 9,446	1,685	2.1
1962	781,112	77.2	602,854	[2] 1,673,227	17,417	96	2.2
1963	751,198	77.2	579,852	[2] 1,617,112	------	-----	2.2
1964	929,486	77.8	722,752	[3] 2,082,074	10,371	-----	2.2
1965	1,148,011	77.8	892,725	[3] 2,685,649	12,067	-----	2.3

[1] Excluding scrap and other secondary materials.
[2] Includes ore used in producing silicomanganese.
[3] Includes ore used in producing silicomanganese and metal.

Table 7.—Manganese ore used in producing ferromanganese, silicomanganese, and manganese metal in the United States, by source of ore

Source	1964		1965	
	Gross weight (short tons)	Mn content, natural (percent)	Gross weight (short tons)	Mn content, natural (percent)
Domestic	10,371	56.1	12,067	55.6
Foreign:				
Africa	872,356	47.4	1,505,782	47.6
Brazil	461,034	45.9	526,376	45.8
British Guiana	82,949	39.4	111,778	38.0
Chile	2,021	48.1	4,088	48.4
Cuba	21,635	38.9	9,048	44.1
India	288,828	44.2	221,564	43.2
Mexico	160,335	43.0	110,046	38.4
Philippines	991	46.4	15,110	45.0
Other or unidentified	191,925	----	181,857	----
Total	2,092,445	45.8	2,697,716	46.0

steady rate of increase. In 1965 the proportion was 18.5 percent compared with 17.4 percent in 1964 and 12.3 percent in 1960.

Spiegeleisen.—The New Jersey Zinc Co., using electric furnaces at Palmerton, Pa., was the only producer of spiegeleisen.

Pig Iron.—In producing pig iron, 505,000 tons of manganese-bearing ores containing over 5 percent manganese (natural) were used. Domestic sources supplied 349,000 tons and foreign sources supplied 156,000 tons. The domestic ore included 164,000 tons of manganiferous iron ore containing 5 to 10 percent manganese (natural), 183,000 tons of ferruginous manganese ore containing 10 to 35 percent manganese, and 2,000 tons of manganese ore containing more than 35 percent manganese. The foreign ore consisted of 130,000 tons of manganiferous iron ore of 5 to 10 percent manganese content (natural) and 26,000 tons of manganese ore containing over 35 percent manganese. Canada supplied all the foreign manganiferous iron ore.

Battery and Miscellaneous Industries.—The domestic portion of the ores used in manufacture of dry cell batteries was 14.0 percent of the total in 1965. This was the same proportion as recorded for 1963, but less than 17.5 percent reported for 1964.

The domestic ore and much of the foreign ore used for chemical and miscellaneous purposes did not meet National Stockpile Specification P-81-R for chemical-grade ore.

PRICES

Manganese Ore.—All manganese ore prices are negotiated, being dependent in part on character and quantity of ore offered, delivery terms, and fluctuating shipping rates. For the first half of the year, price quotations of the American Metal Market for manganese ore containing 46 to 48 percent manganese were 68 to 72 cents, nominal, per long ton unit of manganese, c.i.f. eastern seaboard and gulf ports. In the second half they increased to 73 to 78 cents, nominal, same basis, closing the year without change.

Manganese Alloys.—The average value at furnaces for ferromanganese shipped by domestic producers was $146.42 per short ton, compared with $143.38 in 1964. Prices for standard high-carbon ferromanganese were not well defined and were expressed by one producer's published schedule as "Price available on request." Several producers announced after midyear that they were raising the price $8 per long ton "above current competitive levels," effective October 1. However, this was formally rescinded in mid-December and it is probable that little business was done at the higher level, which was generally credited to be approximately $175.50 per long ton for the alloy containing 74 to 76 percent manganese. For most of the year, prices were probably negotiated from a $167.50-per-long-ton base with freight as one of the negotiable points. Price increases announced in December 1964 apparently did not hold.

The price of spiegeleisen was increased $2, effective February 1. The resulting

Table 8.—U.S. imports of manganese ore (35 percent or more Mn), by countries

Country	General imports [1] (short tons)				Imports for consumption [2]					
					Short tons				Value	
	Gross weight		Mn content		Gross weight		Mn content			
	1964	1965	1964	1965	1964	1965	1964	1965	1964	1965
North America: Mexico	153,258	99,984	70,408	45,437	145,539	111,070	66,975	50,598	$4,836,153	$3,100,049
South America:										
Brazil [3]	545,734	553,028	260,770	255,703	708,238	1,528,795	333,359	725,386	18,613,338	49,941,112
British Guiana [4]	60,832	129,580	26,208	49,442	166,101	177,936	73,743	72,016	3,372,834	3,444,412
Chile	---	9,607	---	4,606	---	9,607	---	4,606	---	302,210
Peru	962	528	467	243	1,532	528	715	243	25,165	14,377
Total	607,528	692,743	287,445	309,994	870,871	1,716,866	407,817	802,251	22,011,337	53,702,111
Europe:										
Greece	2,489	10,995	1,194	5,278	1,254	11,613	526	5,612	60,000	630,124
Netherlands	28	---	12	---	28	---	12	---	1,807	---
Total	2,517	10,995	1,206	5,278	1,282	11,613	538	5,612	61,807	630,124
Africa:										
Angola [5]	21,436	40,206	10,959	19,578	43,643	53,009	22,194	26,091	1,236,474	1,351,249
Burundi and Rwanda [6]	---	7,063	---	3,000	---	7,063	---	3,000	---	166,080
Congo (Léopoldville)	171,359	245,582	84,784	122,707	322,989	343,704	163,821	172,860	7,965,059	9,648,408
Ethiopia	3,581	---	1,805	---	3,581	---	1,805	---	129,759	---
Gabon [7]	212,884	290,178	105,666	144,818	209,458	304,658	104,391	151,626	4,659,637	8,977,876
Ghana	120,582	245,018	61,958	122,582	267,301	312,553	135,585	157,107	7,911,462	8,823,186
Ivory Coast [8]	22,588	77,422	9,790	32,364	27,084	77,422	11,739	32,364	565,952	1,508,579
Mauritania [6]	---	37,804	---	18,903	---	37,804	---	18,903	---	1,202,470
Morocco	43,097	28,000	21,561	14,586	69,534	28,000	36,339	14,586	3,157,404	1,393,643
Portuguese Western Africa, n.e.c	---	---	---	---	3,796	---	1,898	---	132,904	---
South Africa, Republic of	191,690	204,139	78,662	85,865	325,149	205,667	134,761	86,462	6,123,951	3,919,523
Western Africa, n.e.c [9]	266,908	312,273	132,120	152,152	237,654	314,362	117,568	153,215	6,276,626	8,561,470
Zambia, Southern Rhodesia, and Malawi	21,506	3,365	10,058	1,851	21,506	3,365	10,058	1,851	595,049	136,084
Total	1,075,631	1,491,050	517,363	718,406	1,531,695	1,687,607	740,159	818,065	38,754,277	45,688,568

Asia:										
Goa	---	9,912	---	5,343	---	9,912	---	5,343	---	83,910
India	219,791	255,995	100,311	118,459	468,584	303,979	211,758	137,235	11,174,601	6,198,895
Japan	---	99	---	40	---	99	---	40	---	13,996
Philippines	3,920	---	2,105	---	3,920	---	2,105	---	86,000	---
Taiwan	---	18	---	8	---	18	---	8	---	7,213
Turkey	2,345	5,451	1,079	2,071	2,345	5,451	1,079	2,071	52,979	72,026
Total	226,056	271,475	103,495	125,921	474,849	319,459	214,942	144,697	11,313,580	6,376,040
Oceania: British Western Pacific Islands	---	8,982	---	4,491	---	8,982	---	4,491	---	250,090
Grand total	2,064,990	2,575,229	979,917	1,209,527	3,024,236	3,855,597	1,430,431	1,825,709	76,977,154	109,746,982

[1] Comprises ore received in the United States; part went into consumption during the year, and the remainder entered bonded warehouses.
[2] Comprises ore received during the year for immediate consumption and material withdrawn from bonded warehouses.
[3] Data adjusted to include material reported from country of transhipment (Uruguay).
[4] Data adjusted to include material reported from country of transhipment (Trinidad and Tobago).
[5] An appreciable part of the ore credited to Angola was apparently Congo (Léopoldville) ore exported from Angola.
[6] Apparently incorrectly classified as to country or commodity.
[7] In addition, Gabon imports reported as Western Africa, n.e.c., were approximately 238,000 tons (gross weight) in 1964 and approximately 271,000 tons (gross weight) in 1965.
[8] In addition, Ivory Coast imports reported as Western Africa, n.e.c., were approximately 29,000 tons (gross weight) in 1964 and approximately 41,000 tons (gross weight) in 1965.
[9] Actually from Gabon and Ivory Coast.

price of $89 per long ton, f.o.b. Palmerton, Pa., for the 19 to 21 percent manganese grade was unchanged for the remainder of the year.

Manganese Metal.—Pricing of the standard grade of electrolytic manganese metal was changed in February from a delivered to an f.o.b. producer's plant, freight equalized, basis. A further change after midyear, holding to yearend, brought the bulk, carlot price on the new basis to 28.85 cents per pound. Premiums for hydrogen-removed metal and for the 5.5-plus percent nitrogen grade were 0.75 cent and 5.75 cents per pound, respectively.

FOREIGN TRADE

Exports.—Ferromanganese exports totaled 3,273 tons valued at $727,407. With the new export classifications which became effective January 1, 1965, ferromanganese exports no longer include silicomanganese and it is possible that the 1965 figures are not directly comparable with those of preceding years. Both silicomanganese and spiegeleisen under the new classification schedule were placed in a blanket classification with the result that export data for them was not obtainable. Exports formerly classified as "manganese metal and alloys in crude form and scrap" were changed to "manganese and manganese alloys, wrought or unwrought, and waste and scrap." These exports in 1965, totaling 2,428 tons valued at $1,883,690, were believed to be electrolytic manganese metal for the most part. Exports classified as "manganese ores and concentrates containing over 10 percent manganese" totaled 14,150 tons valued at $1,387,000. They were believed to consist almost entirely of imported manganese dioxide ore exported after grinding, blending, or otherwise classifying.

Imports.—The average grade of imported

Table 9.—U.S. imports for consumption of ferromanganese, by countries

Country	1964			1965		
	Gross weight (short tons)	Mn content (short tons)	Value	Gross weight (short tons)	Mn content (short tons)	Value
North America: Canada	3,254	2,503	$377,911	7,284	5,640	$1,044,684
South America:						
Brazil	---	---	---	661	430	60,736
Chile	5,815	4,374	782,300	729	557	88,035
Peru	---	---	---	27	20	2,946
Total	5,815	4,374	782,300	1,417	1,007	151,717
Europe:						
Belgium-Luxembourg	32,763	25,067	3,189,193	16,621	12,751	1,839,503
France	39,360	30,162	4,143,601	69,167	52,847	7,500,866
Germany, West	21,731	16,528	2,328,689	33,561	25,707	3,530,216
Italy	1,600	1,284	299,728	1,384	1,115	279,724
Netherlands	616	467	59,843	915	680	92,131
Norway	---	---	---	224	175	21,210
Spain	9,584	7,385	841,615	6,410	5,068	928,337
United Kingdom	---	---	---	11,017	8,468	1,165,594
Yugoslavia	---	---	---	904	705	95,639
Total	105,654	80,893	10,862,669	140,203	107,516	15,453,220
Africa:						
South Africa, Republic of	18,232	14,145	1,847,480	34,035	26,667	3,688,949
Zambia, Southern Rhodesia, and Malawi	---	---	---	58	46	5,868
Total	18,232	14,145	1,847,480	34,093	26,713	3,694,817
Asia:						
India	74,551	56,000	10,941,727	64,029	48,990	8,931,752
Japan	5,123	4,160	999,033	10,313	8,252	2,209,912
Total	79,674	60,160	11,940,760	74,342	57,242	11,141,664
Grand total	212,629	162,075	25,811,120	257,339	198,118	31,486,102

manganese ore dropped to 47.0 percent manganese from 47.5 percent in 1964. Gabon and Brazil, each with approximately 22 percent of the total, again were the principal individual sources of supply.

General imports of manganiferous ores containing more than 10 but less than 35 percent manganese totaled 27,292 tons, of which 325 tons came from Mexico and the remainder from African sources, including Ghana and the Republic of South Africa. Imports for consumption of this grade were 36,167 tons from the same sources.

Ferromanganese imports for consumption increased 21 percent. Unlike the previous year, the increase for 1965 can be attributed to the commercial accounts rather than Government receipts. The 1965 imports from India for the most part were for the Government under previously executed barter agreements, but the tonnage received was less than that received in 1964. Imports for consumption of silicomanganese totaled 17,490 tons and contained 11,601 tons of manganese. Norway supplied 9,969 tons; Brazil, 2,535 tons; Yugoslavia, 2,275 tons; Chile, 1,779 tons; Japan, 740 tons; and France, 192 tons. Manganese metal imports for consumption were 1,384 tons, with 1,118 tons from the Republic of South Africa and 266 tons from Japan. In addition, 2 pounds of metal came from Italy with a value of $292. Spiegeleisen imports for consumption were 2,240 tons, all from West Germany.

Imports for consumption classified as "Manganese compounds, other" totaled 1,025 tons with an average value of approximately 11.8 cents per pound in 1965. Of this quantity, Japan provided 533 tons (16.2¢) and the United Kingdom supplied 455 tons (6.4¢). The 1964 total quantity was 646 tons with an average value of 9.9 cents per pound, of which 196 tons (17.2¢) came from Japan and 398 tons (6.7¢) from the United Kingdom. The imports from Japan possibly consisted entirely of synthetic manganese dioxide.

Tariff.—The duty on manganese ore of 0.25 cent per pound of contained manganese, applicable to most countries, remained suspended throughout the year. Ore from the U.S.S.R., mainland China, and certain other specified Communist countries, continued to be subject to a tariff of 1 cent per pound of contained manganese.

WORLD REVIEW

NORTH AMERICA

Canada.—Market and capital studies for an electrolytic manganese metal plant were undertaken by Union Carbide Canada Ltd. Preliminary indications suggested an initial capacity of 3,500 tons per year of metal with provision for expansion to 5,000 tons, apparently with the aluminum industry in mind as the principal market. Canada has had no production of electrolytic manganese metal. Its requirements for making stainless steel and for the aluminum, magnesium, and copper-alloy industries have been met entirely by imports.

Costa Rica.—A $1.5 million plant for the manufacture of dry cell batteries will be built in San Jose by Union Carbide Corp. and operated by Union Carbide Centro Americana, S.A. Output, expected to begin early in 1966, will replace U.S. battery exports to the Central American Common Market. Affiliated companies have plants in Argentina, Brazil, Colombia, Mexico, and Venezuela.

Mexico.—Cia. Minera Autlan, operator of the Autlan, Jalisco, manganese mine, the reserves of which apparently are nearing exhaustion, will invest $22 million by the end of 1967 in development of the large manganese deposits at Molango, Hidalgo.

SOUTH AMERICA

In an investigation of 15 manganese occurrences of the Guiana Shield, extending from the Amazon River estuary in Brazil to central Venezuela, the principal manganese minerals were determined by microscopic and X-ray studies to be pyrolusite-polianite, cryptomelane, and lithiophorite. Limonite was usually found as a contaminant. The main types of ore were classified as residual, mantle lateritic, and

Table 10.—World production of manganese ore by countries [1]

(Short tons)

Country	Percent Mn e	1961	1962	1963	1964	1965 p [2]
North America:						
Costa Rica (exports)	35+	---	---	661	---	---
Cuba e	35–50	46,000	83,000	83,400	83,400	83,000
Mexico e	44–46	155,900	184,900	189,300	206,500	202,800
United States (shipments)	35+	46,088	24,758	10,622	26,058	29,258
Total e	------	248,000	292,700	284,000	316,000	315,000
South America:						
Argentina	30–40	19,724	13,921	r 12,436	r 21,385	e 21,400
Bolivia (exports)	NA	53	291	---	---	---
Brazil	38–50	1,120,336	1,290,461	1,382,727	r 1,490,077	1,296,987
British Guiana	40–42	r 216,203	303,636	157,331	130,907	186,137
Chile	43–47	35,012	47,578	51,234	r 21,893	18,285
Peru	45	3,879	7,403	r 532	r 453	617
Total	------	r 1,395,207	1,663,290	r 1,604,260	r 1,664,715	1,523,426
Europe:						
Bulgaria	30+	40,785	38,581	42,432	57,320	e 55,100
Greece	35+	31,195	15,097	16,389	e 33,100	e 77,200
Hungary	30−	137,610	142,447	167,960	r 188,711	e 194,000
Italy	30−	54,196	r 48,966	r 49,887	r 52,694	52,701
Portugal	38+	12,492	12,666	9,434	r 7,711	8,584
Rumania	35	227,076	208,337	286,601	re 110,000	e 110,000
Spain	30+	17,092	14,101	16,858	r 17,762	18,912
U.S.S.R. [3]	NA	6,583,000	7,057,000	7,345,000	r 7,822,000	e 8,598,000
Yugoslavia	30+	15,595	16,358	8,964	8,580	8,925
Total [1]	------	7,119,041	r 7,553,553	r 7,943,525	r 8,297,878	e 9,120,000
Africa:						
Angola	38–48	22,695	9,115	---	---	---
Bechuanaland	30+	31,737	26,458	r 11,877	27,116	9,717
Congo (Leopoldville)	48+	348,595	348,547	297,660	341,385	416,205
Ethiopia (shipments)	51	7,716	6,614	---	---	---
Gabon	50–53	---	224,038	r 702,716	1,045,324	1,417,571
Ghana [5]	48	r 483,253	r 418,263	r 449,081	r 509,341	665,821
Ivory Coast	32–47	137,825	117,928	153,291	150,384	198,179
Morocco	35–50	629,512	517,377	369,217	375,974	414,337
Rhodesia, Southern	30+	205	7,977	---	160	e 230
South Africa, Republic of	30+	1,562,729	1,614,599	1,441,503	1,455,271	1,727,822
South-West Africa	45+	50,296	---	---	---	4,185
Sudan	36–44	---	1,120	re 300	re 9,400	1,102
United Arab Republic (Egypt) [6]	35+	2,272	42,577	23,798	e 47,000	e 26,000
Zambia	35+	58,517	r 63,432	38,856	41,899	33,965
Total [1]	------	r 3,335,352	r 3,398,045	r 3,488,299	r 4,003,254	4,915,134
Asia:						
Burma	42+	196	213	e 220	---	e 220
China, Mainland e	30+	882,000	882,000	1,102,000	1,102,000	1,102,000
Goa	32–50	109,790	97,732	r 214,950	r 112,027	122,500
India	35+	1,355,868	r 1,350,951	r 1,213,404	r 1,437,412	1,657,874
Indonesia	35–49	r 14,661	r 7,176	r 3,136	e 550	---
Iran [4]	40+	2,315	2,205	r 3,307	re 3,300	3,858
Japan	32–40	335,236	340,162	305,028	r 313,826	338,409
Korea, South	40+	1,518	1,105	4,580	4,753	7,376
Malaysia	30+	7,130	341	7,696	---	1,754
Pakistan	42+	---	1,036	1,553	1,098	---
Philippines	35+	20,986	13,160	8,450	8,824	57,038
Thailand	40+	588	3,194	7,285	12,185	36,848
Turkey	30–50	33,069	23,422	6,949	22,366	15,675
Total e	------	r 2,763,000	2,723,000	r 2,879,000	r 3,018,000	3,344,000
Oceania:						
Australia	45–48	97,901	80,244	r 40,389	r 69,450	109,200
Fiji	40+	3,869	1,202	3,621	1,004	6,040
New Hebrides	50–55	5,060	21,859	28,016	r 66,430	73,535
Papua	46	2	---	4	3	---
Total	------	106,832	103,305	r 72,030	r 136,887	188,775
World total e	------	r 14,967,000	r 15,734,000	r 16,271,000	r 17,437,000	19,406,000

e Estimate. p Preliminary. r Revised. NA Not available.

[1] Czechoslovakia and Sweden report production of manganese ore (approximately 13 to 17 percent manganese content), but since the manganese content averages substantially less than 30 percent, the output is not included in this table. Czechoslovakia averaged annually 100,000 short tons and Sweden approximately 9,000 tons for the last five years. Malagasy Republic produces a negligible amount of manganese.

[2] Compiled mostly from data available June 1966.

[3] Grade unstated. Source: The Industry of the U.S.S.R., Central Statistical Administration, (Moscow).

[4] Year ending March 20 of year following that stated.

[5] Dry weight.

[6] In addition to high-grade ore shown in the table, Egypt produced the following tonnages of less than 30 percent manganese content: 1961, 304,663; 1962, 162,102; 1963, 160,673; 1964, 314,000 (est.); 1965, 174,000 (est.).

nodular lateritic; protores were of the spessartite, rhodochrosite (Amapa, Brazil, and Upata, Venezuela), and braunite (Matthews Ridge, British Guiana). Individual deposits have more than one type of ore and more than one type of protore. The spessartite protore was observed at many of the deposits.[2]

Bolivia.—The Bolivian Government was reported to have budgeted $1.2 million for an 18-month transportation study for the iron and manganese ores of El Mutun.

Brazil.—Manganese ore exports from the Amapa deposits went to 13 countries in 1965, principally the United States, West Germany, and Japan. In 1964, Brazilian manganese ore exports from all sources totaled 918,000 tons, of which the United States took 65 percent; the United Kingdom, 13 percent; West Germany, 6 percent; Japan, 5 percent. Lesser quantities, in decreasing order, went to Norway, France, Argentina, Czechoslovakia, Italy, and Belgium. All ore from the Morro de Mina open pit operation at Lafaiete, Minas Gerais, was consumed in Brazil—some for the production of ferromanganese and some for direct use in steelmaking. Cia. Meridional de Mineração, a subsidiary of United States Steel Corp., was the mining operator. All ore from the underground mine at Urucum, near Corumbá, Mato Grosso, another U.S. Steel Corp. interest, was for export via barge down the Paraguay and Paraná Rivers with transfer to ocean vessels at Nueva Palmira, Uruguay. This mine's 1963 output of 67,000 tons was considered to be its normal production rate. Low river levels in 1964, 1962, and 1961 necessitated production cutbacks in those years.

Chile.—Bethlehem Chile Iron Mines Co. was reported to have optioned the Corral Quemado manganese mines of Cia. Manganeseos Atacama. These mines accounted for virtually all of Chile's manganese ore production in 1964, with only approximately 1,300 tons produced by small mining operations in Coquimbo and Atacama Provinces and operations of Cia. Manganesos Chile having ceased. Ferromanganese was made at Concepcion and Santiago by Fabrica Nacional de Carburo y Metalurgia, and at Coquimbo by Cia. Manganesos Atacama.

EUROPE

Germany, West.—Knapsack A.G. a subsidiary of Farbwerke Hoechst A.G. was building an electrolytic manganese dioxide plant to begin production by the middle of 1966 using a new process developed by the company. Capacity of the plant was expected to be sufficient to supply much of the European market.[3]

Italy.—Imports of manganese ore in 1964 were less than half those of 1963, with the United Arab Republic, the Republic of the Congo (Léopoldville), and the U.S.S.R. as the principal suppliers. The general economic recession and recourse to previously acquired stocks accounted for much of the drop.[4] The manganese ore produced in 1965 and 1964 averaged 28 and 30 percent manganese, respectively.

Spain.—Manganese ore produced in 1965 had an average manganese content of 31.7 percent compared with 32.2 percent in 1964. Ferromanganese production was 48,000 tons in 1965.

AFRICA

Angola.—Manganese ore exports in 1965, 1964, and 1963, respectively, 950, 11,000. and 3,000 tons, were made from previously mined stocks—there was no production in any of these years. The 1964 exports were by the Angolan Manganese Co. and by the Bermanite-Quissama Co. Both companies were reported to have experienced marketing difficulties because of high silica and sulfur content of the ores. That shipped by Angolan Manganese Co. came from mines at Saia, near Salazar, where the company produced significant quantities of iron ore. The Bermanite-Quissama ore was obtained in prospecting.

Gabon.—Production of battery-grade manganese ore started in 1963 when 2,700 tons was produced. This was followed by 4,600 tons in 1964 and 6,400 tons in 1965 as a concentrate in the form of pellets containing 82 to 84 percent manganese dioxide.

Ghana.—African Manganese Ltd., a subsidiary of Union Carbide Corp., mined and conducted beneficiation research on man-

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[2] Holtrop, J. F. The Manganese Deposits of the Guiana Shield. Econ. Geol., v. 60, No. 6, September–October 1965, pp. 1185–1212.

[3] Chemical Trade Journal and Chemical Engineer (London). V. 157, No. 4082, Sept. 2, 1965, p. 269.

[4] Bureau of Mines. Mineral Trades Notes. V. 61, No. 3, September 1965, p. 45.

ganese carbonate ore. Exports of battery and chemical grade ore in 1965 totaled 48,000 tons, of which 28,000 tons went to the United States and 18,000 tons went to Norway.

Ivory Coast.—Exports of manganese ore in 1965 totaled 188,000 tons, of which 113,000 tons was of a 45- to 47-percent manganese grade; 21,000 tons, 40- to 42-percent; 7,600 tons, 40-percent. The remaining 46,000 tons was mixed grade. The value of the ore sent to the United States was double the value of that sent in 1964. The United Kingdom, Belgium-Luxembourg, Sweden, and Spain, were the other destinations for 1965 exports. In 1964, a total of 115,000 tons was exported. The United States, United Kingdom, Spain, and Poland, in decreasing order of importance were the recipients.

Morocco.—In 1965, chemical-grade manganese ore production was 60,000 tons with a manganese dioxide content of 80 percent, compared with 82,000 tons of 82 percent manganese dioxide content in 1964. There were 93,000 tons of sinter, of approximately 56 percent manganese content, obtained in 1965 from 118,000 tons of metallurgical ore. Sinter production of this grade in 1964 was 71,000 tons.

South Africa, Republic of.—Production of chemical manganese ore in 1964 was broken down to grades as follows (1963 production in parentheses): over 85 percent manganese dioxide, 420 tons (none in 1963); 75 to 85 percent, 5,700 (3,400); 65 to 75 percent, 3,200 (7,700); and 35 to 65 percent, 37,000 (57,000). Local sales for the 35 to 65 percent grade for the 2 years were, respectively, 52,000 and 78,000 tons. Maganiferous ore containing 15 to 30 percent manganese and 20 to 35 percent iron was produced to the extent of 163,000 tons in 1964 and 55,000 tons in 1963, with exports of 142,000 tons and 46,000 tons, respectively. Germany and the Netherlands were the recipients of this ore in both years with Germany taking much the larger portion each year.[5] A shortage of railroad cars in 1965 cut shipments from mines to consumers and export docks with the result that stocks were at times critically low at those points. South African Manganese Ltd. decided to increase the capacity of its new Mamatwan mine to 25,000 tons per month by early 1966. The rate of production of the Adams and Devon mines of The Associated Manganese Mines of South Africa Ltd. was increased by the installation of new compressors and by acquisition of other equipment.

South-West Africa.—The Otjisondu mine of South African Minerals Corp. Ltd., reopened early in 1965 under a lease agreement whereby Walvis Bay Mining Co., a newly formed subsidiary of Consolidated African Mines Ltd. of Johannesburg, will operate the mine for 10 years from January 5, 1965. Royalties were fixed on an ascending scale beginning at 5 percent of the selling price, with a minimum set for the last 5 years.

Upper Volta, Republic of.—Considerable Japanese interest was shown in the manganese deposits of Tambao in the northeastern part of the country near Markoye. These were the subject of much investigation in 1965. Financial aid for railway construction would be an important part of any plans for exploitation of the deposits.

ASIA

China.—Three grades of metallurgical manganese ore were advertised for export, namely 44, 40, and 35 percent minimum manganese content, in bulk; six grades of lump pyrolusite (manganese dioxide), namely 85, 80, 75, 70, 65, and 60 percent minimum manganese dioxide content, in lumps or in chips and powder mixed, in bulk or in single gunny bags; and four grades of pyrolusite (manganese dioxide) powder, namely 80, 75, 70, and 65 percent minimum manganese dioxide content, in cloth or paper bags, for use in the manufacture of dry batteries principally and of matches and manganese compounds, as a drier for paints and varnishes, a coloring agent for ceramics, etc.

India.—With exhaustion of its accumulated ore stocks expected by the end of 1965, future revenues for Central Provinces Manganese Ore Co. must come from investment income, operation of its Balapur Hamesha mine, dividends from its 49-percent interest in Manganese Ore (India) Ltd., and from commissions on sales for that Government-controlled company. Much of the company's revenue since 1962 has come from sales of its stockpile ores.[6] Shivrajpur

[5] Bureau of Mines. Mineral Trade Notes. V 61, No. 6, December 1965, pp. 33–35.
[6] Mining Journal (London). V. 265, No. 6786, Sept. 3, 1965, p. 171.
Metal Bulletin (London). No. 5014, July 16, 1965, p. 18.

Syndicate Ltd. changed its plans to resume production because prices offered by the State-owned Minerals and Metals Trading Corp (MMTC) were not high enough.[7] In working the open pit mines of the Srikakulam and Visakhapatnam districts of Andhra Pradesh since 1892, the better grades of ore have been exported leaving dumps of low-grade ores averaging 15 to 30 percent manganese and 0.35 to 0.45 percent phosphorus. The dump material was the subject of ore dressing studies conducted at Andhra University looking toward their use for producing ferromanganese at Garividi. A satisfactory reduction in phosphorus was not achieved.[8] Indian production of manganese dioxide in 1965 was said to be at the rate of 7,000 tons per year, while the country's annual requirements were estimated by a Mineral Advisory Board subcommittee to be 15,000 tons by 1970.[9] For the year ending April 1, 1965, MMTC experienced a loss of 16 million rupees ($3,336,000) in exporting 1.7 million tons of manganese ore, the largest quantity exported since 1957. The loss reflected the difference between the prices paid mine owners and the contract prices obtained on sale of the ore in international markets.[10] Exports after February of manganese ores containing 48 percent and less manganese were granted a tax credit of 15 percent.[11] Beginning December 1, a quality control entailing an inspection fee was to be placed by the Government on manganese ore, ferromanganese, and ferromanganese slag, among other mineral items. In July, the Government made MMTC responsible for negotiation and coordination of all manganese ore exports except those for ore produced or acquired by Manganese Ore (India) Ltd. Internal rail transportation problems, including high rail freight rates, poor loading facilities, and inadequate access roads were a matter of concern, as were some port problems. In the last quarter of 1964, the average price of manganese dioxide (80 percent MnO_2), f.o.b. Calcutta, was 200 rupees ($42.00) per metric ton while that for metallurgical ore containing 46 to 48 percent manganese, f.o.b. port of shipment, averaged 104.5 rupees ($22.00). Exports of standard peroxide ore with a manganese dioxide content of 86 percent and lower were 2,000 tons in 1964 compared with 8,800 tons in 1963; total manganese ore imports were 8,600 tons in 1964 and 10,300 tons in 1963. Exports of ferromanganese in 1964 were approximately 100,000 tons, of which the United States took 90 percent, Netherlands, Australia, Belgium, United Kingdom, South Korea, and Singapore, the remainder in decreasing order. Production of ferromanganese in 1964 was 144,000 tons.

Japan.—The metallurgical manganese ore (concentrate) produced in 1964 had an average manganese content of 32.1 percent.

Philippines.—A new 24-ton-per-day manganese dioxide grinding and drying plant was being built in Manila by Union Carbide Philippines Inc. A 6-foot by 36-inch Hardinge ball mill will dry grind the crushed ore to minus 200 mesh.[12] Pan Asia Mining Co., began to mine a metallurgical manganese ore containing 33 percent manganese at Dingalan, Quezon, in 1964 and started to ship to Japan in the second quarter of 1965. Metallurgical ore was also exported to Japan by Acoje Mining Co., Inc.

OCEANIA

Australia.—Development of the Groote Eylandt manganese deposits proceeded in preparation for first shipments early in 1966. In 1964, Australia produced 614 tons of dioxide ore containing 66.8 percent manganese dioxide, and 818 tons containing 61.6 percent. The metallurgical ore produced in that year averaged 49.7 percent manganese.

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[7] Metal Bulletin (London). No. 4996, May 11, 1965, p. 26.

[8] Rao, A. Narasinga. Studies on the Beneficiation of Low-Grade Manganese Ores from Srikakulam and Visakhapatnam Districts With Special Reference to Reduction of Phosphorus. J. Mines, Metals, and Fuels (Calcutta, India), v. 13, No. 2, February 1965, pp. 55–59.

[9] European Chemical News (London). V. 7, No. 170, Apr. 16, 1965, p. 6.

[10] Metal Bulletin (London). No. 5050, Nov. 23, 1965, p. 25.

[11] Metal Bulletin (London). No. 5018, July 30, 1965, p. 19.

[12] World Mining. V. 18, No. 3, March 1965, p. 81.

TECHNOLOGY

The findings of extensive Bureau of Mines research on recovery of manganese pyrometallurgically from slags, by smelting followed by selective oxidation, were reported in a comprehensive Bureau report.[13] Similarly, the data and results of extensive research with manganese-copper damping alloys were collected in a Bureau bulletin.[14]

The feasibility of extracting manganese from Georgia umber ore by a three-stage leaching process using a sulfate "pickle liquor" was demonstrated in a small pilot plant. After ovendrying, the umber used for feed had a manganese content of approximately 5 percent and an iron content of more than 40 percent. Leaching efficiency ranged from 83 to 89 percent, and the leach residues were used to make iron pellets suitable as an iron furnace feed.[15]

The heats of formation of manganese molybdate were determined from the elements and from the oxides by solution calorimetry using a mixture of hydrofluoric and hydrochloric acids.[16]

A patent was issued for a method to improve the economics of the matte smelting process investigated some years ago for utilizing low-grade manganese ores. The new procedure was claimed to eliminate the recycling of large quantities of finished oxide product, a disadvantage of the original process, and to require less operating energy.[17]

As an aid to prospecting in the U.S.S.R., it was suggested that the manganese deposits which have been considered to be of sedimentary origin are really of volcanic-sedimentary origin, and even the manganese contained in the Chiatura and Nikopol deposits may have had a deep-seated source.[18]

In comparing the metamorphosed manganese protores of India with those of the rest of the world, a case was made for restriction of the terms "gondite" and "kodurite" to their original usage. Gondite would be limited to those silicate-oxide protores which feature an abundance of high-temperature lower oxides of manganese in the absence of manganese carbonates and sulfides. Kodurite would be limited to manganese silicate rocks formed by contact metamorphism of manganiferous sediments by granitic intrusives. High-temperature lower oxides of manganese may or may not be present in the kodurites depending on availability of excess manganese. The protores of Madhya Pradesh and Maharashtra in India, and those at Otjosondu in South-West Africa, would qualify as true gondites. The Indian deposits at and around Kodur, Srikakulam District, Andhra Pradesh, and Goldongri, Panch Mahal District, Gujarat would qualify as typical kodurites, although other investigators have suggested abandonment of the term "kodurite."[19]

Many data on the subject of ocean-floor manganese deposits were gathered together in a published work on the general subject of the ocean's mineral resources. An extensive bibliography was included.[20]

The molybdenum-manganese process for joining ceramics to metal, better known as the moly-manganese process, reportedly has become the most widely employed method used for this purpose in electronic applications. A thin (0.0005 to 0.002 inch) coating of a fine suspension of molybdenum and manganese is fired on the ceramic in a reducing atmosphere at temperatures approaching 3,000° F. Over this is electroplated a coating of nickel and copper which can be wet by a brazing alloy. It is claimed that the resulting ceramic-metal bonds have better high-temperature strength than those by any other method. Tensile strengths of 20,000 pounds per square inch have been reported.[21]

At the Atlantic City, N.J., Power Sources Conference, sponsored by the Army Electronics Command (Fort Monmouth, N.J.), both the Army and The Eagle-Picher Co.

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[13] Buehl, R. C., Miles B. Royer, and J. P. Morris. The Recovery of Manganese From Open-Hearth Slags and Low-Grade Ores by Smelting and Selective Oxidation. BuMines Rept. of Inv. 6596, 1965, 33 pp.

[14] Jensen, J. W., and D. F. Walsh. Manganese-Copper Damping Alloys. BuMines Bull. 624, 1965, 55 pp.

[15] LeVan, H. P., E. G. Davis, and F. E. Brantley. Extraction of Manganese From Georgia Umber Ore by a Sulfuric Acid-Ferrous Sulfate Process. 1. Countercurrent-Decantation Extraction and Agglomeration of Leached Residues Tests. BuMines Rept. of Inv. 6692, 1965, 21 pp.

[16] Barany, R. Heats of Formation of Goethite, Ferrous Vanadate, and Manganese Molybdate. BuMines Rept. of Inv. 6618, 1965, 10. pp.

[17] Kirby, Ralph C. (assigned to the U.S. Department of the Interior.) Upgrading Primary Manganese Matte. U.S. Pat. 3,179,514, Apr. 20, 1965.

[18] Sapozhnikov, D. G. Current Problems in the Study of Manganese Deposits. Reviewed in Econ. Geol., v. 60, No. 2, March–April 1965, pp. 388–389.

[19] Roy, Supriya. Comparative Study of the Metamorphosed Manganese Protores of the World–The Problem of the Nomenclature of the Gondites and Kodurites. Econ. Geol., v. 60, No. 6, September–October 1965, pp. 1238–1260.

[20] Mero, John L. The Mineral Resources of the Sea. Elsevier Publishing Co., New York, 1965, 312 pp.

[21] Kutzer, L. G. Joining Ceramics and Glass to Metals. Mat. in Design Eng. v. 61, No. 1, January 1965, p. 109.

(Joplin, Mo.) reported promising research and development of magnesium-manganese dioxide batteries using a magnesium perchlorate electrolyte. The objective was to obtain an improved battery for new walkie-talkie sets with four times the energy density of older models and a minimum delay time.[22]

Good correspondence was found between stability relations of synthesized manganese oxides and those observed as natural occurrences in the course of investigations conducted at 25° C and 1 atmosphere total pressure.[23]

Silver resistance alloys containing 8 to 9 percent manganese and 0.5 to 5 percent antimony were developed in the U.S.S.R. for use where corrosion problems make ordinary resistance alloys unsatisfactory. Mechanical and electrical properties vary with antimony content. The antimony addition improved wear resistance.[24]

A patent was issued for a manganese-aluminum alloy magnetic material consisting essentially of 65.65 to 72.17 percent manganese, 1 to 5 percent titanium, 0.1 to 2 percent of either zinc, copper, iron, or nickel, and the remainder aluminum.[25]

A low-alloy austenitic manganese steel, containing 6 percent manganese and 1 percent molybdenum, was tested in use as ball mill liners and in other abrasive applications. It was reported to have better wear and gouging resistance than 12-percent-manganese Hadfield steel and to compare favorably in regard to toughness, although not as tough. Improvement in abrasion resistance was due to the lower manganese content. Addition of molybdenum inhibits carbide formation which has an embrittling effect and which would otherwise form in these alloys of relatively low manganese content.[26]

Study of the iron-nickel-manganese alloy system resulted in development of a maraging steel, designated 12-2 maraging steel, in which part of the nickel is replaced by manganese. It was reported to compare favorably in its properties with 18-percent-nickel maraging steels, while having a cost advantage because of its lower nickel content. Its percentage composition, similar in its other alloying constituents to the regular 18-percent maraging steels, was 12.5 nickel, 8 cobalt, 4 molybdenum, 2 manganese, 0.2 titanium, 0.1 aluminum, and the remainder iron.

Investigations were reported of the deformation of oriented manganese sudfide inclusions in steel,[27] manganese vapor pressures,[28] the kinetics of the oxidation of manganese in carbon dioxide-carbon monoxide mixtures,[29] and the cathodic reduction of electrolytic manganese dioxide in an alkaline electrolyte.[30]

A process was patented for absorbing the sulfur oxide of waste gases with an aqueous suspension of manganese oxide, thereby forming manganese sulfate. Hydrogen chloride is added to the manganese sulfate in the liquid phase, converting it to sulfuric acid and crystalline manganous chloride. The latter is decomposed by a combustion gas containing excess free oxygen, producing chlorine and manganese oxide. This oxide then returns to the start of the cycle.[31]

By using electric separation methods of concentration together with magnetic separation, it was possible to recover sufficient fines to achieve an upgrading of Chiatura mill products from 22.3 to 29.6 percent manganese to 50.2 to 52.2 percent manganese, with recoveries up to 71 percent and with rejects containing only 6 percent manganese.[32]

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[22] Chemical Week. New Call for Power. V. 96, No. 25, June 19, 1965, pp. 79–80, 84.

[23] Bricker, Owen. Some Stability Relations in the System $Mn\text{-}O_2\text{-}H_2O$ at 25° and One Atmosphere Total Pressure. Am. Mineral., v. 50, No. 9, September 1965, pp. 1296–1354.

[24] Light Metals & Metal Industry (London). V. 28, No. 328, September 1965, p. 68.

[25] Kaneko, Hideo. Manganese Aluminum Alloy Magnets. U. S. Pat. 3,194,654, July 13, 1965.

[26] Norman, T. E. Climax Finds New Austenitic Alloy Ideal For Ultra-Abrasive Mine-Mill Applications. Eng. and Min. J., v. 166, No. 4, April 1965, pp. 86–90.

[27] Chao, H. C., and L. H. Van Vlack. Deformation of Oriented MnS Inclusions in Low-Carbon Steel. Trans. AIME, v. 233, (Metallurgy), 1965, pp. 1227-1231.

[28] Roy, Prodyot, and Ralph Hultgren. Vapor-Pressure Studies of Iron-Manganese Alloys. Trans. AIME, v. 233 (Metallurgy) 1965, pp. 1811–1815.

[29] Fueki, Kazuo, and J. B. Wagner, Jr. Oxidation of Manganese in CO_2-CO Mixtures. J. Electrochem. Soc., v. 112, No. 10, October 1965, pp. 970–974.

[30] Kozawa, A., and J. F. Yeager. The Cathodic Reduction Mechanism of Electrolytic Manganese Dioxide in Alkaline Electrolyte. J. Electrochem. Soc., v. 112, No. 10, October 1965, pp. 959–963.

[31] Atsukawa, Masumi, Kazuhiro Matsumoto, and Hiroyuki Murokawa (assigned to Mitsubishi Shipbuilding & Engineering Co., Ltd.) Process of Treating Waste Gas Containing Sulfur Oxide. U. S. Pat. 3,226,192, Dec. 28, 1965.

[32] Plaksin, I. N. and N. F. Olofinsky. Review of Electrical Separation Methods in Mineral Technology. Trans. Inst. of Min. and Met., v. 75, No. 712, March 1966, pp. C57–C64.

Mercury

By George T. Engel [1]

Mercury prices reached record highs for the second consecutive year ranging from a low of $475 to a high of $775 per flask.[2]

Disposal of mercury declared surplus by the Atomic Energy Commission (AEC) continued, and an additional 38,000 flasks was authorized for release by the AEC.

An engineering evaluation of potential mercury production, together with the locations and pertinent data of all known U.S. mercury mines, was published.[3]

Table 1.—Salient mercury statistics

	1956–60 (average)	1961	1962	1963	1964	1965
United States:						
Producing mines	103	69	56	48	72	149
Production ....flasks	32,270	31,662	26,277	19,117	14,142	19,582
Value ....thousands	$7,534	$6,257	$5,024	$3,623	$4,452	$11,176
Exports ....flasks	863	285	224	187	r 188	7,543
Reexports ....do	1,421	180	257	40	196	494
Imports:						
For consumption ....do	33,829	12,326	31,552	42,872	41,153	16,238
General ....do	35,641	12,527	31,516	43,126	41,107	17,838
Stocks Dec. 31 ....do	18,463	17,533	14,924	12,181	r 16,108	19,132
Consumption ....do	53,142	55,763	65,301	77,963	82,608	76,454
Price: New York, average per flask	$234.84	$197.61	$191.21	$189.45	$314.79	$570.75
World:						
Production ....flasks	234,400	240,000	245,000	239,000	r 255,000	275,000
Price: London, average per flask	$218.50	$181.87	$172.79	$171.42	$282.25	$607.85

r Revised.

LEGISLATION AND GOVERNMENT PROGRAMS

The U.S. Government offered financial assistance through the Office of Minerals Exploration (OME). This program offers 50 percent of total allowable costs for exploration of eligible domestic mercury deposits. Four exploration projects were active in 1965:

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[1] Commodity specialist, Division of Minerals.

[2] Flasks as used in this chapter refers to a 76-pound flask.

[3] Bureau of Mines Staff. Mercury Potential of the United States. BuMines Inf. Circ. 8252, 1965, 376 pp.

Company:	*Location*	*Total cost*
Joseph A. Johnson	San Luis Obispo County, Calif	$21,160
Pacific Minerals & Chemicals Co., Inc	Crook County, Oreg	63,000
J. Selby and Wm. Dawson (assigned to San Simeon Keystone, Inc.)	San Luis Obispo County, Calif	45,388
Sonoma International, Inc	Sonoma County, Calif	105,400

During 1965 the U.S. Government began the release to industry of mercury from the large stock built up in 1964 when the AEC had declared 72,500 flasks of mercury surplus to its needs. Of this quantity 17,000 flasks had been released in 1964 to other government agencies for their use or to be donated to hospitals and schools. In October 1965 an additional 38,000 flasks was declared surplus by the AEC and was to be made available for disposal.

Mercury sold as surplus in 1965 totaled 31,764 flasks, leaving a yearend balance of 23,736 flasks. Of the quantity sold, 2,011 flasks had not been shipped in 1965. This Government surplus mercury could only be sold for domestic consumption or direct use in domestic plants and could not be exported in the form of metal.

On February 5, General Services Administration (GSA) opened bids ranging from $38 to $451.11 per flask, and 175 flasks were sold at prices ranging from $425 to $455.11. Based on bids for this offering GSA established a shelf-price of $430 per flask for 10,000 flasks on February 23. Thirty-one domestic consumers bought this material. Shortly after this sale, GSA announced availability of another 10,000 flasks at $460 per flask in lots of 500 or more and $475 for less than 500 flasks. Additional quantities were sold between June and August at $685 per flask.

The Interior Department called a meeting of Government officials with representatives of producers, consumers, and dealers on September 22. As a result of this meeting GSA announced a plan to release excess mercury at bid sales at the rate of 1,500 flasks a month on the second Friday in each month. Unsold mercury was to be returned to the program. The three sales under this new program sold only 1,061 flasks. On December 31, there was 184,501 flasks of mercury in the Government strategic stockpile and 16,000 in the supplemental stockpile.

DOMESTIC PRODUCTION

Domestic primary mercury production rose sharply but would undoubtedly have been higher had it not been for floods, fires, and equipment breakdowns which interrupted production in the fourth quarter.

Production of secondary mercury rose to 45,698 flasks largely as a result of the release of 29,753 flasks of AEC mercury in 1965. Recovery of secondary mercury from commercial sources was at the highest level since 1947 when data were first collected. It was approached only by 1958 production of 10,300 flasks.

Sources of secondary mercury were reclaimed dental amalgams, oxide and acetate sludges, battery scrap, and a decommissioned mercury boiler.

The following 5 mines produced more than 1,000 flasks:

State:	*County*	*Mine*
California	San Benito	New Idria.
Do	San Luis Obispo	Buena Vista.
Do	Sonoma	Mt. Jackson.
Idaho	Washington	Idaho-Almaden.
Nevada	Humboldt	Cordero.

Mines producing 100 flasks or more were as follows:

State:	*County*	*Mine*
Alaska	Aniak district	White Mountain.
California	Marin	Gambonini.
Do	San Benito	Aurora.
Do	Santa Barbara	Sun Bird (Gibralter).
Do	Santa Clara	Guadalupe.
Do	do	New Almaden.
Do	Shasta	Welty.
Do	Sonoma	Culver Baer.
Do	do	Socrates.
Nevada	Esmeralda	B & B.
Do	Nye	Ione Mercury.
Do	Pershing	Kitten Springs.
Oregon	Lane	Black Butte.
Do	Malheur	Bretz.

Table 2.—Mercury produced in the United States, by States

Year and State	Producing mines	Flasks	Value [1] (thousands)
1964:			
Alaska	3	303	$95
Arizona	4	77	24
California	39	10,291	3,240
Idaho	1	83	26
Nevada	21	3,262	1,027
Oregon	4	126	40
Total	72	14,142	4,452
1965:			
Arizona	7	158	$90
California	84	13,404	7,650
Idaho	2	1,119	639
Nevada	42	3,333	1,902
Oregon	7	1,364	779
Alaska, Texas, Washington	7	204	116
Total	149	19,582	11,176

[1] Value calculated at average New York price.

Table 3.—Mercury ore treated and mercury produced in the United States [1]

Year	Ore treated (short tons)	Mercury produced: Flasks	Mercury produced: Pounds per ton of ore
1956–60 (average)	283,182	31,918	8.6
1961	262,108	31,633	9.2
1962	146,523	26,228	13.6
1963	113,539	19,101	12.8
1964	149,950	14,115	7.2
1965	339,124	19,353	4.3

[1] Excludes mercury produced from placer operations and from cleanup at furnaces and other plants.

Table 4.—Production of secondary mercury in the United States

Year:	Flasks
1960	5,350
1961	8,360
1962	5,800
1963	10,520
1964	23,780
1965	45,700

CONSUMPTION AND USES

Industrial consumption of mercury rose about 17 percent in 1965 despite the high price, but total consumption was lower because 1964 consumption included 17,000 flasks distributed to Government agencies from surplus AEC material. The larger industrial consumption was due largely to demand for new or expanded mercury-cell caustic-soda chlorine plants.

Of the declining uses, paper and pulp uses were down 40 percent, antifouling paints used 58 percent less, and pharmaceuticals used 72 percent less. These declines can probably be attributed to the high price of mercury in 1965. Some producers or users of these materials were obviously either drawing from their stocks of mercury or substituting other materials for mercury.

Of the contemplated six mercury-cell caustic-soda chlorine plants for 1965, one solvay plant was terminated, one other plant was converted to a diaphragm-cell type, and four came on stream as mercury-cell

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plants. There were also two plant expansions in 1965. Consumption data for new plants and expansions are included under other uses in table 5.

New caustic-soda chlorine plants using the mercury-cell process and expansions of existing plants in 1965 were:

Company:
- Detrex Chemical Industries, Inc., Ashtabula, Ohio [4]
- Diamond Alkali Co., Delaware City, Del.
- The Dow Chemical Co., Plaquemine, La.[4]
- Georgia-Pacific Corp., Bellingham, Wash.
- Olin Mathieson Chemical Corp., Augusta, Ga.
- Stauffer Chemical Co., Le Moyne, Ala.

[4] Plant expansion.

Table 5.—Mercury consumed in the United States by uses

(Flasks)

Use	1956–60 (average)	1961	1962	1963	1964	1965
Agriculture (includes fungicides, and bactericides for industrial purposes)	7,311	2,557	4,266	2,538	3,144	3,116
Amalgamation	250	278	299	306	667	495
Catalysts	906	707	874	612	656	924
Dental preparations [1]	1,610	2,154	2,033	2,346	2,612	1,619
Electrical apparatus [1]	9,285	10,255	11,564	11,115	10,690	14,764
Electrolytic preparation of chlorine and caustic soda	4,792	6,056	7,314	7,999	9,572	8,753
General laboratory use:						
Commercial	1,052	1,484	1,752	1,241	1,516	2,827
Government	--------	--------	--------	3,821	17,000	---------
Industrial and control instruments[1]	6,177	5,627	5,186	4,943	4,972	4,628
Paint:						
Antifouling	1,913	915	124	252	547	255
Mildew proofing	NA	5,146	4,554	6,403	4,898	7,534
Paper and pulp manufacture	NA	3,094	2,600	2,831	2,148	619
Pharmaceuticals	1,645	2,515	3,378	4,081	5,047	3,261
Redistilled [1]	9,529	9,013	8,987	9,227	11,405	12,257
Other	8,673	5,962	12,370	r 20,248	7,734	15,402
Total	53,143	55,763	65,301	77,963	82,608	76,454

NA Not available.

[1] A breakdown of the "redistilled" classification showed ranges of 45 to 38 percent for instruments, 21 to 8 percent for dental preparations, 44 to 25 percent for electrical apparatus, and 18 to 8 percent for miscellaneous uses in 1956–64, compared with 45 percent for instruments, 15 percent for dental preparations, 19 percent for electrical apparatus, and 21 percent for miscellaneous uses in 1964.

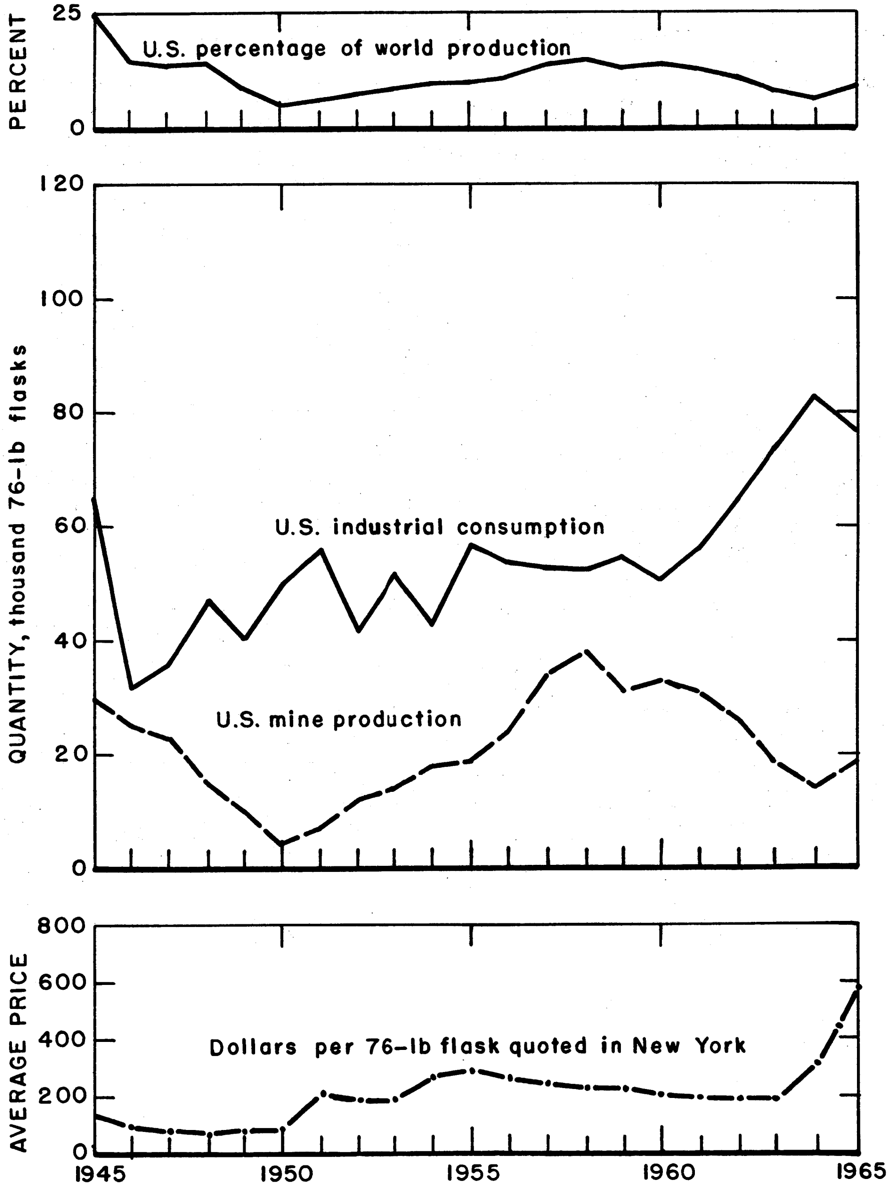

Figure 1.—Trends in production, consumption, and price of mercury.

STOCKS

Consumer and dealer stocks in each quarter of 1965 were higher than for the corresponding quarters of 1964. Producer stocks were lower until the third quarter when apparently production began to meet demand and producer stocks in the fourth quarter were half again the 1964 stocks.

Table 6.—Stocks of mercury, December 31

(Flasks)

Year	Producer	Consumer and dealer	Total
1956–60 (average)	1,983	16,480	18,463
1961	2,033	15,500	17,533
1962	1,224	13,700	14,924
1963	1,581	10,600	12,181
1964	[r] 708	15,400	[r] 16,108
1965	1,432	17,700	19,132

[r] Revised.

PRICES

The average price of mercury in the United States in 1965 reached the record high of $570.75 per flask. The price on January 1 in New York was $490 to $500 a flask (£170 in London). On July 1, the price reached $725 to $775 a flask in New York and £280 to £285 on the London Metals Exchange. This was the period also of maximum GSA mercury sales. By the first of August, the price had dropped to $660 to $685 and £265 and thereafter slowly declined to $530 to $535 and £200 on December 31.

Table 7.—Average monthly prices of mercury at New York and London

(Per flask)

Month	1964		1965	
	New York[1]	London[2]	New York[1]	London[2]
January	$234.36	$219.95	$478.75	$432.65
February	261.25	243.33	475.00	475.17
March	261.86	243.43	475.00	493.91
April	264.18	243.51	499.29	552.25
May	263.85	246.35	628.75	573.41
June	267.32	244.49	709.09	691.09
July	276.86	259.16	673.81	739.62
August	294.76	278.66	595.68	739.56
September	330.71	285.65	624.05	718.75
October	367.73	337.76	610.95	693.77
November	470.00	382.91	545.50	588.78
December	484.55	390.68	533.10	560.42
Average	314.79	282.25	570.75	607.85

[1] Engineering and Mining Journal, New York.
[2] Mining Journal (London) prices in terms of pounds sterling were converted to U.S. dollars by using average rates of exchange recorded by Federal Reserve Board.

FOREIGN TRADE

Exports of mercury went to 20 countries in 1965. The principal customers in order were the United Kingdom, Japan, Canada, Taiwan, and France.

Reexports of mercury went mainly to Canada, with lesser amounts to West Germany, France, and the United Kingdom.

Imports of mercury were at a low level due to domestic commitments in the producer countries and production previously committed to other countries. Most of the Philippines production evidently went to Japan.

Table 8.—U.S. exports of mercury

Year	Flasks	Value
1956–60 (average)	863	$207,705
1961	285	70,622
1962	224	64,024
1963	187	46,357
1964 [1]	188	52,107
1965	7,543	5,030,630

[1] Excludes 10,275 pounds of spent catalysts valued at $12,272 and 171,152 pounds residues, valued at $17,980.

Table 9.—U.S. reexports of mercury

Year	Flasks	Value
1956–60 (average)	1,421	$323,705
1961	180	33,067
1962	257	42,549
1963	40	6,400
1964	196	50,284
1965	494	315,522

Table 10.—U.S. imports for consumption [1] of mercury, by countries

Country	1956–60 (average)		1961		1962		1963		1964		1965	
	Flasks	Value (thousands)	Flasks	Value (thousands)	Flasks	Value (thousands)	Flasks	Value (thousands)	Flasks	Value (thousands)	Flasks	Value (thousands)
North America:												
Canada	68	$14	24	$4	61	$10	150	$27	538	$136	32	$13
Mexico	6,201	1,235	3,023	445	7,618	1,064	4,292	585	1,230	272	1,290	544
South America:												
Bolivia	4	1	-----	-----	-----	-----	-----	-----	106	15	50	18
Chile	298	60	82	15	200	31	740	112	-----	-----	-----	-----
Colombia	25	4	25	4	-----	-----	-----	-----	-----	-----	-----	-----
Peru	320	64	-----	-----	-----	-----	3,227	511	3,065	502	1,368	318
Europe:												
Germany, West	-----	-----	-----	-----	-----	-----	-----	-----	(2)	(2)	150	80
Italy	7,113	1,582	2,073	365	10,501	1,800	8,474	1,401	5,236	1,262	1,203	334
Netherlands	4	1	-----	-----	-----	-----	-----	-----	200	49	-----	-----
Spain	17,812	3,750	6,544	1,118	9,826	1,638	19,950	3,176	24,344	5,037	10,995	5,811
Sweden	-----	-----	-----	-----	70	10	-----	-----	-----	-----	-----	-----
United Kingdom	617	137	(2)	(2)	(2)	(2)	-----	-----	75	31	3	1
Yugoslavia	998	225	355	62	3,276	537	4,459	696	3,953	939	1,101	474
Asia:												
Israel	-----	-----	-----	-----	-----	-----	-----	-----	145	21	-----	-----
Philippines	300	63	-----	-----	-----	-----	1,580	258	1,550	383	-----	-----
Turkey	32	10	200	35	-----	-----	-----	-----	711	128	46	21
Oceania:												
Australia	25	5	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
New Zealand	12	2	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Total	33,829	7,153	12,326	2,048	31,552	5,090	42,872	6,766	41,153	8,775	16,238	7,614

[1] Data include mercury imported for immediate consumption plus material withdrawn from bonded warehouses.
[2] Less than 1/2 unit.

Table 11.—U.S. imports [1] of mercury, by countries
(Flasks)

Country	1956-60 (average)	1961	1962	1963	1964	1965
North America:						
Canada	68	24	61	150	538	32
Mexico	6,587	3,205	7,560	4,328	1,350	1,825
South America:						
Bolivia	4	--------	--------	--------	106	50
Chile	365	82	200	740	--------	--------
Colombia	25	115	--------	--------	--------	--------
Peru	322	--------	--------	3,406	2,657	1,899
Europe:						
Germany, West	--------	--------	--------	--------	(2)	150
Italy	7,487	2,002	10,498	8,474	5,654	1,297
Netherlands	4	--------	--------	--------	200	--------
Spain	18,539	6,544	9,826	19,950	24,344	10,996
Sweden	--------	--------	70	--------	--------	--------
United Kingdom	650	(2)	(2)	--------	75	3
Yugoslavia	1,221	355	3,301	4,498	3,778	1,451
Asia:						
Israel	--------	--------	--------	--------	145	--------
Philippines	300	--------	--------	1,580	1,550	--------
Turkey	32	200	--------	--------	710	135
Oceania:						
Australia	25	--------	--------	--------	--------	--------
New Zealand	12	--------	--------	--------	--------	--------
Total	35,641	12,527	31,516	43,126	41,107	17,838

[1] Data are "general" imports; that is, they include mercury imported for immediate consumption plus material entering the country under bond.
[2] Less than 1/2 unit.

WORLD REVIEW

The rapid rise in mercury prices starting early in 1964 had remarkably little effect on mine production. Although the average London price was three and one-half times higher in 1965 than in 1963, preliminary world production was only 15 percent higher. Those countries substantially increasing production were Spain, 6 percent; the United States, 38 percent; and Mexico, 44 percent. Production rates in Italy, the Philippines, Yugoslavia, and Peru held fairly constant, with efforts being made for early increased production.

Another major factor in the mercury market was the actions of the Eastern European countries and the Far Eastern Communist areas. Ever since the mercury price began to rise in 1964, the Soviet Union and some of the Eastern European countries have been net buyers instead of net sellers as in previous years. This has created a major drain from Western origins where the material under normal circumstances would have been available to other more regular outlets. The exact reasons for the turnaround are problematical. Expansions of their chemical industries is probably a big factor. Chinese material, previously subjected to substantial discounting on the world market because of impurities, seems to have been available at world prices during 1965, but in small and irregular quantities.

Table 12.—World production of mercury by countries
(Flasks)

Country	1961	1962	1963	1964	1965 p[1]
Bolivia (exports)	--------	11	105	[2] 32	e 30
Canada	--------	--------	--------	73	20
Chile	1,509	791	613	r 275	e 370
China e	26,000	26,000	26,000	26,000	26,000
Colombia	191	--------	3	3	3
Czechoslovakia e	725	725	725	725	725
Italy	r 55,376	r 54,506	54,448	57,001	57,291
Japan	5,437	4,199	4,668	r 4,812	e 4,820
Mexico	18,101	18,855	16,302	r 12,560	e 18,000
Peru	3,001	r 3,481	r 3,092	3,275	e 3,280
Philippines	3,167	2,767	2,651	r 2,496	e 2,500
Rumania	350	222	194	r 194	e 200
Spain	51,202	52,798	56,954	r 78,322	82,760
Tunisia	54	--------	--------	--------	174
Turkey	r 1,881	2,687	3,042	r 2,615	e 2,620
United States	31,662	26,277	19,117	14,142	19,582
U.S.S.R. e	25,000	35,000	35,000	35,000	40,000
Yugoslavia	15,954	16,273	15,838	17,318	16,419
World total e	240,000	245,000	239,000	r 255,000	275,000

e Estimate. p Preliminary. r Revised.
[1] Compiled from data available May 1966.
[2] Purchases by Banco Minero.

Table 13.—Italy: Exports of mercury by countries
(Flasks)

Destination	1964	1965	Destination	1964	1965
Argentina	386	---------	Korea:		
Australia	1,305	490	North	1,497	---------
Belgium-Luxembourg	354	899	South	1,134	348
Bulgaria	377	---------	Netherlands	1,004	452
Canada	719	---------	Norway	313	299
China	--------	203	Poland	1,105	725
Czechoslovakia	1,346	1,578	Rumania	1,201	---------
France	4,778	2,782	Sweden	461	580
Germany:			Switzerland	891	125
East	1,845	830	Taiwan	395	---------
West	12,682	8,270	United Kingdom	21,666	15,598
Hungary	653	594	United States	4,627	4,453
India	795	99	Yugoslavia	3,002	---------
Japan	19,517	12,018	Other countries	1,470	754
			Total	83,523	51,097

Table 14.—Mexico, Spain, and Yugoslavia: Exports of mercury, by countries

(Flasks)

Destination	Exporting countries: Mexico 1963	Mexico 1964	Spain 1963	Spain 1964	Yugoslavia 1963	Yugoslavia 1964
Argentina	59	109	-	-	-	-
Australia	-	-	480	250	-	-
Austria	-	-	-	-	355	38
Brazil	1,547	578	145	-	-	-
Canada	-	-	4,694	1,001	100	-
Czechoslovakia	-	-	1,420	600	290	290
France	-	-	5,479	3,212	100	-
Germany:						
East	-	-	581	-	-	-
West	161	108	2,002	6,670	-	125
India	-	-	3,438	3,190	-	-
Israel	-	-	-	-	1,000	-
Italy	-	-	-	250	348	-
Japan	1,878	353	5,660	18,750	-	275
Korea, South	306	500	-	-	-	-
Malaysia	-	-	-	300	-	-
Netherlands	-	-	281	88	-	325
Norway	-	-	145	275	-	-
Pakistan	-	-	581	-	-	-
Poland	-	-	-	-	870	1,160
Portugal	-	-	190	683	-	-
Sweden	-	-	1,801	826	60	370
Switzerland	-	-	396	150	150	425
Taiwan	121	114	165	295	-	-
Tunisia	-	-	320	-	-	-
United Kingdom	229	43	5,564	8,957	150	-
United States	14,439	11,479	15,508	24,085	4,501	5,176
U.S.S.R.	-	-	-	-	2,612	2,611
Yugoslavia	-	-	-	1,001	-	-
Other countries	123	108	276	164	31	52
Total	18,863	13,392	49,126	70,747	10,567	10,847

TECHNOLOGY

New developments in mercury lamps promise broader uses by addition of certain chemicals which change some characteristics radically.[5]

Studies have been made of resistance of various materials to corrosion by mercury.[6]

A study of mercury consumption citing uses and future possibilities was published.[7]

A detailed study of mercury vapor hazards and control measures was published by the School of Public Health of the University of Minnesota.[8]

Detailed discussions of various types of mercury cells for producing chlorine and caustic soda, together with cost data, trends, advantages, and disadvantages, were published.[9]

A review of mercury marketing, together with a discussion of mercury economics, was published.[10]

An automatic vacuum mercury still which is useful in distilling mercury for use in McLeod gages, diffusion pumps, polarographic, and other equipment was described. It is said to be simple, trouble-free, and inexpensive.[11]

An oil-damped mercury pool is found to virtually eliminate vibrations when using mercury as an optically flat reference surface.[12]

[5] Unglert, M. C., and D. A. Larson. A New Era for Mercury Lamps. Westinghouse Eng., v. 25, No. 4, July 1965, pp. 116–120.

[6] Nejedlik, J. F., and E. J. Vargo. Material Resistance to Mercury Corrosion. Electrochem. Technol., v. 3, Nos. 9–10, September–October 1965, pp. 250–258.

[7] Williamson, D. R. Mercury Prices and Consumption. Colorado Sch. Mines Res. Foundation Miner. Ind. Bull., v. 8, No. 3, May 1965, 20 pp.

[8] Steere, Norman V. Safety in the Chemical Laboratory XVIII. J. Chem. Education, v. 42, No. 7, July 1965, pp. A529–A533.

[9] Sommers, H. A. The Chlor-Alkali Industry. Chem. Eng. Prog., v. 61, No. 3, March 1965, pp. 94–109.

[10] E&MJ Metal and Mineral Markets. Mercury. Jan. 25, 1965, pp. 5–20.

[11] Low, M. J. D., and L. Abrams. An Automatic Mercury Still. J. Chem. Education, v. 42, No. 10, October 1965, pp. 557–558.

[12] Steel. V. 157, No. 12, Sept. 20, 1965, p. 20.

Mica

By Benjamin Petkof [1]

The sale or use of domestically produced sheet mica continued the upward trend that began in 1964. Scrap and flake mica production continued to rise. Consumption of all forms of sheet mica rose. Mica imports for consumption rose slightly; exports of all varieties declined to the 1963 level.

Table 1.—Salient mica statistics

	1956–60 (average)	1961	1962	1963	1964	1965
United States:						
Domestic, sold or used by producers:						
Sheet mica--------thousand pounds--	707	526	363	103	243	716
Value--------------thousands--	$2,924	$3,386	$1,299	$13	$58	$185
Scrap and flake mica thousand short tons--	94	99	108	109	115	120
Value--------------thousands--	$2,277	$2,417	$2,639	$2,776	$3,353	$3,468
Ground mica---thousand short tons--	98	103	114	117	116	127
Value--------------thousands--	$5,740	$5,468	$6,489	$6,805	$6,902	$7,615
Consumption, block and film thousand pounds--	3,132	2,536	2,811	2,293	2,618	2,659
Value------------------thousands--	$4,486	$3,630	$3,490	$2,782	$3,002	$3,188
Consumption, splittings thousand pounds--	7,096	5,514	6,728	6,687	7,608	8,260
Value------------------thousands--	$3,502	$2,266	$2,813	$2,588	$3,149	$3,701
Exports-------------thousand short tons	5	4	4	4	5	4
Imports for consumption------do--------	12	7	10	13	8	9
Consumption, apparent,[1] sheet thousand pounds--	11,757	8,356	11,582	9,112	r 10,243	11,330
World: Production--------------do---------	331,000	365,000	390,000	400,000	410,000	435,000

r Revised.
[1] Sheet mica sold or used, plus imports of unmanufactured and manufactured sheet mica, minus exports of sheet mica.

DOMESTIC PRODUCTION

Sheet Mica.—The quantity of sheet mica sold or used by producers doubled that of 1964 in both quantity and value. North Carolina produced the bulk of the material, with Georgia making a small contribution.

Scrap and Flake Mica.—The quantity of scrap and flake mica sold or used increased 5 percent in quantity and 3 percent in value over that of 1964. North Carolina was the largest producer, supplying 60 percent of the total tonnage. Nine other States produced the remainder.

Ground Mica.—Ground mica sales rose 9 percent in quantity and 10 percent in value over those of 1964. Dry-ground material accounted for 87 percent of total production. Reports were received from 23 grinders operating 19 dry-grinding plants and 4 wet-grinding plants. No production was reported from New Hampshire for the year.

Summit Industries, Inc., in Pennsylvania mined and processed sericite schist for use as a filler material.

[1] Commodity specialist, Division of Minerals.

Table 2.—Mica sold or used by producers in the United States

Year and State	Sheet mica: Uncut punch and circle mica		Sheet mica: Uncut mica larger than punch and circle [1]		Sheet mica: Total sheet mica		Scrap and flake mica [2]	
	Pounds	Value	Pounds	Value	Pounds	Value	Short tons	Value
1956-60 (average)	421,827	$35,516	284,785	$2,888,777	706,612	$2,924,293	94,309	$2,277,303
1961	265,444	21,774	260,563	3,363,986	526,007	3,385,760	99,044	2,416,819
1962	263,123	23,450	99,893	1,275,828	363,016	1,299,278	107,702	2,639,297
1963	97,828	9,206	5,133	3,698	102,961	12,904	109,323	2,776,381
1964	220,586	37,693	22,076	20,788	242,662	58,481	114,729	3,352,572
1965:								
Georgia	2,793	336	-------	---------	2,793	336	13,065	W
New Mexico	-------	------	-------	---------	-------	---------	4,263	45,290
North Carolina	667,713	139,508	45,580	45,142	713,293	184,650	72,199	1,986,970
Other States [3]	-------	------	-------	---------	-------	---------	30,728	1,435,441
Total	670,506	139,844	45,580	45,142	716,086	184,986	120,255	3,467,701

W Withheld to avoid disclosing individual company confidential data, included with "Other States."
[1] Includes the full-trimmed mica equivalent of hand-cobbed mica, 1956-62.
[2] Includes finely divided mica recovered from mica and sericite schist, and mica that is a byproduct of feldspar and kaolin beneficiation.
[3] Alabama, Arizona, California, Connecticut, Pennsylvania, South Carolina, South Dakota, and value indicated by symbol W.

Table 3.—Ground mica sold by producers in the United States by methods of grinding [1]

Year	Dry-ground: Short tons	Dry-ground: Value (thousands)	Wet-ground: Short tons	Wet-ground: Value (thousands)	Total: Short tons	Total: Value (thousands)
1956-60 (average)	85,028	$3,764	13,103	$1,976	98,131	$5,740
1961	90,519	3,747	12,176	1,721	102,695	5,468
1962	99,936	4,351	13,851	2,138	113,787	6,489
1963	101,943	4,596	15,308	2,209	117,251	6,805
1964	99,245	4,397	16,725	2,505	115,970	6,902
1965	110,600	5,316	15,997	2,299	126,597	7,615

[1] Domestic and some imported scrap.

CONSUMPTION AND USES

Sheet Mica.—Domestic sheet mica (block, film and splittings) consumption reached 10.9 million pounds, an increase of almost 7 percent over that of 1964.

About 2.63 million pounds of muscovite block and film was used for fabrication in various applications such as vacuum tubes and capacitors. Of this quantity 4 percent was Good Stained or better material, 32 percent Stained, and 64 percent lower than Stained. About 69 percent of the block and film was consumed by electronic and electrical uses. Vacuum tube production accounted for 56 percent of the total consumption of muscovite block and film. Consumption of phlogopite block increased 48 percent to about 30,000 pounds. Muscovite block and film was fabricated during the year by 17 companies in 9 States. New Jersey had four operating plants during the year, North Carolina four, Massachusetts three, and New York three. These States consumed 50 percent of the domestically fabricated block and film mica.

Mica splittings consumption increased almost 9 percent over that of 1964. India supplied 96 percent by weight of the total splittings consumption. The remainder was from the Malagasy Republic. Splittings were fabricated by 11 companies in 12 plants. Four plants, two in New York, one in New Hampshire, and one in Massachusetts, used almost 6 million pounds of splittings, or about 70 percent of the total quantity consumed.

Built-Up Mica.—This material was used mostly as an electrical insulator and was produced in various forms by fabricators. Tape was the form greatest in demand (30 percent), followed closely by segment (25 percent), and molding plate (24 percent). Consumption of built-up mica was 8 percent greater in quantity and 7 percent greater in value over that of 1964.

Reconstituted Mica.—General Electric Co. at Schenectady, N.Y., and Samica Corp. (subsidiary of Minnesota Mining & Manufacturing Co.) at Rutland, Vt., continued to fabricate this material from specially delaminated mica scrap by papermaking techniques. This sheet material continued to displace built-up mica in various applications.

Table 4.—Fabrication of muscovite ruby and nonruby block and film mica and phlogopite block mica, by qualities and end-product uses in the United States in 1965

(Pounds)

Variety, form, and quality	Electronic uses				Nonelectronic uses			Grand total
	Capacitors	Tubes	Other	Total	Gage glass and diaphragms	Other	Total	
Muscovite:								
Block:								
Good Stained or better	1,293	17,420	2,930	21,643	5,124	-------	5,124	26,767
Stained	3,408	805,947	4,401	813,756	3,746	12,693	16,439	830,195
Lower than Stained [1]	18,853	652,683	220,645	892,181	19,644	777,657	797,301	1,689,482
Total	23,554	1,476,050	227,976	1,727,580	28,514	790,350	818,864	2,546,444
Film:								
First quality	5,489	---------	-------	5,489	------	-------	-------	5,489
Second quality	73,717	---------	-------	73,717	------	-------	-------	73,717
Other quality	3,250	---------	-------	3,250	------	-------	-------	3,250
Total	82,456	---------	-------	82,456	------	-------	-------	82,456
Block and film:								
Good Stained or better [2]	80,499	17,420	2,930	100,849	5,124	-------	5,124	105,973
Stained [3]	6,658	805,947	4,401	817,006	3,746	12,693	16,439	833,445
Lower than Stained	18,853	652,683	220,645	892,181	19,644	777,657	797,301	1,689,482
Total	106,010	1,476,050	227,976	1,810,036	28,514	790,350	818,864	2,628,900
Phlogopite: Block (all qualities)	-------	---------	2,090	2,090	------	28,300	28,300	30,390

[1] Includes punch mica.
[2] Includes first- and second-quality film.
[3] Includes other-quality film.

Synthetic Mica.—Molecular Dielectrics, Inc., Clifton, N. J., and Synthetic Mica Co., Division of Mycalex Corporation of America, West Caldwell, N.J., continued commercial production of synthetic mica flake for use in glass-bonded mica ceramic materials. Molecular Dielectrics continued recovery of high-quality synthetic mica crystals for splitting and punching.

Other Substitutes for Sheet Mica.—Farnam Manufacturing Co., Inc., continued to make heat-resistant mica electrical insulation from natural mica which had been finely divided and bonded with water-soluble aluminum phosphate. Production was in the form of ridged sheets and various shapes.

Table 5.—Fabrication of muscovite ruby and nonruby block and film mica in the United States in 1965 by qualities and grades

(Pounds)

Form, variety, and quality	Grade					
	No. 4 and larger	No. 5	No. 5½	No. 6	Other [1]	Total
Block:						
Ruby:						
Good Stained or better	5,474	1,648	723	5,708	-------	13,553
Stained	15,858	13,217	95,655	619,173	66,421	810,324
Lower than Stained	112,821	173,978	77,539	581,127	551,667	1,497,132
Total	134,153	188,843	173,917	1,206,008	618,088	2,321,009
Nonruby:						
Good Stained or better	2,415	206	20	10,573	-------	13,214
Stained	1,216	1,997	3,590	13,068	-------	19,871
Lower than Stained	33,700	80,500	4,250	1,400	72,500	192,350
Total	37,331	82,703	7,860	25,041	72,500	225,435
Film:						
Ruby:						
First quality	1,040	749	700	550	-------	3,039
Second quality	29,744	32,035	7,290	3,043	-------	72,112
Other quality	------	------	------	------	3,250	3,250
Total	30,784	32,784	7,990	3,593	3,250	78,401
Nonruby:						
First quality	------	------	1,550	900	-------	2,450
Second quality	75	30	1,500	------	-------	1,605
Other quality	------	------	------	------	-------	------
Total	75	30	3,050	900	-------	4,055

[1] Figures for block mica include all smaller than No. 6 grade and "punch" mica.

Table 6.—Consumption and stocks of mica splittings in the United States, by sources

(Thousand pounds and thousand dollars)

	Indian		Malagasy		Total	
	Quantity	Value	Quantity	Value	Quantity	Value
Consumption:						
1956–60 (average)	6,630	$3,148	[1] 466	[1] $354	7,096	$3,502
1961	5,274	2,077	240	189	5,514	2,266
1962	6,382	2,559	346	254	6,728	2,813
1963	6,406	2,413	281	175	6,687	2,588
1964	7,261	2,949	347	200	7,608	3,149
1965	7,948	3,513	312	188	8,260	3,701
Stocks Dec. 31:						
1956–60 (average)	3,861	1,973	[2] 336	[2] 257	4,197	2,230
1961	2,546	1,212	258	167	2,804	1,379
1962	3,588	NA	143	NA	3,731	NA
1963	2,908	NA	172	NA	3,080	NA
1964	3,523	NA	245	NA	3,768	NA
1965	3,912	NA	210	NA	4,122	NA

NA Not available.
[1] Includes Canadian, 1957–59.
[2] Includes Canadian, 1956–58.

PRICES

Prices offered by mica fabricators for domestic clear sheet mica (roughly trimmed), as reported in E&MJ Metal and Mineral Markets, remained unchanged from 1964 and ranged from 7 to 12 cents per pound for the smallest size (punch) to $4 to $8 per pound for 6- by 8-inch sheets. Stained or electric mica was quoted 10 to 20 percent lower.

North Carolina scrap mica was quoted throughout the year in the E&MJ Metal and Mineral Markets at $30 to $40 per short ton, depending on quality.

Prices listed for dry-and wet-ground mica have remained unchanged since March 1956. Prices depended primarily on method of grinding. Prices are published regularly in the Oil, Paint and Drug Reporter.

Table 7.—Built-up mica [1] sold or used in the United States, by products

(Thousand pounds and thousand dollars)

Product	1964 Quantity	1964 Value	1965 Quantity	1965 Value
Molding plate	1,304	$3,887	1,344	$4,159
Segment plate	1,317	3,015	1,427	3,311
Heater plate	W	W	414	W
Flexible (cold)	566	1,572	611	1,536
Tape	1,506	6,048	1,708	6,729
Other	571	2,107	180	2,048
Total	5,264	16,629	5,684	17,783

W Withheld to avoid disclosing individual company confidential data; included with "Other."
[1] Consists of alternate layers of binder and irregularly arranged and partly overlapped splittings.

Table 8.—Ground mica sold by producers in the United States, by uses

Use	1964 Short tons	1964 Value (thousands)	1965 Short tons	1965 Value (thousands)
Roofing	35,119	$1,100	30,847	$1,057
Wallpaper	1,327	209	W	87
Rubber	7,634	865	7,228	810
Paint	20,782	1,895	20,286	1,816
Welding rods	944	34	745	32
Joint cement	W	W	38,767	2,531
Other uses [1]	50,164	2,799	28,724	1,282
Total	115,970	6,902	126,597	7,615

W Withheld to avoid disclosing individual company confidential data, included with "Other uses."
[1] Includes mica used for molded electric insulation, house insulation, Christmas tree snow, annealing, plastics, well drilling, other purposes, and uses indicated by symbol W.

FOREIGN TRADE

Total exports of mica decreased 8 percent in quantity and rose 40 percent in value over that of 1964. Ground mica accounted for the bulk of the exports.

Total imports of all forms of mica showed a 3-percent increase over those of 1964, after a major decline had occurred in imports. Total value of all imports increased by 24 percent.

Table 9.—U.S. exports of mica and manufactures of mica, in 1965, by countries

Destination	Mica, including sheet, waste and scrap and ground: Pounds	Mica, including sheet, waste and scrap and ground: Value	Manufactured: Pounds	Manufactured: Value
North America:				
Bahamas	---	---	2,025	$4,588
Canada	2,345,383	$177,212	187,938	645,528
Guatemala	29,722	2,110	719	2,350
Jamaica	21,000	740	87	1,216
Mexico	129,084	21,772	28,918	111,242
Panama	21,078	2,338	352	2,924
Trinidad	100,000	8,369	1,070	2,584
Other	3,590	3,132	1,612	7,574
South America:				
Argentina	6,500	669	13,613	31,434
Brazil	---	---	45,754	110,663
Chile	---	---	2,482	29,015
Colombia	165,945	16,890	5,497	12,799
Ecuador	68,800	5,310	90	422
Peru	242,150	13,144	3,207	8,099
Venezuela	921,620	48,532	2,798	10,167
Other	---	---	346	778
Europe:				
Belgium-Luxembourg	248,800	18,646	---	---
France	281,597	20,051	9,242	29,369
Germany, West	155,096	22,423	100,826	194,568
Greece	---	---	6,755	19,047
Iceland	10,000	754	---	---

Table 9.—U.S. exports of mica and manufactures of mica, in 1965, by countries—Continued

Destination	Mica, including sheet, waste and scrap and ground		Manufactured	
	Pounds	Value	Pounds	Value
Europe—Continued				
Italy	426,000	$20,925	12,696	$31,186
Netherlands	130,000	7,315	3,707	40,758
Norway	16,000	1,382	522	5,241
Spain	171,400	8,555	6,179	37,655
Sweden	36,600	3,474	14,145	24,211
Switzerland	10,780	993	232	684
United Kingdom	362,029	72,141	7,565	33,056
Other	4,400	2,126	802	3,894
Africa:				
Algeria	20,000	679	---	---
Congo (Léopoldville)	8,800	860	273	2,181
Libya	89,600	2,446	70	312
Morocco	20,000	1,784	125	830
Nigeria	147,850	4,892	---	---
South Africa, Republic of	107,775	8,865	5,833	61,169
Western Africa	---	---	9,354	9,929
Zambia, Southern Rhodesia, and Malawi	---	---	756	9,836
Other	---	---	110	988
Asia:				
Aden	12,500	1,095	---	---
Arabia	20,000	2,530	---	---
Bahrain	856,363	24,400	---	---
India	19,455	5,174	2,485	10,772
Indonesia	3,800	362	392	1,771
Iran	89,774	10,482	---	---
Israel	15,097	1,462	979	2,212
Japan	188,736	21,892	3,888	9,970
Kuwait	49,615	4,250	110	820
Lebanon	6,000	814	---	---
Pakistan	---	---	20,978	42,238
Philippines	143,000	11,326	728	1,995
Turkey	5,000	500	2,321	6,303
Other	---	---	1,601	4,893
Oceania:				
Australia	57,600	3,882	13,746	64,265
French Pacific Islands	10,000	900	53	691
New Zealand	24,000	936	357	2,617
Total	7,802,539	588,534	523,338	1,634,844

Table 10.—U.S. exports and imports of mica

Year	Imports for consumption						Exports	
	Uncut sheet and punch		Scrap		Manufactured		All classes	
	Pounds	Value (thousands)	Short tons	Value (thousands)	Short tons	Value (thousands)	Short tons	Value (thousands)
1956–60 (average)	2,058,047	$4,317	5,470	$65	5,108	$7,668	4,821	$1,407
1961	852,648	1,841	3,024	41	3,763	6,115	3,799	1,227
1962	1,110,739	1,796	4,458	55	5,403	7,922	4,028	1,363
1963	1,133,521	1,615	8,150	132	4,353	5,950	4,021	1,392
1964	2,267,681	2,434	2,733	71	4,433	4,566	4,544	1,586
1965	2,116,113	2,142	1,521	71	5,973	6,541	4,163	2,223

Table 11.—U.S. imports for consumption of mica by kinds and countries

Year and country	Unmanufactured									
	Waste and scrap, valued not more than 5 cents per pound				Other					
	Phlogopite		Other		Valued not above 15 cents per pound, n.e.s.		Valued above 15 cents per pound		Block [1]	
	Pounds	Value	Pounds	Value	Pounds	Value	Pounds	Value	Pounds	Value
1956–60 (average)	73,159	$610	10,868,128	$64,800	138,290	$10,187	1,919,757	$4,306,610	---	---
1961	96,138	1,212	5,951,448	40,053	68,619	4,085	784,029	1,837,127	---	---
1962	---	---	8,916,421	55,150	55,336	4,841	1,055,403	1,791,215	---	---
1963	224,622	7,360	16,075,434	124,528	181,151	8,929	952,370	1,606,553	419,409	$429,506
1964	629,338	12,067	4,836,410	59,120	287,814	11,847	654,733	1,180,304	1,325,134	1,241,891
1965:										
North America:										
Canada	216,227	6,712	80,000	1,851	---	---	---	---	---	---
Guatemala	---	---	11,023	350	---	---	---	---	---	---
Leeward and Windward Islands	---	---	---	---	---	---	---	---	292	255
South America:										
Argentina	---	---	---	---	34,943	1,049	38,007	32,765	---	---
Brazil	---	---	1,949,063	44,847	18,408	1,122	294,931	337,769	1,365,745	1,216,036
Surinam	---	---	---	---	---	---	9,057	12,186	---	---
Europe: United Kingdom	---	---	---	---	---	---	339	1,989	---	---
Africa:										
Malagasy Republic	114,639	4,700	---	---	---	---	---	---	2,224	6,197
Mozambique	---	---	---	---	---	---	---	---	1,543	2,320
Tanzania	---	---	---	---	---	---	33,492	90,119	---	---
Asia: India	---	---	672,403	12,588	---	---	29,249	138,429	287,883	301,820
Total	330,866	11,412	2,712,489	59,636	53,351	2,171	405,075	613,257	1,657,687	1,526,628

Table 11.—U.S. imports for consumption of mica by kinds and countries—Continued

Year and Country	Manufactured—films and splittings							
	Not cut or stamped to dimensions				Cut or stamped to dimensions		Total films and splittings	
	Not above 12/10,000 of an inch in thickness		Over 12/10,000 of an inch in thickness					
	Pounds	Value	Pounds	Value	Pounds	Value	Pounds	Value
1956-60 (average)	7,776,839	$3,389,761	2,135,485	$2,644,302	67,727	$1,029,190	9,980,051	$7,063,253
1961	5,800,568	2,572,106	1,469,972	1,812,709	67,116	1,140,572	7,337,656	5,525,387
1962	8,615,571	2,814,751	1,746,221	2,554,567	98,645	1,686,564	10,460,437	7,055,882
1963	6,820,647	2,330,633	1,551,752	1,823,742	70,488	1,174,694	8,442,887	5,329,069
1964	8,505,460	2,901,955	93,902	338,334	45,223	844,757	8,644,585	4,085,046
1965:								
North America:								
Canada	3,600	6,110	---	---	---	---	3,600	6,110
Leeward and Windward Islands	---	---	1,075	1,281	2,863	9,966	3,938	11,247
Mexico	---	---	320	2,640	5,366	146,683	5,686	149,323
South America: Brazil	10,007	9,709	41,165	35,880	2,427	10,183	53,599	55,772
Europe:								
France	---	---	---	---	323	5,886	323	5,886
Germany, West	13,200	12,543	---	---	---	---	13,200	12,543
Italy	6,848	4,630	1,000	6,432	---	---	7,848	11,062
Sweden	240	159	---	---	---	---	240	159
United Kingdom	3,000	10,032	---	---	3,111	69,636	6,111	79,668
Africa:								
Madeira Islands	4,409	1,900	---	---	---	---	4,409	1,900
Malagasy Republic	340,500	196,293	---	---	---	---	340,500	196,293
South Africa, Republic of	1,653	1,875	---	---	---	---	1,653	1,875
Tanzania	---	---	4,578	38,751	---	---	4,578	38,751
Asia:								
Burma	---	---	500	440	---	---	500	440
India	9,076,604	3,249,944	160,420	580,153	69,933	1,399,177	9,306,957	5,229,274
Japan	---	---	---	---	5,186	146,796	5,186	146,796
Total	9,460,061	3,493,195	209,058	665,577	89,209	1,788,327	9,758,328	5,947,099

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	Manufactured—cut or stamped to dimensions, shape or form		Manufactured—other: Mica plates and built-up mica		Manufactured—other: All mica manufactures of which mica is the component material of chief value		Manufactured—other: Ground or pulverized	
	Pounds	Value	Pounds	Value	Pounds	Value	Pounds	Value
1956-60 (average)	21,237	$29,129	54,635	$81,075	108,655	$491,268	51,057	$3,097
1961	793	1,617	57,609	49,966	105,777	537,270	23,000	1,380
1962	1,537	7,582	141,739	104,872	132,920	748,502	69,000	3,935
1963	1,660	11,626	127,425	99,681	102,198	507,985	31,488	1,636
1964	2,093	14,859	115,786	85,304	81,393	379,608	23,000	1,171
1965:								
North America:								
Canada	---	---	---	---	19	463	10,000	508
Mexico	---	---	---	---	5,749	55,975	---	---
South America: Brazil	---	---	---	---	9,653	20,711	---	---
Europe:								
Austria	---	---	---	---	190	484	---	---
Belgium-Luxembourg	---	---	10,302	10,942	32,901	71,344	---	---
France	---	---	---	---	2,546	103,842	43,206	4,167
Germany, West	---	---	86	896	98	1,529	---	---
Italy	---	---	---	---	8	438	---	---
Norway	---	---	---	---	---	---	33,360	2,924
Netherlands	---	---	---	---	1,068	19,792	---	---
Switzerland	---	---	76	675	---	---	---	---
United Kingdom	17	396	38	428	4,315	42,754	---	---
Asia:								
India	597	7,031	---	---	28,132	62,536	---	---
Japan	---	---	---	---	466	16,222	---	---
Total	614	7,427	10,502	12,941	85,145	396,090	86,566	7,599

[1] Not separately classified prior to Sept. 1, 1963.

WORLD REVIEW

Canada.—Production consisted only of phlogopite mica during 1964. Imports provided the country with its muscovite mica requirements.[2]

Guatemala.—The firm of Mica de Guatemala has produced a green variety of muscovite mica since 1964. The firm's primary mica deposit is in the Zacualpa area in the Department of Quiché. Mica block and scrap has been exported to Europe and Japan.

India.—Exports of all varieties of mica totaled 41,370 short tons valued at $23.1 million, an increase of 26 percent in quantity and 12 percent in value over that of 1964. Of this material 29 percent was sheet mica.

Southern Rhodesia.—Mica was produced during the year in the Miami district, northwest of Salisbury. Ketelby & Gelletich (Rhod.) (Pvt.) Ltd., a Johannesburg firm, began production of ground mica at its Marandellas plant, southeast of Salisbury, in January 1965.[3]

[2] Reeves, J. E. Mica. Canadian Minerals Yearbook 1964. No. 36, 1964, 6 pp.
[3] Bureau of Mines. Mineral Trade Notes. V. 63, No. 1, July 1966, p. 23.

Table 12.—Word production of mica by countries [1]

(Thousand pounds)

Country	1961	1962	1963	1964	1965 p [2]
North America:					
Canada (shipments):					
Block	155	r 132	r 16	r 89	
Splittings	22	---	---	---	
Ground	1,434	r 610	r 814	r 616	886
Scrap	205	r 456	r 353	r 494	
United States (sold or used by producers):					
Sheet	526	363	103	243	716
Scrap	198,088	215,404	218,646	229,458	240,510
South America:					
Argentina	r 121	r 108	r 196	r 701	e 660
Brazil	9,101	3,885	3,289	r 3,241	e 3,300
Europe:					
Austria [3]	194	33	---	---	---
France	304	190	381	r 646	e 660
Germany, West	18	20	r 11	r 18	e 18
Norway, including scrap	7,700	2,200	---	8,800	6,600
Sweden (ground)	110	126	r 44	---	---
Yugoslavia	4	4	77	r 26	e 45
Africa:					
Angola:					
Scrap and splittings	51	108	---	---	---
Malagasy Republic (phlogopite):					
Block	223	181	214	205	201
Splittings	2,002	2,780	1,914	1,299	1,186
Rhodesia, Southern:					
Block	64	33	60	75	64
Crude	101	172	225	157	176
South Africa, Republic of:					
Sheet	2	2	40	r 104	2
Scrap	5,440	4,900	4,680	6,764	5,000
South-West Africa	---	150	1,197	831	260
Tanzania (exports):					
Sheet	196	218	236	r 212	227
Scrap	---	---	---	r 324	370
Asia:					
India (exports):					
Block	4,592	4,396	3,979	4,264	3,179
Splittings	18,208	18,838	15,595	19,378	20,781
Scrap	35,355	[5] 45,523	[5] 55,547	[5] 42,256	[5] 58,781
Oceania: Australia:					
Scrap	185	---	---	---	e 75
Damourite	1,138	1,087	1,100	r 1,270	e 1,280
World total e	365,000	390,000	400,000	410,000	435,000

e Estimate. p Preliminary. r Revised.
[1] Mica is also produced in China, Rumania, and U.S.S.R., but data on production are not available; estimates are included in the total for China and U.S.S.R.
[2] Compiled mostly from data available July 1966.
[3] Including reclaimed from dumps.
[4] Less than ½ unit.
[5] Includes condenser film as follows: 1962, 412,000 pounds; 1963, 234,000 pounds; 1964, 198,000 pounds; and 1965, 176,000 pounds.

Zambia.—Mica was produced for the first time in several years in 1964. The entire output came from the Lundazi area of the Northern Province where mining operations by native Africans had been organized by the British South Africa Co.[4]

TECHNOLOGY

Laboratory and flotation pilot plant tests of Alabama and North Carolina weathered mica pegmatite ores showed that high-grade mica concentrates could be prepared by flotation methods. These ores were only slightly deslimed. Effective flotation was carried out by combinations of ionic and cationic reagents from alkaline pulps. Concentrates containing 98 and 97 percent mica were obtained from the Alabama and North Carolina ores, respectively.[5]

Similar tests were conducted to recover mica from California mica schist. Laboratory tests successfully used sodium carbonate and sodium silicate to provide pH control and quartz depression. Fatty acid and cationic reagents were used as a collector. Pilot plant operation recovered a 96-percent mica concentrate.[6]

A method was developed to bathe synthetic fluorphlogopite crystals in a fresh liquid melt by slowly rocking the reaction vessel through an angle of 30 degrees while the melt is cooling and crystallizing.[7]

A new mica phase was synthesized by hydrothermal techniques from starting materials of potassium silicate glass and periclase. The phase appears thermodynamically stable under synthesis conditions. The existence of this mica phase represents an intermediate member between the dioctahedral and trioctahedral series which were regarded as independent. The lattice constants are given for this phase.[8]

The piezoelectric effect has been observed in epoxy resin which has been filled with ground mica from a particular deposit. The phenomenon is observed under impact loading conditions. Experiments were carried out to confirm these observations and an explanation was suggested.[9]

To accurately determine the optic axial angle, 2V, for synthetic fluormica, care must be taken to use a single crystal. If interlayerings of twinned crystals are used, the value obtained for 2V can be appreciably low.[10]

Experimental work was done to find the stable mica polymorphs. Only one form was found by hydrothermal methods.[11]

Experimentation was carried out to learn the mechanism of dehydroxylation in hydrated silicates. Very small phlogopite and muscovite mica crystals were used in this work. The mica crystals were heated at different rates to different degrees of dehydroxylation and final temperature. Strain fields were observed nondirectionally in phlogopite and directionally in muscovite. The strain fields could be explained by the variance in the mechanism of dehydroxylation.[12]

The bonding and cutting qualities of reconstituted mica were improved by adding a small quantity of waxy material.[13]

Apparatus was developed to electrophoretically deposit large lamellar sheets of mica from a suspension of fluorphlogopite mica. Provision was made to circulate fresh fluorphlogopite suspension between the anode and cathode for deposition.[14]

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[4] Bureau of Mines. Mineral Trade Notes. V. 61, No. 6, December 1965, p. 35.

[5] Browning, James S., Frank Millsaps, and Paul E. Bennett. Anionic-Cationic Flotation of Mica Ores from Alabama and North Carolina. BuMines Rept. of Inv. 6589, 1965, 9 pp.

[6] Browning, James S., and Paul E. Bennett. Flotation of California Mica Ore. BuMines Rept. of Inv. 6668, 1965, 7 pp.

[7] Shell, H. R., and N. A. Pace (assigned to U.S. Department of the Interior). Synthesis of Large Crystals of Fluorphlogopite Mica. U.S. Pat. 3,222,142, Sept. 10, 1963.

[8] Seifert, F., and W. Schreyer. Synthesis of a New Mica. Am. Mineral., v. 50, Nos. 7–8, July–August 1965, pp. 1114–1118.

[9] Fitzgerald, R. G. Electrical Charge as a Function of Dynamic Stress in a Mica-Filled Epoxy. Mat. Res. and Standards, v. 5, No. 5, May 1965, pp. 240–242.

[10] Bloss, F. Pitfall in Determining 2V in Micas. Am. Mineral., v. 50, Nos. 5–6, May–June 1965, pp. 789–792.

[11] Velde, B. Experimental Determination of Muscovite Polymorph Stabilities. Am. Mineral., v. 50, Nos. 3–4, March–April 1965, pp. 436–449.

[12] Nakahira, M. Surface Structures of Dehydroxylated Micas, Phlogopite and Muscovite, as Observed by a Phase-Microscope. Am. Mineral., v. 50, No. 9, September 1965, pp. 1432–1440.

[13] Howard, C. F. (assigned to General Electric Co., a corporation of New York). Reconstituted Micaceous Products. U.S. Pat. 3,175,927, Mar. 30, 1965.

[14] McNeill, William, and Thomas J. Mackus (assigned to U.S. Department of the Army).

A method of making mica mat from reconstituted mica impregnated with an ammonium silicate water solution was described. After impregnation the material was heated at 75° to 200° while subjected to pressures of 25 to 2,000 pounds per square inch.[15]

Improved wet grinding of mica was obtained by making a water slurry of mica and nylon pellets or other non-abrasive, resilient grinding material. The slurry was subjected to a fine milling action that included a mild viscous shear, percussion, and friction. The final delaminated mica was suitable for use as a pigment and had a bulk density of 15 pounds per cubic foot.[16]

Reinforced mica sheet was prepared by bonding a layer of mica flakes to a synthetic cloth backing.[17]

The use of sheet mica to electrically insulate a fuel elment for a nuclear reactor was described.[18]

Apparatus for Electrophoretic Deposition of Lamellar Fluorphlogopite Mica Sheets. U.S. Pat. 3,211,639, Oct. 12, 1965.

[15] Ketterer, R. J. (assigned to General Electric Co., a corporation of New York). Process for Preparing Bonded Reconstituted Mica. U.S. Pat. 3,183,115, May 11, 1965.

[16] Morris, H. H., and K. L. Turner (assigned to Freeport Sulphur Co., New York). U.S. Pat. 3,206,127, Sept. 14, 1965.

[17] Heyman, Moses D. (assigned to Acim Paper Corp., a corporation of New York). Paper-Backed Mica. U.S. Pat. 3,168,434, Mar. 1, 1962.

[18] Katz, Kurt (assigned to the U.S. Atomic Energy Commission). U.S. Pat. 3,167,482, May 11, 1962.

Molybdenum

By John L. Morning [1]

Expanded molybdenum output by domestic and Canadian producers in 1965 plus a 3-million-pound release early in the year from the strategic stockpile tended to ease the worldwide short supply that has existed for the past few years. Domestic production reached a record high of 77.4 million pounds exceeding by 13 percent the previous annual high produced in 1960. Canada became the free world's second largest molybdenum producer with three new mines initiating production.

Increased domestic and foreign consumption of molybdenum products continued the upward trend that started in 1960.

Total domestic exports of molybdenum were lower than in 1964, but exports of most molybdenum primary products exceeded those for the previous year.

Despite these records the short supply persisted in the domestic and foreign markets. Rumors of premium prices for molybdenum products were reported by both domestic and foreign consumers for spot purchase of molybdenum.

Table 1.—Salient molybdenum statistics

(Thousand pounds of contained molybdenum and thousand dollars)

	1956-60 (average)	1961	1962	1963	1964	1965
United States:						
Concentrate:						
Production	55,695	66,563	51,244	65,011	65,605	77,372
Shipments	55,628	66,753	50,506	65,839	65,097	77,310
Value	$66,788	$87,925	$69,390	$91,096	$97,121	$120,801
Consumption	39,027	42,261	40,990	49,241	56,409	68,112
Imports for consumption	6	--------	--------	--------	--------	295
Stocks, Dec. 31: Mine and plant	4,642	2,815	3,490	2,436	4,303	4,208
Primary products:						
Production	37,908	41,050	40,074	48,756	55,946	66,616
Shipments	39,696	47,106	46,673	49,599	60,403	71,718
Consumption	30,386	32,621	35,674	37,478	43,119	48,621
Stocks, Dec. 31: Producer	6,159	5,074	3,068	4,504	4,398	3,839
Free world: Production	63,300	74,000	59,300	75,000	78,000	98,400

Legislation and Government Programs.—National stockpile objectives and subobjectives established by the Office of Emergency Planning in 1964 remained in effect during 1965. (On March 17, 1966 the Office of Emergency Planning (OEP) reduced the national stockpile objective for molybdenum, in ore equivalent, to 55 million pounds from the previous level of 68 million pounds).

American Metal Climax, Inc., was low bidder for a contract to upgrade stockpile molybdenite concentrate to grade B ferromolybdenum. The contract for 3,475,000 pounds of contained molybdenum in ferromolybdenum will complete all molybdenum subobjectives for the national stockpile. Because of the worldwide short supply of molybdenum, no ferromolybdenum was delivered to the stockpile in 1965.

General Services Administration released to industry 3 million pounds of molybdenum from the national stockpile under authorization of Public Law 88-377 (July 14, 1964).

[1] Commodity specialist, Division of Minerals.

Molybdenum in the national stockpile at yearend is shown in table 2. Molybdenum concentrate in excess of stockpile objective will be used for conversion to ferromolybdenum under an existing contract to fill the deficit in the ferromolybdenum subobjective. Molybdenum excess to stockpile needs was about 1 million pounds in 1965. (Under the revised molybdenum objective established by OEP on March 17, 1966, 14 million pounds of molybdenum were declared excess to stockpile needs).

Table 2.—Molybdenum material in Government inventories on December 31, 1965

(Thousand pounds molybdenum)

Type	Stockpile objective	National (strategic) stockpile
Concentrate	39,500	44,417
Ferromolybdenum	7,500	4,025
Molybdic oxide	19,500	19,554
Total	66,500	67,996

DOMESTIC PRODUCTION

Expanded domestic molybdenum output reached a record high of over 77 million pounds for the year. Climax Molybdenum Co., Lake County, Colo. accounted for 65 percent of the total. Recovery of molybdenum as a byproduct from copper mines in Arizona, Nevada, New Mexico, and Utah, and from a tungsten mine in California accounted for most of the balance.

According to the annual report of American Metal Climax, Inc., the Climax mine operated continuously around the clock

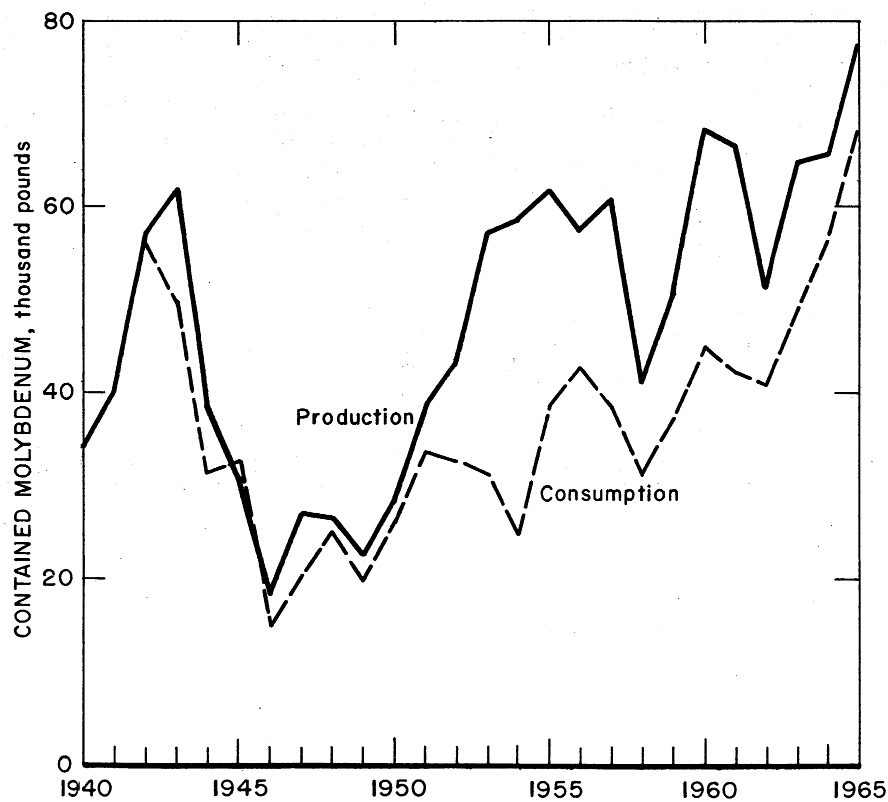

Figure 1.—Domestic molybdenum concentrate production and consumption.

Table 3.—Production, shipments, and stocks of molybdenum products in the United States

(Thousand pounds of contained molybdenum)

	Molybdic oxide [1] 1964	Molybdic oxide [1] 1965	Metal powder 1964	Metal powder 1965	Ammonium molybdate 1964	Ammonium molybdate 1965
Received from other producers	3,472	4,011	368	180	190	221
Gross production during year	52,610	61,153	2,253	3,171	1,373	2,405
Used to make other products listed here	12,355	13,440	761	797	1,170	1,696
Net production	40,255	47,713	1,492	2,374	203	709
Shipments:						
Domestic consumers	35,056	39,894	1,854	2,353	443	902
Exports	8,387	12,727	173	118	43	47
Total	43,443	52,621	2,027	2,471	486	949
Producer stocks, Dec. 31	2,776	1,879	252	335	205	185

	Sodium molybdate 1964	Sodium molybdate 1965	Other [2] 1964	Other [2] 1965	Total 1964	Total 1965
Received from other producers	121	78	200	54	4,351	4,544
Gross production during year	551	705	13,463	15,134	70,250	82,568
Used to make other products listed here	7	12	11	7	14,304	15,952
Net production	544	693	13,452	15,127	55,946	66,616
Shipments:						
Domestic consumers	687	734	12,076	13,151	50,116	57,034
Exports	11	18	1,673	1,774	10,287	14,684
Total	698	752	13,749	14,925	60,403	71,718
Producer stocks, Dec. 31	34	53	1,131	1,387	4,398	3,839

[1] Includes molybdic oxide briquets, molybdic acid, and molybdenum trioxide.
[2] Includes ferromolybdenum, calcium molybdate, phosphomolybdic acid, molybdenum disulfide, pellets, molybdenum pentachloride, and molybdenum hexacarbonyl.

setting record production highs for ore mined and molybdenum produced. A total of 14.35 million tons of ore, an average of about 39,900 tons per day, was mined from which 50.3 million pounds of molybdenum contained in concentrate was recovered. Ore mined from the Ceresco Ridge portion of the ore body reached about 4,000 tons per day, adding flexibility to Climax's operations. Proven ore reserves remained at 430 million tons, a 30-year supply based on current scale of operations.

At year end Duval Corp. increased output 25 percent at its Mineral Park mill near Kingman, Ariz. According to Duval's annual report, Mineral Park accounted for 60 percent of Duval's 3.6 million pounds of molybdenum produced, the balance came from the Esperanza mine. San Manuel Division of Magma Copper Co. mine expansion program was completed in July raising mine production to 40,000 tons of ore per day. Molybdenum recovered increased 13 percent over the 1964 output.

The Questa open pit mine and mill under development for the past several years by Molybdenum Corporation of America was placed on stream late in the fourth quarter. Annual capacity of these facilities was announced at 10 million pounds of molybdenum. With this new development, Molybdenum Corp. became the second integrated company producing concentrate and primary products.

Construction of a new plant for the recovery of molybdenum from oxide ore by Climax Molybdenum Co. was near completion at yearend. The new plant will have a capacity of about 3 million pounds per year. Plant facilities for recovery of molybdenite as byproduct from copper operations were under construction during the year by Kennecott Copper Corp., Ray

Mines Division. Startup of the plant was scheduled for late 1966.

An additional ore zone underlying Climax's Urad Molybdenite mine near Empire, Colo. was discovered 2,000 to 3,000 feet below and to one side of the ore body currently being developed. Reserves of the Urad mine prior to the new discovery were said to be 43.6 million pounds of molybdenum. Plans were announced by American Smelting and Refining Company to expand its Mission mine by 50 percent. Completion of the expansion was scheduled for May 1967.

Throughout the year the Great Lakes Chemical Corp. continued exploration of its molybdenum-uranium deposit in Kern County, Calif. Bear Creek Mining Co. subsidiary of Kennecott Copper Co. was actively engaged in exploration for molybdenum in Washington and Wyoming.

Domestic molybdenite roasting capacity was expanded with the addition of roasting facilities by the Kennecott Copper Corp. Completion of M&R Refractory Metals, Inc. new roaster was delayed until early 1966.

Seventy-four occurrences of molybdenum minerals were described in a report of molybdenum resources of New Mexico.[2]

Climax Molybdenum Co. of Michigan opened a new research laboratory at Ann Arbor, Mich. The laboratory will continue the company's research on iron and steel, molybdenum, and tungsten as well as performing technical services for other Divisions of Amax, the parent company.

CONSUMPTION AND USE

Since 1963 the trend in the domestic molybdenum industry has been toward converting a higher percentage of molybdenum concentrate to molybdic oxides by roasting. This trend is reflected by export shipments, as reported by producers, of molybdic oxide equaling those of molybdenum concentrate for the first time. Domestic consumption of molybdenum concentrate exceeded the previous high established in 1964 by 21 percent. This was made possible by a record domestic molybdenum concentrate production that was augmented by a 3-million-pound release from the stockpile.

Domestic end-use consumption of molybdenum primary products increased substantially for most reported categories with high-speed steels, molybdenum mill products, and catalysts showing the highest percentage increase in consumption.

Decreased usage was reported for gray iron and malleable iron castings, organic pigments, and a miscellaneous classification.

A large share of the molybdenum consumption was for molybdenum-bearing alloy steels. Some of the reported use of these steels was in forged automobile ring and pinion gears, front automobile spindles, machine tools, machine shafting, bolting stock, pressure vessels, and high-strength structural steels. Steelmakers were said to have conserved on their molybdenum supply by manufacturing to the low side of molybdenum specifications.

Molybdenum wire for high-temperature service was the subject of trade releases. General Electric Co. announced the availability of molybdenum wire coated with aluminum for use as grid wire in electronic tubes. When heated to above 900° C, the wire develops an excellent radiation coating of molybdenum aluminide. The same company developed small diameter TZM (molybdenum alloy) wire for use in high-temperature springs, special heater coils, fasteners, and high-temperature electrical contact springs. At temperatures of 2,300° F, the alloy wire is twice as strong as pure molybdenum wire.

Metallwerk Plansee, Austria, manufactured molybdenum wire that retains ductility after exposure to 3,450° F.

Flat molybdenum wire (ribbon) was available from Sylvania Electric Products, Inc., in various sizes ranging from 3 to 50 mils thick and 3 to 120 mils wide.

Ultra-high-purity molybdenum single crystals and mill products were available from Materials Research Corp.

A small but growing use of purified molybdenum disulfide was in various types of lubricants. When added to greases, molybdenum disulfide significantly improves

[2] Schilling, John H. Molybdenum Resources of New Mexico. State Bureau of Mines and Mineral Resources, New Mexico Inst. of Min. and Tech., Socorro, N. Mex. Bull. 76, 1965, 76 pp.

Table 4.—Consumption of molybdenum products by end uses, in 1965
(Thousand pounds of contained molybdenum)

End use	Molybdic oxides [1]	Ferro-molybdenum [2]	Molybdenum metal powder	Ammonium molybdate	Sodium molybdate	Other [3]	Total
Steel:							
High-speed	2,029	754	1	----------	---------	30	2,814
Hot-work tool	315	352	----------	----------	---------	22	689
Other tool	496	128	----------	----------	---------	------	624
Stainless	4,780	2,505	13	----------	---------	34	7,332
Other alloy[4]	19,900	2,201	29	----------	---------	263	22,393
Steel mill rolls	2,093	307	----------	----------	---------	------	2,400
Gray and malleable castings	435	2,891	2	----------	---------	7	3,335
Welding rods	--------	288	4	----------	---------	------	292
High-temperature alloys	774	369	20	----------	---------	683	1,846
Molybdenum powder:							
Wire, rod and sheet	--------	------------	1,713	----------	---------	2	1,715
Other (forging billets, etc.)	--------	8	181	----------	---------	------	189
Chemicals:							
Inorganic pigments	547	------------	----------	8	68	------	623
Organic pigments	147	------------	----------	7	221	3	378
Catalysts	1,480	------------	----------	487	8	------	1,975
Miscellaneous[5]	82	765	47	33	40	1,049	2,016
Total	33,078	10,568	2,010	535	337	2,093	48,621
Stocks at consumer plants, Dec. 31	3,227	1,589	95	284	58	384	5,637

[1] Includes technical and purified oxides.
[2] Includes molybdenum silicide and calcium molybdate.
[3] Includes thermite molybdenum and molybdenum pellets, purified molybdenum disulfide, and molybdenite concentrate added directly to steel.
[4] Includes quantities that were believed used in producing high-speed and stainless steels because some firms failed to specify individual uses.
[5] Includes magnets, other special alloys, friction material, lubricants, pesticides, refractories, packings, etc.

lubricating properties such as load-carrying capacity, friction reduction, and wear prevention.

Molybdenum catalyst usage in the petroleum and chemical industries continued to grow. The Bureau of Mines expanded its statistical coverage of manufactures of catalysts during the year.

STOCKS

Total yearend industry stocks increased slightly as compared with those of 1964. Producers inventories of concentrate and of primary products were reduced to a minimum in an effort to lessen the short supply. Consumer stocks of primary products increased 20 percent during the year, but molybdenum continued in tight supply.

PRICES

Quoted prices of molybdenum products remained unchanged during the year. The published price of products marketed on a per pound basis of molybdenum contained, f.o.b. point of shipment, was molybdenum concentrate, $1.55; bagged molybdic oxide, $1.74; technical molybdic oxide in cans, $1.75; molybdic oxide briquets, $1.77; and ferromolybdenum, $2.04. Price of molybdenum products sold on a per pound basis, f.o.b. point of shipment was as follows: Pure molybdic oxide, $1.35; carbon-reduced molybdenum powder, $3.35; and hydrogen-reduced molybdenum powder, $3.75.

The tight supply situation that existed throughout the year resulted in somewhat higher prices for molybdenum sold on a spot basis. Foreign markets were especially vulnerable to prices higher than published.

Concentrate released from the national stockpile early in the year on competitive bid brought prices ranging from $1.811 to $2.7125 per pound of molybdenum.

FOREIGN TRADE

Exports.—Molybdenum ore and concentrate (including roasted concentrate) exports were 3 percent lower than in 1964. Reduced shipments from the United States were supplemented by increased Canadian exports to the free world, but the supply of molybdenum was insufficient to fill increased foreign demand. Decreased exports of unwrought molybdenum and molybdenum alloys, waste and scrap, and molybdenum alloy were more than offset by increased exports of ferromolybdenum, molybdenum and molybdenum-alloy powder, and wrought molybdenum and molybdenum alloys not elsewhere classified.

Increased foreign demand, particularly from Australia, has increased exports of molybdenum powder 36 fold since 1963.

Table 5.—Molybdenum reported by producers as shipments for export from the United States

(Thousand pounds of contained molybdenum)

Product	1964	1965
Molybdenite concentrate	13,791	12,507
Molybdic oxide	8,387	12,727
All other primary products	1,900	1,957

Imports.—The domestic short supply of molybdenum resulted in a large increase in imports of molybdenum products; molybdenum concentrate was received for the first time since 1957. Imports for consumption of molybdenum concentrate totaled 295,178 pounds containing 141,596 pounds of molybdenum valued at $219,430; molybdenum compounds totaled 457,305 pounds containing 265,009 pounds of molybdenum valued at $553,259; ferromolybdenum totaled 106,953 pounds containing 67,336 pounds of molybdenum valued at $226,761; wrought molybdenum totaled 34-531 pounds valued at $252,290; molybdenum orange totaled 27,019 pounds valued at $9,024. Molybdenum waste and scrap imports were 71,082 pounds valued at $165,609. An additional 84,977 pounds of molybdenum contained in concentrate remained in general imports at yearend.

Canada supplied all imports of molybdenum concentrate. Ferromolybdenum imports were mainly from Sweden and the United Kingdom. Molybdenum compounds were received chiefly from Canada and Chile.

Table 6.—U.S. exports of molybdenum products

(Pounds, gross weight)

Product and country	1964	1965
Ferromolybdenum:[1]		
Australia	87,500	176,235
Belgium—Luxembourg	91,600	146,800
Canada	271,605	398,460
Germany, West	182,869	9,870
India	113,000	195,107
Japan	241,534	108,939
Mexico	15,011	68,013
Netherlands	15,566	67,646
South Africa, Republic of	56,848	204,536
Spain	27,044	143,352
Sweden	49,016	136,202
United Kingdom	458,324	426,052
Other countries	135,694	161,063
Total	1,745,611	2,242,275
Value	$3,328,494	$4,576,800
Metal and alloys in crude form and scrap:		
Austria	69,984	1,551
Canada	63,977	----
France	5,273	14,155
Germany, West	796,163	23,923
Italy	11,997	33,300
Japan	124,090	2,473
United Kingdom	232,066	26,188
Other countries	100,952	9,119
Total	1,404,502	110,709
Value	$3,629,553	$413,875
Wire:		
Brazil	6,292	2,460
Canada	13,096	3,782
France	331	201
Mexico	3,083	1,958
Netherlands	5,466	6,809
United Kingdom	342	1,859
Other countries	2,293	6,345
Total	30,903	23,414
Value	$499,532	$631,276
Powder:		
Australia	----------	226,998
Austria	27,000	44,374
Belgium—Luxembourg	r16,582	1,400
France	22,049	3,155
Germany, West	148,295	78,070
Italy	100	131,863
Japan	330	16,216
Sweden	24,400	28,984
United Kingdom	3,420	33,028
Venezuela	32,741	19,192
Other countries	27,107	19,479
Total	r302,024	602,759
Value	r $1,176,057	$2,095,358
Semifabricated forms, not elsewhere classified:		
Canada	5,519	6,673
France	1,807	1,721
Germany, West	2,376	3,042
Italy	758	13,316
Netherlands	8,045	2,087
United Kingdom	2,061	13,309
Other countries	14,384	26,218
Total	34,950	66,366
Value	$289,873	$516,198

r Revised.

[1] Ferromolybdenum contains about 60 to 65 percent molybdenum.

Table 7.—U.S. exports of molybdenum ore and concentrates (including roasted concentrates), by countries

Destination	1964 Molybdenum content (pounds)	1964 Value	1965 Molybdenum content (pounds)	1965 Value
North America:				
Canada	563,697	$871,265	541,287	$1,111,682
Mexico	8,864	13,746	44,301	120,404
Total	572,561	885,011	585,588	1,232,086
South America:				
Argentina	2,473	3,358	333	715
Brazil	1,353	1,575	21,575	55,411
Chile	10,315	16,536	24,836	43,836
Colombia	516	860	----------	----------
Peru	500	800	----------	----------
Venezuela	9,831	15,456	90,200	180,087
Total	24,988	38,585	136,944	280,049
Europe:				
Austria	1,899,531	3,209,906	1,874,406	3,239,992
Belgium-Luxembourg	255,731	584,462	2,074,468	3,637,616
Denmark	44,500	47,558	----------	----------
France	4,068,259	6,118,975	2,736,249	4,401,861
Germany, West	4,701,301	8,130,082	5,315,369	10,832,472
Greece	144	206	----------	----------
Iceland	----------	----------	210	300
Italy	1,365,701	2,093,923	1,185,085	1,902,548
Netherlands	347,591	677,746	1,485,918	2,665,423
Norway	----------	----------	354	870
Spain	4,316	6,025	13,044	25,338
Sweden	2,002,671	3,076,515	2,080,571	3,551,970
Switzerland	----------	----------	28,818	56,691
United Kingdom	4,400,901	6,920,870	2,890,876	5,097,112
Total	19,090,646	30,866,268	19,685,368	35,412,193
Africa:				
South Africa, Republic of	4,027	6,130	6,308	13,793
Zambia, Southern Rhodesia and Malawi	----------	----------	1,500	2,700
Total	4,027	6,130	7,808	16,493
Asia:				
Hong Kong	2,103	3,192	1,177	2,110
India	----------	----------	1,606	2,655
Japan	5,188,252	9,059,760	3,598,822	7,183,979
Philippines	4,500	7,290	6,010	10,290
Total	5,194,855	9,070,242	3,607,615	7,199,034
Oceania:				
Australia	52,703	120,613	72,299	141,524
New Zealand	----------	----------	236	612
Total	52,703	120,613	72,535	142,136
Grand total	24,939,780	40,986,849	24,095,858	44,281,991

Table 8.—U.S. import duties

(Per pound)

Item	Articles	Rate of duty [1]
601.33	Molybdenum ore (molybdenum content)	24 cents on molybdenum content.
607.40	Ferromolybdenum (molybdenum content)	20 cents on molybdenum content plus 6 percent ad valorem.
	Molybdenum:	
628.72	Unwrought (molybdenum content)	Do.
628.74	Wrought	25.5 percent ad valorem.
	Chemical elements:	
419.60	Molybdenum compounds (molybdenum content)	20 cents on molybdenum content plus 6 percent ad valorem.
420.22	Potassium molybdate (molybdenum content)	Do.
421.10	Sodium molybdate (molybdenum content)	Do.
473.18	Molybdenum orange	10 percent ad valorem.
417.28	Ammonium molybdate	20 cents on molybdenum content plus 6 percent ad valorem.

[1] Not applicable to Communist countries.

WORLD REVIEW

An upsurge in molybdenum production was made by Canada with three new mines initiating production. Reported output of 9.4 million pounds of molybdenum compared with 1.2 million pounds in 1964 made Canada the free world's second largest producer.

British Guiana.—The joint mineral exploration program of the Geological Survey of British Guiana and the United Nations resulted in the discovery of possible important molybdenum deposits. Geochemical prospecting has shown substantial molybdenum soil anomalies at Eagle Mountain on the Potaro River. One exploration hole averaged 0.14 percent molybdenite over a drilled intersection of 93.5 feet. Molybdenite also has been discovered at Yakashuri in the northwest district on the Barama River.

Canada.—Molybdenite Corporation of Canada Ltd. reported production of 683,202 pounds of molybdenum recovered from ore grading 0.243 percent molybdenite. Recovery of molybdenum in concentrate was about 94 percent and most of the concentrate was coverted to oxides. The ore reserve was maintained at about 1 year's operating rate.

Anglo American Molybdenite Mining Corp., after 6 years of preparations, officially placed on stream in August its new mine and mill. Operational troubles were slowly being solved as December output reached 142,787 pounds of molybdenite. Indicated ore reserves, to the 400-foot level, were reported to be 3,070,000 tons averaging 0.36 percent molybdenite. All molybdenum output was under contract to Continental Ore Corp. for a period of 8 years.

Table 9.—Free world production of molybdenum in ore and concentrate by countries [1]

(Thousand pounds)

Country [1]	1961	1962	1963	1964	1965 p [2]
Australia	2	2	13		
Canada	771	818	834	r 1,225	9,400
Chile	4,037	5,256	6,400	8,594	e 8,400
Japan	807	825	732	r 619	e 630
Korea, South	71	163	154	r 265	e 260
Mexico	7	128	90	r 117	179
Norway	531	575	443	r 509	498
Peru	[3] 937	11	1,175	862	1,484
Philippines	249	249	236	231	170
United States	66,563	51,244	65,011	65,605	77,372
Free world total e [1]	74,000	59,300	75,000	78,000	98,400

e Estimate. p Preliminary. r Revised.
[1] Molybdenum is also produced in Argentina, Nigeria, North Korea, Rumania, South-West Africa, and Spain, but production is negligible.
[2] Compiled from data available May 1966.
[3] Exports.

Preissac Molybdenite Mines Ltd., after doubling the size of its mill to 1,200 tons per day, started production from its new facilities in April. The milling rate was said to have reached design capacity by September. Ore reserves were reported at 1.25 million tons averaging 0.53 percent molybdenite.

Gaspé Copper Mines Ltd., reported production of 454 tons of molybdenum concentrate containing 493,492 pounds of molybdenum as a byproduct from its copper operations.

Endako Mines Ltd. designed, constructed, and brought into production in May its new open pit mine and 10,000 ton-per-day mill in just over 3 years after the first exploratory drillhole. Mill design capacity was exceeded in August and at yearend over 12,000 tons per day was being treated. During the early break-in period, molybdenum recovery was sacrificed in order to meet specifications. Total production for the year was estimated at 6.3 million pounds of molybdenum. The measured ore reserve was reported at 71 million tons grading 0.204 percent molybdenite, with an additional 20 million tons of ore indicated or inferred, but at somewhat lower grade.

Boss Mountain Division of Brynnor Mines, Ltd., began operations in February, but production was halted for 2 months because of a labor strike. During the year the mill treated 259,000 tons of ore from which 1,585,000 pounds of molybdenum were recovered. The milling rate for the last 4 months of the year was 1,150 tons per day exceeding the 1,000-ton-per-day design capacity. Recoveries of 96 percent were reported. Brynnor Mines Ltd. is the British Columbia subsidiary of Noranda Mines Ltd.

British Columbia Molybdenum Ltd., a wholly owned subsidiary of Kennecott Copper Corp., was developing an open pit mine to be brought into production by mid 1967. A 6,000-ton-per-day mill to produce 4 to 5 million pounds of molybdenum was scheduled for construction in 1966.

Chile.—Production of molybdenite totaled 7,670 tons despite a labor strike in the fourth quarter. Chile Exploration Co. accounted for 3,190 tons. Andes Copper Mining Co. for 1,755 tons, and Braden Copper Co. for 2,725 tons.

The long standing agreement between President Frei and the large copper companies awaited throughout the year for approval by the Chilean Congress. The agreement calls for doubling copper production over a 5-year period. The mine and plant expansions will increase Chilean molybdenum production to approximately 18 to 20 million pounds per year.

Carbuo y Metalurgia S.A. (Carbomet) technical molybdic oxide producer planned to start producing ferromolybdenum for domestic and export markets at its plant near Huachipato.

Denmark.—The Arctic Mining Co., Inc., established by Nortic Mining Co. and American Metal Climax, Inc., to exploit molybdenum deposits at Mestervig, East Greenland, will hold in abeyance development of the deposit pending a more favorable market. The deposits are estimated to contain 50 million tons of potential ore. Arctic Mining Co. also holds exploration rights to the molybdenum ore deposits at Malmbjerg, East Greenland. These deposits are estimated to contain 124 million tons of potential ore.

Japan.—Demand for molybdenum as in other free world countries was strong. Reduced shipments from the United States were offset by imports from Canada's new mining venture, Endako Mining Ltd. A 5-year contract to supply 1.8 million pounds per year of molybdenum contained in concentrate was signed by leading Japanese trade firms and Endako. Japanese molybdenum requirement for the year starting April 1 was estimated to be about 8 million pounds.

Niger.—A prospecting permit for molybdenite and related minerals was granted to the Bureau de Recherches Geologique et Minieres (BRGM) of Paris, France. The permit, good for 3 years, allows prospecting on an area of 9,500 square kilometers for which (BRGM) must spend a minimum of $48,000 per year.

Norway.—Recovery of molybdenum from Europe's largest molybdenite mine, Knaben Molybdengruber, was about the same as that of 1964. Plans were announced by the company for doubling the capacity of its milling facilities.

United Kingdom.—American Metal Climax, Inc., secured permission to list common and preferred shares of its stock on the London Stock Exchange.

U.S.S.R.—Mainland China and U.S.S.R. supplied European users with molybdenum at prices greatly above those quoted by Climax.

TECHNOLOGY

Additional information was published by the Bureau of Mines on the process of producing molybdenum metal by electrolytic reduction of molybdenite concentrate to dimolybdenum carbide.[3] A second-stage processing of the carbide by sintering with molybdic oxide yields pure molybdenum metal.

A Bureau of Mines study of chlorination kinetics of various elements including molybdenum was described.[4] The Arrhenius activation energy for molybdenum, over the temperature range of 445° to 491° C, was 37 kilocalories per mole.

Stress corrosion tests by researchers of the Bureau of Mines showed that molybdenum was not susceptible to stress corrosion cracking in mineral acids and inorganic salt solutions.[5] Of five organic acid environments tested, stress corrosion cracking was evident only in 10-percent formic acid solution. Corrosion rates of molybdenum in nitric acid were 2 to 40 times higher when the metal was subjected to stress.

Bureau researchers demonstrated[6] that uniform coatings of molybdenum can be applied to ceramic powders having irregular shapes. Powdered magnesia, alumina, zirconia, zirconium carbide, or zirconium boride was coated with 15 to 38 volume-percent molybdenum. The coated ceramics were pressed into compacts, sintered at 900° C in hydrogen, and sintered in vacuum at 2,100° C prior to physical testing.

Current and future molybdenum metal applications were described.[7] These special applications take advantage of the unusual properties of molybdenum, such as higher melting point, chemical corrosion resistance, good heat conductivity, high moduli of elasticity, inertness to glass, low coefficient of thermal expansion and high-temperature strength.

A research study investigating the extraction of molybdenum from oxide and sulfide ore indicated that oxidizing agents such as hypochlorite, acid chlorate, and manganese dioxide-sulfuric acid will leach molybdenite (MoS_2), although the tests were not optimized.[8] Bacterial leaching was also investigated. Molybdenum recovered from leached solutions of oxidized ores produced a molybdenum oxide-iron compound which the authors believe to be marketable.

A change in process for recovery of molybdenite by the San Manuel Division of the Magma Copper Co. was said to increase the effective flotation capacity of the plant by at least 25 percent.[9] Increased recovery of molybdenite and potential lower maintenance costs are features of the process.

Results of flame spraying of molybdenum by oxy-acetylene and arc plasma processes have been described.[10] Postsintering treatment in hydrogen significantly improved properties such as density, purity, tensile strength, and modulus of elasticity. Lower ductility of the hydrogen-sintered sprayed material was related to oxygen. The structure of the material was similar to recrystallized molybdenum prepared by arc-cast or powdered metallurgy processes. Laminar structure of the sprayed metal was eliminated by sintering.

A phase diagram for the molybdenum-oxygen system based on equilibrium studies over the temperature range of 600° to 1,700° C has been published.[11] Four stable oxides most closely related to MoO_2, Mo_4O_{11}, Mo_9O_{26}, and MoO_3 were encountered during the investigation.

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[3] Heinen, H. J., C. L. Barber, and Don H. Baker, Jr. Conversion to Metal of Dimolybdenum Carbide Electrosynthesized From Molybdenite. BuMines Rept. of Inv. 6590, 1965, 14 pp.

[4] Landsberg, Arne, and Frank E. Block. A Study of the Chlorination Kinetics of Germanium, Silicon, Iron, Tungsten, Molybdenum, Columbium, and Tantalum. BuMines Rept. of Inv. 6649, 1965, 26 pp.

[5] Carter, J. P., C. B. Kenahan, and David Schlain. Stress Corrosion Cracking of Vanadium, Molybdenum, and a Titanium-Vanadium Alloy. BuMines Rept. of Inv. 6680, 1965, 18 pp.

[6] Lansberg, A., T. T. Campbell, and F. E. Block. Tungsten and Molybdenum Coated Nonmetallic Powders. J. Metals, v. 17, No. 8, August 1965, pp. 850–855.

[7] Schwalm, M. A. Molybdenum Technology—What's Ahead. E&MJ Metal and Mineral Markets, v. 36, No. 16, April 1965, p. 4.

[8] Bhappu, Roshan B., Dexter H. Reynolds, and Ronald J. Roman. Molybdenum Recovery From Sulfide and Oxide Ores. J. Metals, v. 17, No. 11, November 1965, pp. 1199–1205.

[9] Burke, Harry K., and Joseph F. Shirley. San Manuel's New Process for the Recovery of Molybdenite. Trans. AIME, v. 232, 1965, pp. 212–217.

[10] Sellers, David J., and Milton Levy. The Effects of Sintering on the Microstructure and Properties of Sprayed Molybdenum. J. Less-Common Metals (Amsterdam, Netherlands), v. 9, No. 4, October 1965, pp. 289–298.

[11] Phillips, Bert, and L. Y. Chang. Condensed-Phase Relations in the System Mo-O. Trans. AIME, v. 233, 1965, pp. 1433–1436.

Additional research was reported [12] on oxidation studies of molybdenum silicides at elevated temperatures under reduced oxygen pressures to delineate mechanisms and conditions of failure.

Coating studies [13] of pure molybdenum and a molybdenum alloy indicated that molybdenum disilicide was superior to a chromium-silicon-aluminum coating in oxidation and vibration-fatigue tests. Both coatings lacked resistance to mechanical shock in room-temperature impact tests.

Patents were granted for recovery of molybdenum values from acidic solutions [14] and for a process for producing high-purity molybdenum metal.[15]

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[12] Bartlett, R. W., and P. R. Gage. Oxidation of Molybdenum Silicides at High Temperatures and Low Pressures. Trans. AIME., v. 233, 1965, pp. 968–974.

Berkowitz-Mattuck, Joan B., and R. R. Dils. High-Temperature Oxidation. Part 2. Molybdenum Silicides. J. Electroehem. Soc., v. 112, No. 6, June 1965, pp. 583–589.

[13] Glenny, E., and J. E. Restall. Evaluation of the Properties of Protected Molybdenum and 0.45-Percent Titanium-Molybdenum Alloy. J. Less-Common Metals, (Amsterdam, Netherlands) v. 9, No. 5, November 1965, pp. 367–387.

[14] Ableson, Arthur E., Robert J. Woody (assigned to Kerr-McGee Oil Industries, Inc.). Recovery Process. U. S. Pat. 3,180,703, Apr. 27, 1965.

Hart, James L. (assigned to Phillips Petroleum Company). Extraction of Metal Values From Acid Solutions. U.S. Pat. 3,223,476, Dec. 14, 1965.

[15] Kunda, Vasyl (assigned to Sherritt Gordon Mines Ltd., Toronto, Ontario, Canada). Molybdenum Recovery Process. U.S. Pat. 3,196,004, July 20, 1965.

Nickel

By Harold W. Lynde, Jr. [1]

For the second successive year world nickel production reached a record high, 472,000 tons, 12 percent above that of 1964, but consumers' needs for nickel also were at record levels. Domestic consumption showed the sharpest rise, up 17 percent to 172,084 tons, because of the demands of a prosperous economy combined with military requirements of the Viet-Nam conflict. Large quantities of Government stockpile surplus nickel authorized for disposal by Congress, were sold by negotiated contracts and competitive bid, and eased the supply situation.

Major world producers, particularly The International Nickel Co. of Canada Ltd. (Inco), Société Le Nickel, and Falconbridge Nickel Mines Ltd., were engaged in aggressive exploration and development programs in Canada, New Caledonia, Guatemala, Greece, and elsewhere. Kaiser Aluminum and Chemical Corp. and Société Le Nickel announced agreement jointly to produce nickel products and to market them in the United States, whose imports currently originate almost entirely in Canada. Remaining U.S. import duties on primary nickel products were suspended. A nickel alloy was used for the first time in our dimes and quarters.

Table 1.—Salient nickel statistics

(Short tons)

	1956-60 (average)	1961	1962	1963	1964	1965
United States:						
Mine production	12,247	13,133	13,110	13,394	15,420	16,188
Plant production:						
Primary	10,888	11,176	11,217	11,432	12,185	13,510
Secondary	10,635	10,688	11,108	18,996	23,114	19,407
Exports	27,831	55,493	27,641	60,927	68,502	20,934
Imports for consumption	117,600	127,000	123,000	119,000	129,000	163,000
Consumption	109,976	118,515	118,677	124,478	146,920	172,084
Stocks Dec. 31: Consumer	15,357	18,298	13,450	17,191	17,076	13,749
Price ... cents per pound	74	74–81¼	81¼–79	79	79	79–77¾
World: Production	302,800	398,000	394,000	389,000	423,000	472,000

Legislation and Government Programs.—Important legislation during the year authorized disposal of surplus nickel from Government stockpiles, suspended import duties on certain forms of primary nickel, and authorized minting of new cupronickel-bearing composite dimes and quarters.

Late in 1964 the General Services Administration (GSA) had undertaken a long range program to dispose of excess nickel from the national stockpile and Defense Production Act (DPA) inventory. Annual sales from the 105-million-pound DPA inventory were to be 15 million pounds per year; July 1, 1965 the goal was raised to 25 million pounds per year, exclusive of commitments to Government agencies.

In addition, approval was sought from Congress for disposal of 224 million pounds of nickel in the national stockpile which was in excess of the quota of 100 million pounds. Public Law 89-323, enacted November 5, 1965 authorized disposal of 200 million pounds of the excess. Subsequently, agreement was reached November 8 to

[1] Commodity specialist, Division of Minerals.

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sell 70 million pounds of full electrolytic cathodes to The International Nickel Co., Inc. over a 4-year period; by yearend 28 million pounds had been committed.

On December 7, agreement was reached to sell 13 million pounds of briquets to Sherritt Gordon Mines Ltd. over 4 years; by yearend 3 million pounds had been committed. Negotiations were continuing with other major producers. This method of disposal was used to bring large amounts of the surplus to market in an orderly way. In addition, 50 million pounds of nickel was committed to the Bureau of the Mint in November for coinage.

GSA stockpile upgrading contracts for production of ferromolybdenum and OFHC copper provided for fees to be paid with 1,550,428 pounds of ferronickel and 1,644,269 pounds of electrolytic nickel from the stockpile surplus.

Sales of nickel by competitive bid, with some offerings restricted to small businesses, were held throughout the year. Nickel disposals for the year included the following: Electrolytic nickel, 89,994,269 pounds; ferronickel (nickel content), 4,800,428 pounds; and nickel oxide (nickel-cobalt content), 1,014,091 pounds. In addition, 732,000 pounds of cupronickel were sold, as were 67,408 pounds of nickel in various fabricated forms.

The import duty on unwrought nickel, ferronickel, and nickel powder was suspended on September 27 by Public Law 89-204; the import duty on nickel waste and scrap was continued suspended on June 30 by Public Law 89-61. Both suspensions continue through June 30, 1967. The former duty on ferronickel, levied on gross weight, was a particular barrier to its importation.

After considerable study of substitute coinage materials, it was proposed to Congress that the composition of dimes, quarters, and half dollars be altered to conserve rapidly diminishing Government silver stocks. The quarters and dimes were to be composed of a sandwich. The two outer layers are composed of 75–25 cupronickel alloy and the interior of pure copper. This legislation was enacted July 23 as Public Law 89-81.

A comprehensive study of possible coinage materials by Battelle Memorial Institute for the Bureau of the Mint provided the basis for choosing the new composition.[2] The judging criteria used were as follows: Availability and price; public acceptability; physical, chemical, and mechanical properties; effect on coin-operated devices; effects on mint operations; and counterfeiting, illegal duplication, and slugging potential. The composite coin scored highest and subsequently was adopted. Pure nickel and 95 nickel-5 silicon alloy did not meet all test standards.

The Office of Minerals Exploration of the Geological Survey, executed a contract with Roland F. Beers, Inc., for a total value of $34,260, to explore the Harriman-Crawford Pond nickel prospect, Knox County, Maine.

DOMESTIC PRODUCTION

The Hanna Mining Co., Riddle, Oreg., mined 1,140,000 dry tons of ore containing 16,188 tons of nickel. The Hanna Nickel Smelting Co. processed the ore into 26,246 tons of ferronickel containing 12,666 tons of nickel, an increase of 13 percent over that of the previous year. This increase was permitted by installation of a rotary dryer, air classifier, two multiple hearth roasters (natural-gas fired), and two transformers.

Nickel salts, mostly nickel sulfate, were produced as a byproduct of copper refining at Carteret and Barber, N.J., Laurel Hill, N.Y., Baltimore, Md., Tacoma, Wash., and El Paso, Tex.; nickel content of salt production was 844 tons and of shipments, 739 tons.

In addition, chemical companies produced salts containing 3,442 tons of nickel and shipped 2,815 tons; raw materials comprised both new and scrap nickel.

Among companies reported conducting exploration for nickel in the United States during the year were Hanna Mining Co. and Inco.

Kaiser Aluminum and Chemical Corp. announced on September 9 a joint venture with Société Le Nickel to produce nickel and to market in the United States. Two new jointly owned companies were to be

[2] Rice, L. P., M. E. Emerson, H. J. Wagner, R. W. Hale, and A. M. Hall. Final Report on Study of Alloys Suitable for Use as United States Coinage to Department of Treasury, Bureau of the Mint. Battelle Memorial Institute, Columbus, Ohio, 1965, 126 pp.

formed. One would own production facilities in New Caledonia to be operated by Le Nickel, and the other would be a U.S. company, Kaiser Nickel Co., which would market ferronickel here and also refine nickel products. The first step in the program on New Caledonia would be installation of facilities to produce 35 million pounds per year of nickel in ferronickel.

Table 2.—Primary nickel produced in the United States

(Short tons, nickel content)

	1956–60 (average)	1961	1962	1963	1964	1965
Byproduct of copper refining	548	625	648	707	949	844
Domestic ore	10,340	10,551	10,569	10,725	11,236	12,666

Table 3.—Nickel recovered from nonferrous scrap processed in the United States, by kind of scrap and form of recovery

(Short tons)

	1964	1965
Kind of scrap:		
New scrap:		
Nickel-base	2,775	3,182
Copper-base	2,448	3,290
Aluminum-base	476	520
Total	5,699	6,992
Old scrap:		
Nickel-base	16,559	11,328
Copper-base	586	687
Aluminum-base	270	400
Total	17,415	12,415
Grand total	23,114	19,407

	1964	1965
Form of recovery:		
As metal	1,567	1,487
In nickel-base alloys	1,996	3,031
In copper-base alloys	3,534	3,855
In aluminum-base alloys	782	984
In ferrous and high-temperature alloys [1]	13,382	8,124
In chemical compounds	1,853	1,926
Total	23,114	19,407

[1] Includes only nonferrous nickel scrap added to ferrous and high-temperature alloys.

1174

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Table 4.—Stocks and consumption of new and old nickel scrap in the United States in 1965

(Gross weight, short tons)

Class of consumer and type of scrap	Stocks, beginning of year	Receipts	Consumption			Stocks, end of year
			New	Old	Total	
Smelters and refiners:						
Unalloyed nickel	184	1,079	696	388	1,084	179
Monel metal	404	2,177	507	1,482	1,989	592
Nickel silver [1]	838	4,758	500	4,342	4,842	754
Miscellaneous nickel alloys	7	5,437	1	5,436	5,437	7
Nickel residues	80	233	---	245	245	68
Total	675	8,926	1,204	7,551	8,755	846
Foundries and plants of other manufacturers:						
Unalloyed nickel	8,114	6,772	1,669	7,985	9,654	5,232
Monel metal	111	534	77	496	573	72
Nickel silver [1]	4,179	13,359	13,391	117	13,508	4,030
Miscellaneous nickel alloys	81	99	24	150	174	6
Nickel residues	513	1,959	1,897	80	1,977	495
Total	8,819	9,364	3,667	8,711	12,378	5,805
Grand total:						
Unalloyed nickel	8,298	7,851	2,365	8,373	10,738	5,411
Monel metal	515	2,711	584	1,978	2,562	664
Nickel silver [1]	5,017	18,117	13,891	4,459	18,350	4,784
Miscellaneous nickel alloys	88	5,536	25	5,586	5,611	13
Nickel residues	593	2,192	1,897	325	2,222	563
Total	9,494	18,290	4,871	16,262	21,133	6,651

[1] Excluded from totals because it is copper-base scrap, although containing substantial nickel.

CONSUMPTION AND USES

Consumption of new nickel again set a record high, increasing 17 percent in 1965 after an 18-percent increase the previous year. The major growth was in nonferrous alloys and to a lesser extent in high-temperature and electrical resistance alloys, which were up 57 and 21 percent, respectively. The latter alloys have shown steady growth in usage since 1960.

Nonferrous alloys have not shown such consistency. The increase can be variously ascribed to greatly increased use of nickel in coinage, military needs, continuing rapid growth of the economy, and change in technology.

Table 5.—Nickel (exclusive of scrap) consumed in the United States, by forms

(Short tons)

Form	1956–60 (average)	1961	1962	1963	1964	1965
Metal	85,617	101,394	103,485	110,365	123,443	146,357
Oxide powder and oxide sinter	18,180	15,883	13,760	12,461	21,090	23,047
Matte	4,829	16	3	2	2	3
Salts [1]	1,350	1,222	1,429	1,650	2,385	2,677
Total	109,976	118,515	118,677	124,478	146,920	172,084

[1] Figures do not cover all consumers.

Table 6.—Nickel (exclusive of scrap) consumed in the United States, by uses
(Short tons)

Use	1956-60 (average)	1961	1962	1963	1964	1965
Ferrous:						
Stainless steels	29,049	34,213	29,711	34,140	48,301	51,700
Other steels	16,296	18,238	18,608	19,727	24,679	27,009
Cast irons	4,933	4,649	5,503	5,901	6,605	6,937
Nonferrous [1]	27,902	28,789	28,215	24,794	23,639	37,082
High-temperature and electrical resistance alloys	9,852	11,294	12,862	13,505	15,291	18,464
Electroplating:						
Anodes [2]	15,498	15,737	16,953	18,621	19,446	19,450
Solutions [3]	958	770	904	1,050	1,645	2,037
Catalysts	1,707	1,519	1,566	1,613	2,167	2,241
Ceramics	375	366	439	554	529	501
Magnets	855	773	910	777	664	828
Other	2,551	2,167	3,006	3,796	3,954	5,835
Total	109,976	118,515	118,677	124,478	146,920	172,084

[1] Comprises copper-nickel alloys, nickel silver, brass, bronze, beryllium alloys, magnesium and aluminum alloys, Monel, Inconel, and malleable nickel.
[2] Figures represent quantity of nickel used for production of anodes, plus cathodes used as anodes in plating operations.
[3] Figures do not cover all consumers.

STOCKS

Indicative of the relatively tight supply situation at yearend was the 19-percent decline in consumers' stocks of new nickel from the year earlier total of less than 1-month average consumption.

Table 7.—Nickel (exclusive of scrap) in consumer stocks in the United States, by forms
(Short tons)

Form	1963	1964	1965
Metal	15,575	14,780	11,868
Oxide powder and oxide sinter	1,395	2,049	1,616
Matte	6	4	1
Salts	215	243	264
Total	17,191	17,076	13,749

PRICES

The price of unwrought nickel metal, metal powder, and ferronickel to consumers declined 1¼ cents per pound on September 27, when the U.S. import duty was suspended. The prices in effect after that date for large lots, all duty-free, were as follows:

	Cents
Inco, electrolytic, f.o.b. Port Colborne, Ontario	77.75
Nickel oxide sinter (75 percent Ni + Co) at Buffalo, N.Y. or other established U.S. points of entry	75.25
Falconbridge, electrolytic, f.o.b. Thorold, Ontario	77.75
Sherritt Gordon, f.o.b. Niagara Falls, Ontario, or Fort Saskatchewan, Alberta, or freight equal Port Colborne, Ontario:	
Briquets and S grade powder	77.75
Powder, grades C and F	82.75
Le Nickel, f.o.b. New York, with freight equal Port Colborne, Ontario:	
Rondelles	77.75
Oxide powder (78 percent Ni + Co)	80.75
Hanna, nickel in ferronickel, Riddle, Oreg., with freight equalled oxide sinter	75.25

Inco's new product, nickel oxide sinter 90, manufactured at Copper Cliff, Ontario, was announced to be priced at 75.50 cents per pound of contained nickel.

Marketing data on primary products (electrolytic cathodes, ferronickel, metal powder, oxide, oxide sinter, briquets, shot, and scrap) and a list of vendors were published.[3]

FOREIGN TRADE

Export classifications were modified January 1, and figures are not strictly comparable with those of previous years. Particularly, "nickel waste and scrap" formerly "nickel and nickel alloy metal scrap") no longer includes nickel stainless steel and other alloy scrap.

In value, 27 percent of our exports of nickel products went to Canada, 19 percent to the United Kingdom, 8 percent each to West Germany and France, 5 percent each to Sweden, Norway, and Mexico, and 3 percent each to Italy and Japan.

Over 99 percent of U.S. nickel imports originated in Canada, 86 percent imported directly and the rest by way of Norway and United Kingdom. Because Société Le Nickel was purchasing Cuban nickel oxide sinter, some imports of nickel-bearing prod-

[3] Lesemann, Robert H. Nickel. E&MJ Met. and Min. Markets, v. 36, No. 26, June 28, 1965, pp. 5–18.

Table 8.—U.S. exports of nickel products, by classes

Class	1963		1964		1965	
	Short tons	Value	Short tons	Value	Short tons	Value
Ore, concentrate, and matte	12	$4,976	8	$2,660	(1)	(1)
Nickel and nickel-alloy metals in ingots, bars, rods, sheets, plates, strips, and other crude forms	9,991	17,158,703	11,940	21,641,981	9,829	$22,268,756
Nickel and nickel-alloy metal scrap	49,116	10,120,194	54,168	13,769,561	6,723	4,168,247
Nickel and nickel-alloy semifabricated forms, not elsewhere classified	714	3,198,688	939	4,754,391	1,198	4,747,767
Nickel-chrome electric-resistance wire except insulated	189	953,154	445	1,928,864	380	1,914,193
Nickel catalysts	905	1,748,599	1,002	2,013,287	2,547	6,063,480
Nickel and nickel alloy foil	(2)	(2)	(2)	(2)	4	15,262
Nickel and nickel powders and flakes	(2)	(2)	(2)	(2)	253	1,355,934
Total	60,927	33,184,314	68,502	44,110,744	20,934	40,533,639

[1] No longer separately classified.
[2] Class established Jan. 1, 1965.

Table 9.—U.S. imports for consumption of nickel products, by classes
(Short tons)

Class	1956–60 (average)	1961	1962	1963	1964	1965
Ore and matte	6,965	(1)	14	34	-----	81
Metal (pigs, ingots, shot, cathodes, etc.)	[2] 86,333	[2] 115,985	[2] 115,972	[2] 108,127	[r2] 105,327	134,406
Oxide powder and oxide sinter	30,861	14,613	8,661	12,887	16,862	13,592
Slurry [3]	1,165	258	406	1,716	15,483	24,057
Refinery residues	431	-----	-----	-----	-----	-----
Scrap	[2] 502	[2] 278	[2] 601	[2] 703	[2] 1,343	1,188
Total: Gross weight	126,257	131,134	125,654	123,467	[r] 139,015	173,324
Nickel content (estimated)	117,600	127,000	123,000	119,000	129,000	163,000

[r] Revised.
[1] Less than ½ unit.
[2] Separation of metal from scrap on basis of unpublished tabulations.
[3] Nickel-containing material in powders, slurry, or any form, derived from ore by chemical, physical, or any other means, and requiring further processing to recover nickel or other metals.

Table 10.—U.S. imports for consumption of new nickel products, by countries
(Short tons)

Country	Metal		Oxide powder and oxide sinter		Slurry and other [1]				Ore and matte [2]	
	1964	1965	1964	1965	1964		1965		1965	
	Gross weight	Gross weight	Gross weight	Gross weight	Gross weight	Nickel content	Gross weight	Nickel content	Gross weight	Nickel content
North America:										
Canada	91,813	112,720	16,153	13,445	15,433	11,135	23,747	17,606	-----	-----
Dominican Republic	-----	32	-----	-----	25	15	-----	-----	-----	-----
South America: Colombia	-----	-----	-----	-----	-----	-----	-----	-----	81	1
Europe:										
France	279	55	709	125	-----	-----	-----	-----	-----	-----
Germany, West	4	61	-----	22	25	5	-----	-----	-----	-----
Norway	r 12,052	20,617	-----	-----	-----	-----	-----	-----	-----	-----
United Kingdom	1,179	920	(3)	-----	-----	-----	-----	-----	-----	-----
Other	(3)	(3)	-----	-----	-----	-----	-----	-----	-----	-----
Africa: South Africa, Republic of	-----	-----	-----	-----	-----	-----	310	225	-----	-----
Asia	-----	1	-----	(3)	-----	-----	-----	-----	-----	-----
Grand total	r 105,327	134,406	16,862	13,592	15,483	11,155	24,057	17,831	81	1

r Revised.
1 Nickel-containing material in powder, slurry, or any form, derived from ore by chemical, physical, or any other means, and requiring further processing to recover nickel or other metals.
2 No transactions in 1964.
3 Less than ½ unit.

ucts from France presumed to contain Cuban nickel were prohibited entry into the United States. This is required by the Cuban Assets Control Regulations administered by the Office of Foreign Assets Control, Department of the Treasury. Following negotiations, a system assuring that no Cuban nickel would be imported was adopted; the Government of France will issue certificates of origin guaranteeing the source of nickel.

The tariff on imports of unwrought nickel, ferronickel, and metal powder, was suspended September 27. After that date all primary nickel products were imported duty free.

WORLD REVIEW

World demand increased during the year to the point where no excess nickel productive capacity remained. World production was estimated at 472,000 tons, 12 percent above that of 1964. The industry was engaged in expensive expansion programs to increase productive capacity in Canada, New Caledonia, and several other countries. Exploration programs were pushed worldwide, with particular activity in Canada, the South Pacific and Australia, parts of South America and Central America, and the United States.

NORTH AMERICA

Canada.—Nickel production reached a record 269,000 tons, 18 percent higher than in 1964. Inco made record deliveries of nickel, 246,480 tons, an increase of 24,385 from those of 1964. This total included 216,595 tons of primary nickel and 29,885 tons in rolling mill products.

The company had eight producing mines in the Sudbury district, Ontario—Clarabelle, Crean Hill, Creighton, Frood-Stobie, Garson, Levack, Maclennan, and Murray (the Maclennan pit started production during the year)—and one producing mine at Thompson, Manitoba. Total ore production was 19.8 million tons, an increase from 16.4 million tons in 1964.

Exploration continued at a substantially increased rate in Canada (Ontario, Manitoba, Quebec, Saskatchewan, and Northwest Territories), and also throughout the world (Africa, Australia, Guatemala, South Pacific, and United States). Inco's proven ore reserves at yearend at Sudbury and Manitoba were listed at 306.2 million tons averaging almost 3.03 percent combined nickel-copper content.

One additional mine, the Totten was to begin production early in 1966, and seven more in future years. In the Sudbury

Table 11.—World production of nickel by countries [1]

(Short tons)

Country	1961	1962	1963	1964	1965 p
North America:					
Canada [2]	232,991	232,242	r 217,030	r 228,496	268,837
Cuba:					
Content of oxide e	16,320	16,222	16,200	16,300	e 16,400
Estimated content of sulfide	-----	2,080	2,200	2,400	e 2,450
United States:					
Byproduct of copper refining	625	648	707	949	844
Nickel recovered from domestic ore	10,551	10,569	10,725	11,236	12,666
South America: Brazil (content of ferronickel)	r 90	r 260	r 1,107	e 1,100	e 1,100
Europe:					
Albania (content of nickeliferous ore) e	3,900	4,600	3,300	3,900	4,000
Finland:					
Content of nickel sulfate	177	179	172	r 162	180
Content of concentrates	2,239	2,715	3,230	r 3,494	3,252
Germany, East (content of ore) e	110	110	110	110	110
Poland (content of ore)	1,453	1,458	r 1,218	e 1,400	e 1,400
U.S.S.R. (content of ore) e	77,000	90,000	90,000	90,000	95,000
Africa:					
Morocco (content of cobalt ore)	284	316	302	336	e 330
Rhodesia, Southern (content of ore)	64	86	131	191	e 770
South Africa, Republic of (content of matte and refined nickel) e	2,900	2,700	2,700	2,700	3,000
Asia:					
Burma (content of speiss)	112	182	112	e 70	e 70
Indonesia (content of ore)	694	491	1,760	1,760	e 3,900
Korea, South (content of ore)	31	29	29	20	e 20
Oceania: New Caledonia (recoverable) [3]	48,600	28,775	r 37,920	e 58,200	e 57,400
World total (estimate)	398,000	394,000	r 389,000	423,000	472,000

e Estimate. p Preliminary. r Revised.
[1] Compiled from data available May 1966.
[2] Comprises refined nickel and nickel in oxide produced and recoverable nickel in matte exported.
[3] Comprises nickel-cobalt content of matte and ferronickel produced in New Caledonia plus recoverable nickel in ore exported. Mine production (nickel content of ore) was as follows: 1961, 58,800 tons; 1962, 37,500 tons; 1963, 49,000 tons; 1964, 65,300 tons; and 1965, estimated 88,400 tons.

district, the Coleman, Kirkwood, Copper Cliff North, and Little Stobie mines were being readied for production in 1967 and 1968, and in Manitoba, the Birchtree and Soab mines were being readied for production in 1967. At the Birchtree mine, a development shaft was completed, and at the Soab, two shafts were being sunk. A new electrolyte purification process being installed at Thompson will increase nickel refining capacity.

Among mine developments at Sudbury was the announced plan to increase production at the Stobie mine and to build a 22,500 ton-per-day concentrator adjacent to the mine. Concentrates will be sent by pipeline 4 miles to the Copper Cliff smelter. The new Little Stobie mine, about 1 mile north of the Frood-Stobie, will be developed to produce about 6,000 tons-per-day of ore from a marginal-grade deposit. The production shaft will be sunk to 2,800 feet; also a development and a service shaft will be sunk.

At the Creighton mine, a new 21-foot diameter shaft was begun. It will reach a depth of 7,150 feet and be the deepest shaft from surface in the hemisphere.

At Copper Cliff, the new oxygen plant began operation in November and raised oxygen production capacity from 325 to 1,175 tons-per-day. The company reported plans to increase smelter production capacity also by replacing four Herreshoff multihearth roasters with a fluid bed roaster, and by adding to the matte separation facilities. Production of oxide sinter 90, a new product, will be increased.

Inco's Huntington Alloy Products Division put into operation a primary plate-rolling mill and a forging press. In addition, new hot-rolling and cold-drawing facilities were being installed. At Burnaugh, Ky., a laboratory was organized to develop new nickel-base alloys.[4]

Falconbridge Nickel Mines Ltd. reported nickel deliveries of 36,492 tons, somewhat below the 1964 deliveries. During 1964, excess sales stocks of nickel were depleted.

[4] The International Nickel Co. of Canada Ltd. Annual Report. Toronto, Ontario, Canada, 1965, 40 pp.

Production continued at the company's Sudbury area mines (Falconbridge, East, Hardy, Onaping, and Fecunis), and mining was started at the North mine, adjacent to, and serviced from the Fecunis shaft. Ore deliveries to treatment plants increased from 1.96 million to 2.34 million tons.

Reserves of proven ore were reported at yearend to be 55.3 million tons containing 2.10 percent combined nickel-copper content. Drilling at the Lockerby property, west of Sudbury, and company exploration in the Thompson nickel belt, Manitoba, continued.

A second blast furnace was put into operation at Falconbridge on January 27. At the Strathcona mine, scheduled for production about the end of 1967, the headframe for the second shaft was erected, and the pilot raise was being enlarged to full size; the main services building and heating plant were constructed; and grading was completed for the 6,000-ton-per-day mill. Mine development at the East mine included sinking of an internal shaft 915 feet below the 4,025 level, and at the Falconbridge mine three levels below the 4,025 level were developed.[5]

Sherritt Gordon Mines Ltd. produced 12,895 tons of nickel, 8 percent less than in 1964, and sold 13,592 tons, 5 percent less than in 1964. Tonnage mined in 1965 at the company's Lynn Lake, Manitoba, mine was 1,363,583 tons, about the same as that in 1964, but lower grade of mill feed resulted in 6 percent less nickel content in concentrates. A supplementary supply of nickel contained in matte from New Caledonia was interrupted because of power shortages and subsequent loss of production on the island.

Yearend reserves at Lynn Lake, taking into account expected dilution, were calculated at 12.6 million tons averaging 0.84 percent nickel and 0.49 percent copper. The 4-foot-diameter drill hole was completed to a 3,000-foot depth, the hydraulic hoisting project was continued, and a prototype installation designed to lift 100 tons per hour a distance of 700 feet will be constructed.

The powder-rolling plant was being expanded to provide a yearly capacity for coinage blanks of 3 million pounds. During 1965, 1,616,000 pounds of Canadian 5-cent pieces and South African 5- and 50-cent pieces were produced, and nickel metal was supplied to Australia for that country's cupronickel coinage. During the year, the company continued research on dispersion-strengthened nickel and nickel-chrome, nickel battery plates, and other special uses for its nickel powder.[6]

Metal Mines Ltd., approximately 85 percent owned by the Canadian Faraday Corp., Ltd., operated its Werner Lake Division mine (formerly the company's Gordon Lake Division) in northwestern Ontario, throughout the year at an average rate of 505 tons per day. Because of a severe shortage of labor, this level of operation was considerably below rated capacity of 800 tons per day. Ore reserves at the end of the year were 1,088,250 tons averaging 1.38 percent nickel and 0.56 percent copper, compared with the year earlier total of 1,030,866 tons averaging 1.40 percent nickel and 0.53 percent copper. The "D" ore zone 1,200 feet east of the main orebody is being developed.[7]

Marbridge Mines Ltd., operating a mine in LaMotte Township, northwestern Quebec, milled 125,000 tons of ore in 1965 and recovered 2,368 tons of nickel in concentrates, 4 percent less than in the previous year. At the No. 2 mine, a shaft was sunk and four levels were cut, and by yearend this new producer was supplying about 60 percent of the tonnage hoisted. Reserves at the end of the year at the No. 1 mine were estimated at 63,000 tons averaging 1.59 percent nickel and at the No. 2 mine, 118,000 tons averaging 3.31 percent nickel. The company is owned equally by Falconbridge Nickel Mines, Ltd. and Marchant Mining Co. Ltd.[8]

Giant Mascot Mines Ltd., which operates near Hope, British Columbia, recovered 1,967 tons of nickel in 19,723 tons of nickel concentrate produced from 330,421 tons of ore, during the year ended September 30, and an estimated 1,911 tons of nickel during the calendar year. Grade of ore treated averaged 0.76 percent nickel and 0.34 percent copper, with recovery of 78.3 percent of the nickel and 92.4 percent of the copper.

Because of a shortage of personnel for mine development work, ore reserves declined 25 percent to 757,464 tons averag-

[5] Falconbridge Nickel Mines Ltd. Annual Report. Toronto, Ontario, Canada, 1965, 36 pp.
[6] Sherritt Gordon Mines Ltd. Annual Report. Toronto, Ontario, Canada. 1965, 16 pp.
[7] Canadian Faraday Mines Ltd. Annual Report. Toronto, Ontario, Canada. 1965, 8 pp.
[8] Pp. 26 and 27 of work cited in footnote 5.

ing 0.81 percent nickel and 0.32 percent copper, allowing for stope-wall dilution.

The company negotiated a 2-year extension, to March 1968, of the contract to sell ore concentrates to Sumitomo Shoji Canada Ltd.[9]

The Lorraine mine, Belleterre, Quebec, came into production early in the year. The mine, in which McIntyre Porcupine Mines Ltd. has an 80-percent interest, produced 162,533 tons of ore, yielding 950 tons of nickel and 2,273 tons of copper. Reserves at yearend were 335,348 tons averaging 0.635 percent nickel and 1.608 percent copper.[10]

Raglan Nickel Mines Ltd. and Falconbridge Mines Ltd. have conducted exploration programs for several years in the Cape Smith-Wakeham Bay area of northern Ungava Peninsula, Quebec. Late in the year the two companies' properties were merged, and Raglan reorganized as New Quebec Raglan Mines Ltd., with Falconbridge holding a 59-percent interest and undertaking a $2 million exploration program. Combined holdings extend 42 miles in an area of copper-nickel mineralization.[11]

Texmont Mines Ltd., formerly Fatima Mining Co. Ltd., continued diamond drilling its nickel property in Bartlett and Geikie Townships, Ontario, south of Timmons. The company reported reserves on October 15 to be 4,770,000 tons averaging 1.0 percent nickel. In November, the company reached agreement with the Canadian Nickel Company, a subsidiary of Inco, to have the property tested, and provision was made for a 2-year development program by Canadian Nickel in which that company would expend at least $400,000.

At yearend it was reported that New Jersey Zinc Exploration Co., (Canada) Ltd. had made a nickel discovery in the Gaspé Provincial Park, Quebec. Severe winter weather hampered further operations to assess the significance of the discovery.

Cuba.—The French firm, Société Le Nickel, contracted to purchase 5,500 tons per year of Cuban nickel, in oxide sinter form, for 3 years, then 3,300 tons each of the next 2 years, with additional purchases possible.

Dominican Republic. — Falconbridge's ferronickel pilot plant operation, Falconbridge Dominicana C. por A., operated through most of the year; some enlargement of production capacity was to be effected.

Guatemala.—On August 25, Inco subsidiary Exploraciones y Explotaciones Mineras Izabal S.A. (Exmibal) was granted a 40-year mining concession to develop an area of about 150 square miles in northeastern Guatemala, adjacent to Lake Izabal. Lateritic ores will be mined and processed to produce annually at least 12,500 tons of nickel in ferronickel. Hanna Mining Company has a 20-percent interest in the project. Financing and engineering studies were continuing at yearend.

SOUTH AMERICA

Brazil.—Ferronickel production during 1964 was 265 tons containing 19 to 25 percent nickel, 1,102 tons containing 25 to 35 percent nickel, and 2,205 tons containing 35 to 40 percent nickel. The two producing companies are Morro do Niquel S.A., with current annual capacity of about 1,100 tons of contained nickel in ferronickel, and Cia. Niquel do Brasil, with annual capacity of about 90 tons of contained nickel.

British Guiana.—Government geochemical prospecting resulted in the discovery of anomalously high nickel content of soils associated with an ultrabasic intrusive in the Wariri area, in northwestern British Guiana.

Venezuela.—Société Le Nickel was investigating nickel deposits in the Loma de Hierro area, Aragua.

EUROPE

Greece.—The Larymna nickel project of Société Minière et Metallurgique de Larymna Larco S.A. was being readied for production early in 1966. Annual output of electrolytic nickel will be about 4,400 tons. The project is a joint venture of Hellenic Chemical Products & Fertilizers Co. and Société Le Nickel.

Norway.—Near yearend, Falconbridge announced that annual nickel production capacity of its refinery at Kristiansand South would be expanded to about 40,000 tons by mid–1967.

[9] Giant Mascot Mines Ltd. Annual Report. Vancouver, British Columbia, Canada. 1965, 12 pp.
[10] McIntyre Porcupine Mines Ltd. Annual Report. Toronto, Ontario, Canada. 1965, 20 pp.
[11] P. 4 of work cited in footnote 5.

United Kingdom.—The former Inco subsidiary, the International Nickel Company (Mond) Ltd., on January 1 became International Nickel Ltd. The company's refinery at Clydach, Wales, was being modernized, with some innovation in the reduction and volatilization sections of the carbonyl process plant. A new, more versatile unit for producing carbonyl nickel powders was put into operation.

AFRICA

Rhodesia, Southern.—Trojan Nickel Mining Co. (Pvt.) Ltd., operated its Trojan mine near Bindura throughout the year, producing about 400 tons per month of concentrate containing about 15 percent nickel. Concentrate production through September was 2,953 tons. In June, the Anglo-American group took an option to examine the potential of a 105-square-mile area surrounding the Trojan mine.

Rio Tinto (Rhodesia) Ltd. was planning to reopen the Empress nickel mine near Gatooma by 1967.

South Africa, Republic of.—Rapidly rising production of platinum ore from the Rustenburg mine resulted in recovery of increased amounts of byproduct nickel.

The Pilansberg nickel mine suspended production in May, and mine equipment was dismantled. Kashane Exploration Ltd. suspended exploration activities in the vicinity of the Pilansberg mine.

ASIA

China, Mainland.—Société Le Nickel concluded an agreement to sell China at least 10,250 tons of nickel at current French prices over a 3-year period.

Indonesia.—Production of nickel ore for export to Japan by the Sulawesi Nickel Development Cooperative Co. (Sunideco) apparently increased considerably over that of 1964. Japanese imports of nickel ore from Indonesia in 1965 were 87,578 tons, compared with 1964 Indonesian ore production of 52,855 tons. Sunideco was considering erection of a nickel refinery in Indonesia.

Indonesian nickel ore reserves were reported to total over 40 million tons, averaging 1.5 to 2.3 percent nickel.

Japan.—Nickel was supplied entirely by imports; 1,065,640 tons of ore and concentrate (including 951,096 tons of ore from New Caledonia, 87,578 tons of ore from Indonesia and 22,576 tons of concentrate from Canada); 4,788 tons of nickel matte from New Caledonia; and 2,847 tons of unwrought nickel (including 1,779 tons from Canada and 910 tons from Norway).

A new company, Tokyo Nickel Co., was formed to produce nickel oxide sinter 75 domestically from nickel sulfide matte supplied by Inco. The firm is a joint investment of Inco (40 percent), Shimura Kako Co. (50 percent), and Mitsui and Co. (10 percent).

Philippines.—The Suragao Mineral Reservation Board invited bids for operation of parcel II of the reservation, which contains large nickel reserves. A qualified bid was received from Benguet Consolidated, Inc., and a second bid from an agent of the MacArthur International Minerals Co. Both bids were rejected by the board, with the recommendation that agreements might better be reached by negotiation.

OCEANIA

New Caledonia.—Production (nickel plus cobalt content) included 17,434 tons in matte and 17,158 tons in ferronickel. Ore production was 2,853,511 wet tons.

Exports to France were 8,237 tons in matte and 15,761 tons in ferronickel. Exports to other countries were 9,162 tons in matte to Canada and Japan, and 1,941 tons in ferronickel to Japan, Australia, United States, and Italy. Ore exports to Japan were 959,749 tons containing about 3.1 percent nickel.

Production of matte and ferronickel by the Société Le Nickel was 34,592 tons, 18 percent more than in 1964. This indicates continuing progress in the company's plans to expand production to 55,000 tons. The company was building a 32,000-kilowatt power-generating station and a sixth electric furnace, had contracted to purchase from Japan two ships, each 15,000 tons deadweight, and was developing a mining, ore pelletizing, and shipping center at Poro, on the northeast coast.

TECHNOLOGY

Nickel oxide sinter 90, a new primary product, was distributed commercially by Inco toward the end of the year.[12] It will be used in wrought and cast alloys and stainless steels and in cast irons. Analyses typically are 90 to 92 percent nickel.

Ultra-high-purity nickel also is available commercially.[13] The metal contains 30 parts per million interstitial content (O_2, N_2, H_2, C) and 20 parts per million substitutional content. An even higher purity nickel has been produced by Bell Telephone Laboratory personnel.[14] The nickel was reported to contain less than 2 parts per million metal impurities and less than 10 parts per million other impurities.

The electrical resistivity of nickel metal up to 1,600° K was reported, and estimates were made for resistivity of pure nickel.[15] Heat of formation, low-temperature heat capacity, and entropy at —298.15° K were determined for $NiSO_4$.[16]

Geologic publications described nickel occurrences in Nevada, [17] British Guiana,[18] Southern Rhodesia,[19] Australia,[20] and Canada.

Canadian deposits described included the Marbridge mine, Quebec,[21] Pride of Emory mine, British Columbia,[22] and Strathcona,[23] Falconbridge,[24] and Frood mines,[25] Sudbury district, Ontario.

The Thompson, Manitoba, Canada operation of Inco, which came into production in 1961, was the subject of a symposium.[26] The mine, mill, smelter, and refinery equipment and operations were described, as well as project planning and development and community planning.

The continuing quest for economy in mining, particularly for increased production from each working area, has led to the use of wagon-mounted drills for drilling holes inclined upward into the stope back.[27]

Hydrometallurgical recovery of cobalt, nickel, and copper from an oxidized-sulfide concentrate of those metals was described.[28] Continuing studies of hydrogen reduction methods of producing nickel powders delineated the effects of various addition agents on nucleation or growth.[29]

Nickeliferous laterite deposits have a typical vertical profile in which the relative amounts of iron, magnesium, silicon, nickel, and cobalt vary at depth according to the stage of weathering. A metallurgical process generally would be suitable only for certain of the ores, such as those with high-nickel content or low-magnesia content. A more versatile chemical process

12 The International Nickel Co., Inc. New Primary Nickel Product Introduced by International Nickel. Press Information, Nov. 29, 1965, 2 pp.

13 Materials Research Corp., Advanced Materials Div. Ultra-High Purity Nickel. Orangeburg, N.Y., February 1965, 1 p.

14 Chemical and Engineering News. Nickel That Is Pure Enough To Allow Studies of Its Electronic Structure. V. 43, No. 27, July 5, 1965, p. 31.

15 Pallister, P. R. Resistivity of Nickel. Metallurgia (Manchester, England), v. 71, No. 426, April 1965, pp. 165–168.

16 Adami, L. H., and E. G. King. Heats of Formation of Anhydrous Sulfates of Cadmium, Cobalt, Copper, Nickel, and Zinc. BuMines Rept. of Inv. 6617, 1965, 10 pp.

Weller, W. W. Low-Temperature Heat Capacities and Entropies at 298.15° K of Anhydrous Sulfates of Cobalt, Copper, Nickel, and Zinc. BuMines Rept. of Inv. 6669, 1965, 6 pp.

17 Beal, Laurence H. Geology and Mineral Deposits of the Bunkerville Mining District, Clark County, Nevada. Nevada Bureau of Mines, Bull. 63, 1965, 96 pp.

———. Cobalt-Nickel-Platinum Occurrences in Nevada. Nevada Bureau of Mines, Map 21, March 1964.

18 Bateson, J. H. Geochemical Breakthrough In Mineral Prospection in British Guiana. Canadian Min. J., Quebec, v. 86, No. 12, December 1965, pp. 71–73, 78.

19 De Kun, Nicolas. The Mineral Resources of Africa. American Elsevier Pub. Co., Inc., New York, 1965, 740 pp.

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20 McAndrew, John, ed. Geology of Australian Ore Deposits. Eighth Commonwealth Min. and Met. Cong., Australia and New Zealand, Melbourne, Australia, v. 1, 1965, 547 pp.

21 Clark, Lloyd A. Geology and Geothermometry of the Marbridge Nickel Deposit, Malartic, Quebec. Econ. Geol., v. 60, No. 4, June–July 1965, pp. 792–811.

22 Minister of Mines and Petroleum Resources, Province of British Columbia. Annual Report. 1964, pp. 137–142.

23 Naldrett, A. J., and G. Kullerud. Investigations of the Nickel-Copper Ores and Adjacent Rocks of the Sudbury District, Ontario. Carnegie Institution of Washington, Yearbook 64, (1964–1965), pp. 177–188.

24 Borchert, Von H., and B. Lamby. Mikroskopische Untersuchungen an Erzproben aus der Falconbridge-Grube (Sudbury, Ontario/Kanada) und daraus resultierende genetische Folgerungen (Microscopic Examination of Ore Samples from the Falconbridge Mine (Sudbury, Ontario, Canada), and Genetic Conclusions Resulting From This Investigation). Zietschrift Fur Erzbergbau und Metallhuttenwesen, v. 17, No. 12, December 1964, pp. 645–653.

25 Hawley, J. E. Upside-Down Zoning At Frood, Sudbury, Ontario. Econ. Geol., v. 60, No. 3, May 1965, pp. 529–575.

26 Canadian Mining and Metallurgical Bulletin.

that would not be so selective of feed material was described,[30] and the economics discussed.[31] The end product, nickel and cobalt sulfide, would be further processed in existing nickel refineries. The process involves pugging the ore with sulfuric acid, drying, roasting, leaching, and precipitation.

A Bureau of Mines publication described a sulfatizing process for laterites using a sulfur dioxide-air reaction gas.[32] Among patents issued was one for a metallurgical separation of nickel from cobalt occurring in ocean floor manganese nodules.[33]

A. A. Tseidler's 1958 monograph on extractive metallurgy of nickel was translated from Russian, and published in English.[34]

Growing use of maraging steels was highlighted by the construction of 260-inch-diameter solid propellant rocket motor cases using 18-percent nickel, 9-percent cobalt, 5-percent molybdenum steel. Maraging steels also have been used in research submarine hulls, shotgun barrels, and machine tools. The high strength, toughness, and ductility of this constructional steel, and ease of machining and heat treatment have resulted in extensive study of its properties and fabrication and in the development of less expensive alloys with similar properties. One such alloy was developed by Foote Mineral Co.; it is a 12.5-percent nickel, 8-percent cobalt, 4-percent molybdenum, 2-percent manganese, 0.2-percent titanium, 0.1-percent aluminum alloy steel with yield strength above 214,000 pounds per square inch and tensile strength above 227,000 pounds per square inch.[35]

Inco reported that a new ultra-high-strength alloy steel, 8-percent nickel, 14-percent molybdenum, 18-percent cobalt had a tensile strength of 506,000 pounds per square inch.[36] Abstracts of technical articles on maraging steels and other nickel-bearing alloys, nickel, analyses, and patents, were published during the year in the Nickel Bulletin.[37] A history of development of nickel-bearing steels was published.[38]

Nickel-bearing stainless steels were used more extensively in architectural uses. The 630-foot-high Gateway Arch in St. Louis, Mo., is faced with 900 tons of ¼-inch polished stainless steel plates. Other new uses include easily assembled and maintained stainless steel lightpoles. Architectural stainless steels were inspected and found to be easily maintained, with indefinitely long life when use is properly designed.[39]

Free-machining stainless grades were heavily advertised. A new iodine-base lubricant was developed which effectively lubricates stainless steels.[40]

A Bureau of Mines publication reported that substitution of cobalt in types 302 and 309 stainless steel had an irregular effect on corrosion resistance; at some levels of cobalt content, corrosion resistance was improved by the presence of cobalt.[41]

Use of stainless steel tubing in powerplants was attractive due to its strength,

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Symposium On the Thompson Operation. V. 57, No. 631, November 1964, pp. 1147–1200.

[27] Holmes, Roy. Uppers and Wagon Drills in Cut-and-Fill Stoping. Canadian Min. and Met. Bull., v. 58, No. 642, October 1965, pp. 1064–1069.

[28] Maschmeyer, D., and B. Benson. Hydrometallurgical Treatment of Oxidized Nickel-Cobalt Concentrate. Canadian Min. and Met. Bull., v. 58, No. 641, September 1965, pp. 931–938.

[29] Kunda, W., D. J. I. Evans, and V. N. Mackiw. Effect of Addition Agents on the Properties of Nickel Powders Produced by Hydrogen Reduction. Sherritt Gordon Mines Ltd., Res. and Devel. Div., Fort Saskatchewan, Alberta, Canada, 1965, 33 pp.

[30] Zubryckyj, N., D. J. I. Evans, and V. N. Mackiw. Preferential Sulfation of Nickel and Cobalt in Lateritic Ores. J. Metals, v. 17, No. 5, May 1965, pp. 478–486.

[31] Young, K. A., N. Zubryckyj, D. J. I. Evans, and V. N. Mackiw. A Sulphation Leach Process For Recovering Nickel and Cobalt From Laterite Ores. Sherritt Gordon Mines Ltd., Res. and Devel. Div., Fort Saskatchewan, Alberta, Canada, March 1965, 27 pp.

[32] Joyce, F. E., Jr. Sulfatization of Nickeliferous Laterites. BuMines Rept. of Inv. 6644, 1965, 16 pp.

[33] Mero, John L. Process For Separation of Nickel From Cobalt in Ocean Floor Manganiferous Ore Deposits. U.S. Pat. 3,169,856, Feb. 16, 1965.

[34] Tseidler, A. A. Metallurgiya medi i nikelya (Metallurgy of Copper and Nickel), Moscow, U.S.S.R., 1958. Trans. from Russian. U.S. Dept. of Commerce, Office of Tech. Services, ATS 64-11103, 1964, 320 pp.

[35] Chemical & Engineering News. Foote Develops Low Cost Maraging Steel. V. 43, No. 30, July 26, 1965, pp. 41–42.

[36] Iron Age. Fe-Ni Alloys Reach 500,000 Psi. V. 196, No. 18, Oct. 28, 1965, p. 17.

[37] The Nickel Bulletin. International Nickel Company, Inc., New York, v. 12, Nos. 1–12, 1965.

[38] Yeo, R. B. G., and O. O. Miller. A History of Nickel Steels From Meteorites to Maraging. The Sorby Centennial Symposium On The History of Metallurgy, Gordon and Breach Science Publishers, New York, v. 27, 1965, pp. 467–500.

[39] American Society For Testing and Materials, Proceedings. Report on 1964 Inspection of Stainless Steels in Architectural Applications. V. 65, 1965, pp. 145–155.

[40] Business Week. New Lubricants Containing Iodine Will Make it Easier to Use Stainless Steel and Titanium in Moving Parts. No. 1891, Nov. 27, 1965, p. 138.

[41] Tilman, M. M. Effects of Substituting Cobalt For Nickel on the Corrosion Resistance of Two Types of Stainless Steel. BuMines Rept. of Inv. 6591, 1965, 17 pp.

antifouling smooth surface, and long life. Use of corrosion resistant austenitic stainless steel as a construction material was described.[42]

A 60-percent chromium, 40-percent nickel or 50-percent chromium, 50-percent nickel alloy has greatly improved resistance to corrosion caused by burning heavy residual fuel oils, particularly resisting the corrosion induced by vanadium, sulfur, and sodium.[43] It is suitable for boiler superheater supports, refinery furnace tube supports, and other furnace parts.

Progress in developing two iron-base superalloys for use in turbine engines for automobiles was described. The alloys, CRM-6D and CRM-15D, contain only 5 percent nickel and no cobalt.[44]

Some of the white irons were reviewed.[45]

Three factors were reported to influence high-temperature strength of thoria-dispersed nickel; development of fibrous structure, mechanism of strain hardening, and occurrence of the dispersed phase.[46] Strength has been improved by alloying molybdenum and tungsten, and oxidation resistance improved by addition of chromium or by using protective coatings.[47] Properties of thoria-dispersed nickel make its use feasible in some jet engine parts, and advances in properties and fabrication techniques may open other uses.[48]

Nickel has been used in fiber-reinforced composite materials. Among the fibers used with nickel or nickel base superalloys are tungsten and molybdenum wire and alumina whiskers.

Electrochemical reactivity of nickel was found to be affected more by small amounts of impurities such as sulfur, selenium, and phosphorus, than by differences in structure induced by cold rolling.[49] The impurities increase reactivity of nickel and inhibit passivity to a significant degree. The effect of variation in phosphorus content upon structure, strength, ductility, and hardness of electroless nickel also was studied.[50]

Porous nickel plates used in fuel cells and nickel-cadmium batteries must have adequate strength and predictable porosity, pore size range, resistivity, or other special properties. Powder characteristics, particularly shape, and also the manufacture of plates by loose sintering, roll compacting, slurry, and pressing techniques were discussed.[51]

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[42] Merrick, Robert D., and Charles L. Mantell. Low-Nickel Stainless Steels. Chem. Eng., v. 72, No. 18, Aug. 30, 1965, pp. 144, 146, 148–149.

[43] Inco Nickel Topics. Cast and Wrought 60–40 and 50–50 Chromium Nickel. The International Nickel Co., Inc., New York, v. 18, No. 4, 1965, pp. 4–5.

[44] Roy, Amedee, Frederick A. Hagen, and John M. Corwin. Iron-Base Superalloys for Turbine Engines. J. Metals, v. 17, No. 9, September 1965, pp. 934–939.

[45] Provias, P. J. Nickel-Chromium White Irons For Abrasion Service. Canadian Min. and Met. Bull., v. 58, No. 641, September 1965, pp. 923–930.

[46] Fraser, R. W., B. Meddings, D. J. I. Evans, and V. N. Mackiw. Dispersion Strengthened Nickel by Compaction and Rolling of Powder Produced by Pressure Hydrometallurgy. Sherritt Gordon Mines Ltd., Res. Devel. Div., Fort Saskatchewan, Alberta, Canada. June 1965, 54 pp.

[47] Materials in Design Engineering. Higher Strength Oxidation Resistance for TD Nickel. V. 61, No. 4, April 1965, pp. 6–7, 9.

[48] Redden, Thomas K., and James F. Barker. Making TD Nickel Parts. Metal Prog., v. 87, No. 1, January 1965, pp. 107–113.

[49] De Bari, G. A., and J. V. Petrocelli. The Effect of Composition and Structure on the Electrochemical Reactivity of Nickel. J. Electrochem. Soc., v. 112, No. 1, January 1965, pp. 99–104.

[50] Graham, Arthur H., Robert W. Lindsay, and Harold J. Read. The Structure and Mechanical Properties of Electroless Nickel. J. Electrochem. Soc., v. 112, No. 4, April 1965, pp. 401–413.

[51] Kravic, A. F. Production of Porous Membranes For Batteries and Fuel Cells. Canadian Min. and Met. Bull., v. 58, No. 636, April 1965, pp. 422–427.

Tracey, V. A., and N. J. Williams. The Production and Properties of Porous Nickel for Alkaline Battery and Fuel Cell Eelctrodes. Electrochem. Tech., v. 3, No. 1–2, January–February 1965, pp. 17–25.

Nitrogen

By Richard W. Lewis [1]

Domestic production capacity of anhydrous ammonia continued to increase, and by yearend it was 20 percent greater, boosting total output capacity to over 11 million short tons. A trend was established toward the construction of large capacity (1,000 tons per day and greater), single-train plants which, it was believed, would eventually replace most of the smaller plants because the operating cost per unit of ammonia produced will be lower.

[1] Commodity specialist, Division of Minerals.

Table 1.—Salient nitrogen statistics

(Thousand short tons of contained nitrogen)

	1956–60 (average)	1961	1962	1963	1964	1965
United States:						
Production as ammonia	3,521	4,429	4,920	r 5,656	r 6,447	7,252
Production as high-purity nitrogen gas	380	1,045	1,683	1,992	r 2,266	2,801
Imports for consumption of nitrogen compounds	276	325	383	401	494	496
Exports of nitrogen compounds	247	173	246	219	337	459
Consumption [1]	3,679	5,130	r 4,862	r 5,454	r 6,031	6,575
World: Production [1]	11,956	15,403	16,320	r 18,864	r 21,213	23,401

r Revised.
[1] Estimated, exclude nitrogen gas.

Table 2.—Nitrogen production in the United States

(Short tons of contained nitrogen)

	1961	1962	1963	1964 r	1965 p
Anhydrous ammonia: Synthetic plants [1]	4,282,160	4,778,106	r 5,504,581	6,278,717	7,079,035
Ammonia compounds, coking plants:					
Ammonia liquor	10,990	11,166	12,059	13,325	12,791
Ammonium sulfate	125,951	124,112	131,385	144,362	150,318
Ammonium phosphates	10,111	6,909	8,234	10,638	10,292
Total	4,429,212	4,920,293	r 5,656,259	6,447,042	7,252,436
Nitrogen gas [1]	1,045,357	1,682,643	1,992,112	2,266,411	2,801,073

p Preliminary. r Revised.
[1] Bureau of the Census Current Industrial Reports.

Table 3.—Major nitrogen compounds produced in the United States

(Thousand short tons, gross weight)

Compounds	1964 r	1965 p
Ammonium nitrate	4,543	4,599
Ammonium sulfate	2,307	2,661
Ammonium phosphate	3,096	3,531
Nitric acid	4,732	4,860
Urea	1,210	1,374

p Preliminary. r Revised.

Source: U.S. Tariff Commission (urea only).

DOMESTIC PRODUCTION

Anhydrous ammonia production in 1965 exceeded that of 1964 by 973,000 tons, or 13 percent. The output of nitrogen(liquid and gas) also increased and was nearly 24 percent greater than in 1964.

The following anhydrous ammonia (NH_3) plants and expanded facilities with engineered capacities were reported completed during the year:

Company	Plant location	Added NH_3 capacity 1,000 short tons per year
Air Products and Chemicals, Inc	New Orleans, La	210
Ammonia, Inc	Bonnie, Fla	50
Apple River Chemical Co	Dubuque, Ill	200
Calumet Nitrogen Products Co	Hammond, Ind	15
Consumers Cooperative Association	Fort Dodge, Iowa	55
El Paso Natural Gas Products Co. [1]	Odessa, Tex	105
Fel-Tex, Inc	Fremont, Nebr	42
Frontier Chemical Co	Wichita, Kans	15
W. R. Grace & Co	Memphis, Tenn	75
Hercules Powder Co	Hercules, Calif	70
Monsanto Co	Luling, La	210
Nipak, Inc	Kerens, Tex	115
Olin Mathieson Chemical Corp	Lake Charles, La	500
Phillips Chemical Co	Beatrice, Nebr	220
Reserve Oil and Gas Corp	Hanford, Calif	22
Shell Oil Co	Ventura, Calif	55
Western Ammonia Corp. [1]	Dimmitt, Tex	27
Wycon Chemical Co	Cheyenne, Wyo	20

[1] Reported as completed in 1964 Minerals Yearbook.

Additional new anhydrous ammonia plants and expansions either planned or under construction were announced as follows:

Company	Plate location	Added NH_3 capacity 1,000 tons per year	Completion date
Allied Chemical Corp	Geismar, La	350	1967
American Cyanamid Co	Fortier, La	350	1966
Borden Chemical Co	Geismar, La	350	1966
Chevron Chemical Co	Pascagoula, La	500	1967
Coastal Chemical Corp	Yazoo City, Miss	350	1966
Collier Carbon & Chemical Corp	Brea, Calif	250	1966
Continental Oil Co	Blytheville, Ark	350	1966
Commercial Solvents Corp	Sterlington, La	350	1967
The Dow Chemical Co	Freeport, Tex	105	1966
E. I. du Pont de Nemors & Co., Inc	Beaumont, Tex	350	1966
Do	Belle, W. Va. [1]	350	NA
Felmont Oil Corp	Olean, N. Y.	70	1966
First Nitrogen Corp	Donaldson, La	350	1966
Green Valley Chemical Corp	Creston, Iowa	35	1966
Mobile Chemical Co	Beaumont, Tex	250	1966
Shamrock Oil & Gas Co	Dumas, Tex	70	1966
Shell Oil Co	St. Helens, Ore	150	1966
Terra Chemicals International, Inc	Port Neal, Iowa	210	1966
Tuloma Gas Products Co	Texas City, Tex	500	1968
United States Steel Corp	Clairton, Pa	400	1966
Valley Nitrogen Producers Co	El Centre, Calif	210	1966

NA Not available.
[1] Upon completion the original plant would be shut down.

Increasing domestic demands for urea, chiefly for fertilizer use, led to heavy expansion of production capabilities in 1965. If all planned projects and plants under construction in 1965 materialize capacity by the end of 1966 will be double that in 1964. Several new plants were completed and functioning in 1965.

Columbia Nitrogen Corp. began operating a new 25,000-ton-per-year plant at Augusta, Ga. At New Orleans, La., American Cyanamid Co., built a new plant with an output of about 157,000 tons per year. A new plant with a 35,000-ton-per-year output was completed at Henderson, Ky., for Spencer Chemical Division, Gulf Oil Corp. Mississippi Chemical Co. completed a new urea plant at Yazoo City, Miss., adding 35,000 tons per year to its existing output of 45,000 tons. Nipak Inc. had an 85,000-ton-per-year plant under construction at Kerens, Tex., and Solar Nitrogen Chemicals, Inc., had a plant of equal capacity under construction at Lima, Ohio. Both Allied Chemical Corp. and Mobile Chemical Co. were constructing urea production facilities in connection with their large new ammonia plants under construction at Geismar, La., and Beaumont, Tex., respectively. Borden Cemical Co. was planning a 175,000-ton-per-year plant at Geismar, La., where the firm had a large ammonia plant under construction. Shell Oil Co. was reported to be building a urea plant in conjunction with an anhydrous ammonia plant at Portland, Ore. Collier Carbon & Chemical Corp. expected to have a new urea plant operative in 1966 at the site of its new ammonia plant under construction at Brea, Calif. Terra Chemicals International Inc. announced that it would build a large fertilizer-manufacturing facility at Port Neal, Iowa, which was to include a 350-ton-per-day urea plant. Agway, Inc. expected to produce urea at Olean, N.Y., in a new plant adjacent to the new Felmont Oil Corp. ammonia plant scheduled for completion in 1966.

In 1965, facilities for the production of other nitrogen compounds also were expanded. Several new nitric acid and ammonium nitrate plants were constructed. The New Jersey Zinc Co. started construction on a 270,000-ton-per-year diammonium phosphate unit, said to be the largest in the world. The plant was scheduled for completion in 1966. W. R. Grace & Co. had plans for a 100,000-ton-per-year ammonium phosphate plant to be constructed at Henry, Ill., and in operation in 1967.

The following new air-separation plants to produce nitrogen were reported completed in 1965:

Company [1]	Plant location	Gas capacity (tons per day)
Air Reduction Pacific Co	Vancouver, Wash.	[2] 160
Air Reduction Co	Titusville, Fla.	[2] NA
Big Three Industrial Gas & Equipment Co.	Beaumont, Tex.	[3] 800
Chemetron Corp., National Cylinder Gas Division.	Denver, Colo	[2] 45
Burdett Oxygen Co. of Cleveland, Inc.	Parkersburg, W. Va.	[2] 450
Industrial Air Products Co.	Portland, Ore.	[2] 80

NA Not available.
[1] The list is not necessarily complete.
[2] Argon, nitrogen, and oxygen.
[3] Nitrogen and oxygen.

CONSUMPTION AND USES

Domestic consumption of nitrogen, as compounds, was about 9 percent greater than in 1964. More than 80 percent of all nitrogen consumed, with the exception of nitrogen gas and liquid, went into fertilizer materials.

According to reports by the Department of Agriculture, nitrogen consumed by agriculture as fertilizers for the year ending June 30, 1965, was 4,580,519 tons. This was an increase of 5 percent over the tonnage consumed in the 12-month period ending June 30, 1964.

PRICES

Price increases were noted in August on some fertilizer compounds—$2 per ton on ammonium nitrate and $3 per ton on ammonium phosphate and urea. Prices otherwise held steady. The usual seasonal discounts were given on anhydrous ammonia for delivery in August and September.

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Table 4.—Price quotations for major nitrogen compounds in 1965

(Per short ton)

Compound	Jan. 1	Dec. 30	Effective date of change
Ammonium nitrate, fertilizer grade, 33.5 percent N (nitrogen):			
Canadian carlots, bags, f.o.b. shipping point	$67.00	[1] $72.00	Nov. 8
Domestic f.o.b. works, bags	67.00	[2] 69.00–70.00	Nov. 8
Ammonium nitrate, domestic with dolomite, 20.5 percent N bags, carlots, Hopewell, Va	52.00	55.00	Jan. 4
Ammonium sulfate, standard granular, bulk, f.o.b. works	32.00–34.00	32.00–34.00	
Anhydrous ammonia, ferilizer, tanks, works, freight equalized east of Rockies	92.00	92.00	(3)
Sodium nitrate, domestic, commercial, bulk, carlots, works	44.00	44.00	
Sodium nitrate, imported, commercial, bulk, carlots, port warehouse	44.00	44.00	
Urea:			
Industrial, 46 percent N, bags, carlots, delivered, freight equalized	100.00	100.00	
Agricultural, 45 percent N, bags, carlots, delivered	92.00	96.00	Jan. 4

[1] Quoted at $70 from Jan. 4 to Nov. 8.
[2] Quoted at $70 from Jan. 4 to Aug. 2, and $68 from Aug. 2 to Nov. 8.
[3] Quoted at $84 from Aug. 9 to Oct. 4.

FOREIGN TRADE

Gross weight of nitrogenous fertilizer materials exported during the year was nearly 39 percent greater than in 1964. Shipments of ammonium sulfate were nearly double those of 1964, and represented 59 percent of the total quantity of materials exported.

Gross weight of nitrogen compounds imported for consumption was slightly less, but the nitrogen content was slightly more than in 1964. This was due chiefly to a 28-percent increase in incoming shipments of anhydrous ammonia while shipments of most of the other materials decreased. However, the quantity of ammonium phosphate imported increased 81 percent. Although about 17 percent less urea was imported than in 1964, urea remained a major fertilizer import, amounting to 15 percent of the total.

Table 5.—U.S. exports and imports for consumption of major nitrogen compounds
(Short tons)

Compounds	1964 Gross weight	1964 Nitrogen content	1965 Gross weight	1965 Nitrogen content
Exports:				
Industrial chemicals:				
Ammonium nitrate	1,160	406	(1)	(1)
Anhydrous ammonia and chemical-grade aqua (ammonium content)	46,176	37,957	63,879	53,147
Fertilizer materials:				
Ammonium nitrate	87,077	29,171	103,716	34,745
Ammonium phosphates and other nitrogenous phosphatic-type fertilizer materials	363,116	54,467	319,652	47,948
Ammonium sulfate	483,784	101,595	961,601	201,936
Anhydrous ammonia and aqua (ammonia content)	102,303	84,093	120,324	98,906
Nitrogenous chemical materials, not elsewhere classified	60,427	12,085	34,560	6,912
Sodium nitrate	950	152	466	75
Urea	37,432	16,844	33,554	15,099
Total	1,182,425	336,770	1,637,752	458,768
Imports:				
Industrial chemicals: Ammonium nitrate	160	56	240	84
Fertilizer materials:				
Ammonium nitrate	200,015	66,005	177,232	58,487
Ammonium nitrate-limestone mixtures	37,861	7,951	1,500	315
Ammonium phosphates	96,146	14,422	174,460	26,169
Ammonium sulfate	207,964	43,672	180,869	37,982
Calcium cyanamide or lime nitrogen	23,999	6,000	18,719	4,680
Calcium nitrate	54,740	8,485	33,200	5,146
Nitrogen solutions	82,163	28,757	73,584	25,754
Anhydrous ammonia	158,264	130,093	202,622	166,555
Potassium nitrate or saltpeter, crude	3,163	380	3,545	425
Potassium, nitrate, sodium nitrate mixtures	13,498	2,025	7,409	1,111
Sodium nitrate	363,216	58,115	391,943	62,711
Urea	271,485	123,526	225,785	102,732
Other	23,957	4,791	20,455	4,091
Total	1,536,631	494,278	1,511,563	496,242

[1] No longer separately classified.

WORLD REVIEW

Afghanistan.—The Ministry of Mining and Industry signed a contract with the Soviet trade organization, Neftechimpromexport, for the construction of a nitrogen fertilizer plant at the town of Mazar-Sherif, about 43 miles from the Soviet border. The plant, the first of its type in Afghanistan, was expected to have an annual capacity of 71,000 tons of ammonia, and its completion was scheduled for 1969.

Argentina.—Government approval was granted for Petrosur, a company comprised of both foreign and local interests, to build a fertilizer plant at Campana. The plant was designed for annual production of 55,000 tons of ammonia, 50,000 tons of ammonium sulfate, 30,000 tons of compound fertilizers, 39,000 tons of sulfuric acid, and 55,000 tons of urea. The facility was scheduled for operation in 1967.

Australia.—Imperial Chemical Industries of Australia and New Zealand (ICIANZ), with Conzinc Rio Tinto of Australia Ltd. planned to build a nitrogenous fertilizer plant at Newcastle, New South Wales.

Boral Ltd. and Mitsui & Co., a Japanese firm, announced plans to erect a 113,000-ton-per-year nitrogenous fertilizer plant near Sydney.

Table 6.—World production and consumption of nitrogen compounds, years ended June 30, by principal countries

(Thousand short tons of contained nitrogen)

Country	Production [e]			Consumption [e]		
	1962–63	1963–64	1964–65	1962–63	1963–64	1964–65
Australia	22	23	31	55	74	74
Austria	202	202	222	80	91	97
Belgium	321	309	392	148	155	165
Brazil	14	15	8	64	68	77
British West Indies	29	33	33	22	24	26
Bulgaria	109	123	229	82	111	193
Canada	522	516	542	166	209	254
Ceylon	---	---	---	33	44	44
Chile	194	199	214	47	45	66
China	362	497	551	819	1,017	1,085
Cuba	17	17	---	84	88	75
Czechoslovakia	177	179	185	187	214	234
Demark	---	---	23	161	173	191
Finland	50	74	87	73	90	107
France	982	1,200	1,349	905	1,052	1,122
Germany:						
East	418	421	414	328	346	419
West	1,617	1,739	1,809	1,146	1,164	1,253
Greece	---	32	39	120	128	149
Hungary	88	98	109	155	230	234
India	225	254	287	373	482	584
Indonesia	---	17	22	121	106	77
Ireland	---	---	---	36	36	30
Israel	26	29	31	29	30	33
Italy	930	994	1,067	531	532	585
Japan	1,570	1,738	1,874	1,049	1,113	1,182
Korea:						
North	99	99	99	110	110	110
South	44	63	71	248	169	254
Malawi, Southern Rhodesia, Zambia	---	---	---	25	25	49
Mexico	91	133	245	148	244	292
Netherlands	529	546	606	346	341	345
Norway	341	387	408	69	89	95
Pakistan	82	105	90	114	84	91
Peru	19	19	22	45	41	55
Philippines	9	9	10	53	55	55
Poland	394	424	460	407	435	466
Portugal	100	118	129	100	88	106
South Africa, Republic of	131	132	146	144	202	200
Spain	179	205	291	392	413	465
Sweden	61	83	80	142	157	177
Switzerland	28	35	36	31	32	35
Taiwan	94	121	175	130	170	212
U.S.S.R.	1,560	1,932	2,314	1,432	1,771	2,251
United Arab Republic (Egypt)	123	126	166	193	238	288
United Kingdom	820	895	966	850	922	952
United States	4,977	5,634	6,112	5,163	5,746	6,316
Viet-Nam, South	---	---	---	31	75	83
Yugoslavia	14	75	103	138	214	229
World total [1]	17,642	20,086	22,340	17,620	19,916	22,274

[e] Estimate.

[1] Includes quantities for minor producing and consuming countries not listed above.

Source: Nitrogen. No. 39, Jan.–Feb., 1966, pp. 15–16.

Mt. Morgan Grace Ltd., a new company jointly formed by Mount Morgan Ltd. and W. R. Grace & Co., was expected to put a new nitrogenous fertilizer plant on stream in Gladstone, Queensland, by 1967. Ammonia, ammonium sulfate, phosphoric acid, and mixed fertilizers were the planned products.

Ammonia Co. of Queensland Pty. Ltd., announced plans to construct a new anhydrous ammonia plant at Pinkenba, Queensland, for operation early in 1966.

Belgium. — Carbochimique, S.A., contracted to have a 1,000-ton-per-day anhydrous ammonia plant erected at Tertre, the site of the company's existing nitrogenous fertilizer facilities including a 132,000-ton-per-year ammonia plant. The new ammonia unit was scheduled for completion in 1967.

Société Belge de l'Azote et des Produits Chamiques du Marly (SBA) was expanding its facilities at Marly, near Brussels, with new units for producing ammonia, nitric acid, and calcium ammonium nitrate. The ammonia and nitric acid units were due on stream before the end of the year, while the nitrate plant was scheduled for operation by mid-1966.

Bulgaria.—A large chemical plant was reported under construction near Vraza. Units for producing anhydrous ammonia and 600,000 tons per year of urea were included. Also plans were made to begin construction in 1966 on a new petrochemical complex at Pleven, which would include plants for the production of about 200,000 tons per year of nitrogenous fertilizers. First products were expected from the new plants in 1968. Plans were made to expand nitrogenous fertilizer production to 700,000 tons per year (nitrogen content) by 1980.[2]

Canada.—Brockville Chemicals Ltd. was doubling the capacity of its anhydrous ammonia facility at Maitland, Ontario, to 450 tons per day. The firm also had a new urea plant with a daily capacity of 150 tons and a 250-ton-per-day nitric acid plant under construction at the same site. The new units were expected to produce by early summer of 1966.

Brunswick Mining & Smelting Corp. Ltd., announced plans for building an ammonia plant at Belledune Point, New Brunswick, to produce 1,000 tons daily. The date scheduled for completion was in late 1966 or early 1967.

A $50 million fertilizer complex was under construction at Courtright, Ontario, for Canadian Industries Ltd. In addition to a 1,000-ton-per-day anhydrous ammonia plant, units were being installed to produce nitric acid, ammonium nitrate, ammonium phosphate, urea, and phosphoric acid. The five plants were scheduled for completion by mid-1966.

Consolidated Mining & Smelting Co. of Canada, Ltd. (COMINCO), completed an ammonium phosphate plant near Regina, Saskatchewan, having an annual output capacity of 100,000 tons.

Cyanamid of Canada Ltd. had a $17 million expansion project underway at Welland, Ontario. The project included a new 700-ton-per-day anhydrous ammonia plant, and a urea plant, which will have a daily output capacity of 300 tons. Completion was expected by mid-1966.

Northwest Nitro Chemicals, Ltd. was building a new 600-ton-per-day anhydrous ammonia plant at Medicine Hat, Alberta.

Construction was reported to have started late in the summer on a chemical fertilizer facility near Brandon, Manitoba, for J. R. Simplot Chemical Fertilizer Co. The project, scheduled for completion in 1966, included units for annual production of 100,000 tons of anhydrous ammonia, 70,000 tons of nitric acid, 35,000 tons of urea, nearly 90,000 tons of ammonium nitrate, and about 250,000 tons of ammonium phosphate.

Construction was completed on a major expansion of the Sherritt Gordon Mines Ltd. fertilizer production facilities at Fort Saskatchewan, Alberta. The new installations were reported to have nearly doubled the firm's ammonia output capacity and tripled its urea production.

Western Cooperative Fertilizers, Ltd., put a new fertilizer plant on stream with daily production capacities of the individual units as follows: 200 tons of anhydrous ammonia, 600 tons of sulfuric acid, 190 tons of phosphoric acid, 160 tons of nitric acid, 215 tons of ammonium nitrate and 520 tons of ammonium phosphate.

Table 7.—Chile: Exports of nitrate in 1965, by countries [1]

(Short tons)

Destination	Quantity
Argentina	9,546
Australia	4,864
Belgium	20,097
Brazil	63,632
China	41,189
Denmark	33,841
France	52,154
Germany	2,222
Greece	12,470
India	15,013
Ireland	3,321
Japan	31,746
Lebanon	3,868
Mexico	15,680
Near East [2]	4,850
Netherlands	71,104
Peru	9,144
Spain	131,378
Sweden	4,409
United Kingdom	13,852
United States	439,769
Yugoslavia	3,858
Other Central and South America [3]	1,165
In transit	27,400
Total	1,016,572

[1] Includes 107,766 tons of potassium nitrate.
[2] Includes Jordan and Syria.
[3] Includes Colombia, Ecuador, El Salvador, and Uruguay.

[2] Nitrogen. Bulgaria Plans to Produce 700,000 t.p.a. N by 1980. No. 36, July 1965, pp. 22–23.

China.—The Wuching Chemical Works, in Shanghai, started limited production of urea in a new 40,000-ton-per-year plant. Also, the Chinese news agency reported that initial operation of the Hopei project, a large, modern nitrogenous fertilizer plant, had begun. The Government decreed that a series of new nitrogenous fertilizer plants with annual capacities of 25,000 tons of ammonia must be built. Many existing fertilizer plants were being reconstructed and expanded.

Colombia. — Industria Colombiana de Fertilizantes, S.A., 64-percent Government-owned, suspended operation of its chemical fertilizer plant at Barrancabermeja. A reorganization of the corporation and a redesigning and expansion of the plant for more economical operation were planned. Ammonium nitrate was the major product.

France. — Charbonnage de France, a Government-owned coal mining company, planned to invest about $20 million in a nitrogen-products plant with an output of 250,000 tons per year of nitrogen. The plant was to be erected at Nord-Pas-de-Calais.

Etablissement Kuhlman ordered a new ammonia plant built at its LeMadeleine plant near Lille.

A newly organized company, jointly owned by Compagnie Francaise de Raffinage, Office National Industriel de l'Azote, and Société Generale d'Engrais et Produits Chimiques Pierrefitte, was to establish an anhydrous ammonia plant near LeHavre. Production of 1,000 tons ammonia per day was scheduled to begin in 1967.

Germany, West. — A 1,000-ton-per-day ammonia plant and a 540-ton-per-day concentrated nitric acid plant was being built for Erdölchemie, G.m.b.H. at Dormagen between Cologne and Dusseldorf. The units were expected to be productive in 1966.

Two new urea plants were being constructed; a 165-ton-per-day unit at Luneburg for Salzgitter Chemie G.m.b.H. and a unit, capacity unknown, for Saarbergwerke, A.G. at Perl.

Greece.—It was reported that Government approval was given for a group of Greek companies to build a $45 million fertilizer plant in central Greece to be completed in 1967. Among the products to be produced was 165,000 tons per year of urea.

Hungary.—Projected plans for the new integrated chemical works being built at Szeged, established the following annual production capacities: 550,000 tons of nitrophosphates, 186,000 tons of calcium nitrate, and 212,000 tons of calcium ammonium potassium nitrate. However, construction which was underway indicated that the initial capacities would be about one-half of that ultimately planned.

The fertilizer facilities of Borsod Chemical Combine were being expanded, and it was hoped that by the end of the year the ammonia production capacity of the Borsod plant would be increased by 100,000 tons per year.

India.—Fertilizer Corporation of India commissioned a new nitrogenous fertilizer complex at Trombay. Annual capacities of the units included in the plant were stated as 115,000 tons of ammonia, 105,000 tons of nitric acid, 330,000 tons of nitrophosphate, 99,000 tons of urea, and 33,000 tons of methanol. An expansion project by Fertilizers & Chemicals Travancore, Ltd., at Alwaye, Kerala, to add 40,000-ton-per-year capacity, was to be completed by the end of the year.

The following plants were either under construction or approved for construction:[3]

[3] Bureau of Mines. Mineral Trade Notes. V. 61, No. 5, November 1965, pp. 41–43.
Nitrogen. Present Status of India's Nitrogen Expansion Programme. No. 37, September 1965, pp. 13–17.

Company and plant location	Annual capacity in metric tons of nitrogen	Date expected completion
Public sector: (Government plants)		
Neyveli, Madras	70,000	1966
Gorakhpur, Uttar Pradesh	80,000	1967
Namrup, Assam	45,000	1967
Durgapur, West Bengal	125,000	1968
Cochin, Kerla	165,000	1968
Korba, Madhya Pradesh	100,000	1969
Private sector:		
Coromandel Fertilizer Ltd., Visakhapatnam, Andhra Pradesh	80,000	1967
Gujarat State Fertilizer Co. Ltd., Baroda	96,000	1967
Hindustan Allied Chemicals, Ltd., Kothagudem, Andha Pradesh	100,000	1967
Birha Gwailor, Ltd., Goa	160,000	1968
Rajasthan Fertilizers & Chemicals Corp. Ltd., Kotah, Rajasthan	100,000	1968
Imperial Chemical Industries, Ltd., Kanpur, Uttar Pradesh	100,000	1968

Indonesia.—An Italian firm was contracted by the Government to build a fertilizer plant at Gresik to produce annually 7,000 tons of ammonia, 150,000 tons of ammonium sulfate, and 45,000 tons of urea. Operation of the plant was scheduled for 1966.

Iran. — National Petrochemical Co., a subsidiary of the National Iranian Oil Co., joined with Allied Chemical Corp. (U.S.) in a 50–50 partnership to develop a major petrochemical complex. Ammonia, urea, sulfur, and mixed fertilizers were planned for initial production.

Ireland.—A new ammonia plant at Arklow was put into operation in September by Nitrigin Eireann Teoranta (Irish Nitrogen, Ltd.) a State-owned company. Final products of the plant were said to be sulfate of ammonia and calcium ammonium nitrate with a combined annual capacity estimated at 150,000 tons.

Japan.—The Japanese Ministry of International Trade & Industry approved a general production expansion of 20 percent for existing ammonia plants. Many producers planned to have new, large-capacity single-train units built and scrap their existing facilities. Sumitomo Chemical Co. Ltd. was planning a 248,000-ton-per-year plant at Niihama to be completed near the end of 1966. Nissan Chemical Co. decided late in the year to replace its 85,000-ton ammonia plant with a 120,000-ton-per-year plant at Toyama. Ube Kosan Industry planned a 600-ton-per-day ammonia plant and a 300-ton-yer-day urea plant for building in the Sakai area. Mitsubishi Chemical Co. had an ammonia and a urea plant under construction at Mizushima. Annual capacities were stated as 180,000 and 73,000 tons respectively. At Sakai, Toyo Koatsu Industries Inc. were building a 500-ton-per-day ammonia plant and a 600-ton-per-day urea plant. These two plants, equipped with computer process control systems for complete automation, were due on stream in April 1966. Showa Denko K.K., contracted for a 500-ton-per-day ammonia plant to be built at its Kawasaki works near Tokyo. In addition, it was reported that Kasei Mizushima Co., Nihon Gas Chemical Co., Tokai Gas Co., Kyowa Chemicals Co. were expanding urea production capacities for a total increase of about 620 tons per day.

Korea, South.—Negotiations were completed for the construction of two fertilizer plants, each having an annual capacity of 84,000 tons of urea and 180,000 tons of mixed fertilizers. The new plants at Chinhoe and Ulsan were scheduled for completion early in 1967.[4]

The Japanese Government approved the sale of a $44 million urea plant to be erected by Japanese engineers. The plant, having an annual capacity of 330,000 tons of urea, was to be completed 1 year after the signing of the construction contract.[5]

Kuwait. — A 120,000-ton-per-year ammonia plant was to be completed by the end of the year at Shuaibeh, 20 miles south of the city of Kuwait. The Government expects to export nearly all of the production.

Lebanon.—Esso Fertilizer Co., a new company formed by Esso Mediterranean, Inc., and Elie J. Doumet S.A.L. of Lebanon, contracted with an Italian firm to erect a nitrogenous fertilizer plant having

[4] Bureau of Mines. Mineral Trade Notes. V. 61, No. 4, October 1965, p. 40.
[5] Oil, Paint and Drug Reporter. Urea Plant In Korea To Be Built by Japan. V. 188, No. 2, July 12, 1965, pp. 5, 48.

a capacity of 140,000 tons per year. The facility located at Ras Saalata, near Beirut, was to be completed in 1966.

Mexico. — Petroleos Mexicanos (PEMEX), awarded a contract for the construction of a 1,000-ton-per-day anhydrous ammonia plant at Minatitlan. It was reported that PEMEX also started construction of a 50,000-ton-per-year ammonia and fertilizer plant at Ciudad Camargo, Chihuahua, and planned a similar facility for Frontena, Tabasco.

Netherlands.—Maatschappij tot Exploitatie van Kooksovengassen, N.V. (MEKOG) had a 400-ton-per-day urea plant under construction at Pernis, near Rotterdam. Production was expected in 1966.

A new company, Ammoniak Unie N.V., jointly formed by Badische Anilin-und-Soda Fabrik A.G. and Verenigde Kunstmestfabrieken Mekog-Albatros N.V., started construction on a 300,000-ton-per-year ammonia plant at Pernis. First production was scheduled for October 1966.

Esso Nederland NV was building a 300,000-ton-per-year ammonia plant and associated urea facilities near Rotterdam. The plants were expected to be in operation early in 1968.

Nederlandse Stikstof Maatschappij N.V. was expanding its ammonia production facilities near Terneuzen with a new 160,000-ton-per-year unit scheduled for completion in early 1966.

Norway.—Norsk Hydro-Elektrisk A/S, Norway's principal producer of nitrogenous materials completed a 100,000-ton-per-year ammonia plant early in the summer at its chemical center in Herøya. The firm then started construction of another unit to produce annually 50,000 tons, and scheduled an additional unit for completion in 1967. The capacity of the company's urea plant at the same site was also being expanded from 150,000 tons to 250,000 tons.

Pakistan.—A urea plant with an annual capacity of 173,000 tons was planned for Dharki-Mari, West Pakistan, by Esso Pakistan Fertilizer Co. Ltd. The plant was scheduled for completion in 1967.

A contract was reportedly awarded to a consortium of six Japanese firms to erect a 150,000-ton-per-year urea plant in East Pakistan.

Peru.—A new nitrogenous fertilizer plant went on stream at Cuzco. Anhydrous ammonia capacity was stated to be only 14,000 tons per year, but the plant was designed for future expansion to twice this amount. The ammonia is converted to nitric acid and calcium ammonium nitrate.

Philippines. — Completion of the Esso Standard Fertilizer & Agricultural Chemical Co. fertilizer plant was expected by yearend. Units with production capacities of 300 tons per day of ammonia and 200 tons per day of urea were included in the project.[6]

Poland.—A new ammonia plant was reported in production at the Kedzierzyn nitrogen facilities. A daily output of 165 tons of ammonia was expected to produce 165,000 tons of calcium ammonium nitrate annually as the final product. This was the first ammonia plant in Poland to use methane from coke-oven gas for feedstock.

The first ammonium nitrate plant in Poland started production at Tarnow. The capacity was given as 30,000 tons per year. Most of the output was scheduled for use as a raw material for producing caprolactam.

The first stage of a complete nitrogenous fertilizer plant at Pulawy was to be completed by the end of the year, and the ammonia, nitric acid, and ammonium nitrate plants, with daily capacity of 1,650, 2,975, and 3,680 tons respectively were to be completed by mid-1968.

Rumania.—The ammonia, nitric acid, and ammonium nitrate units of the Cravaiova chemical combine were not completed in 1964 as scheduled, but they were expected to be in operation by the end of 1965.

South Africa, Republic of.—According to reports, Fisons (Pty.) Ltd. signed a contract for the construction of a 100,000-ton-per-year ammonia plant at Milnerton, near Cape Town. The plant, to be completed by the end of 1966, was the first of three included in the project. The other two, a nitric acid unit and an ammonium nitrate unit, were to follow.[10]

African Explosives & Chemical Industries Ltd. was erecting a new 160,000-ton-per-year urea plant near Durban. The completion date was scheduled for 1967.

Spain.—The first ammonium nitrosulfate plant built in Spain was completed for Sociedad Espanola de Fabricaciones Nitrogenadas S.A. The annual capacity was

[6] Nitrogen. New Plants and Projects. No. 37, September 1965, p. 10.

[10] European Chemical News (London). Progress on Cape Town Fertilizer Complex. V. 7, No. 170, Apr. 16, 1965, p. 24.

stated to be 130,000 tons. Spanish firms in the nitrogen fertilizer sector were reportedly discussing the formation of a trade organization.[7] Fertilizantes de Iberia S.A. planned to build a 50,000-ton-per-year ammonia plant at La Coruna, a 75,000-ton-per-year ammonium sulfate plant at Huelva, and a complex fertilizer plant at Castellon. The firm was reported to be completing at Castellon a nitric acid plant with an annual capacity of 82,500 tons and a 120,000-ton-per-year ammonium nitrate plant.

It was reported that Fertilizantes Valencia S.A., a newly formed company, planned to build an ammonia plant at Valencia,[8] and Cros S. A. had plans for a new nitric acid and ammonium nitrate plants with annual capacities of 85,000 tons and 100,000 tons respectively to be erected at its Badalona facility.[9]

Sweden.—The first urea plant in Sweden was put on stream by Svenska Saltpeterverken A.B. at Koeping. The annual output capacity was stated to be 55,000 tons. The firm also began operating a newly constructed 50,000-ton-per-year ammonia plant at Kvarntorp.

Syria.—A fertilizer complex including a 150-ton-per-day ammonia plant at Homs was scheduled for completion by the end of 1967.

Taiwan. — Taiwan Fertilizer Corp. planned to build new urea and ammonium sulfate plants with annual output capacities of 100,000 and 150,000 tons respectively. Both plants were expected to be on stream by 1968.[10]

Trinidad.—Federation Chemicals Ltd., expected to have its second 200,000-ton-per-year anhydrous ammonia plant completed by the end of 1965.

Tunisia.—A fertilizer complex was being built at Gabès, which will include facilities for the production of anhydrous ammonia, nitric acid, ammonium nitrate, and ammonium phosphate. An annual output of about 200,000 tons of ammonium phosphate and 85,000 tons of nitrate was expected, most of which would be exported.

U.S.S.R.—The Navoi Works in central Asia, one of the largest chemical complexes in the U.S.S.R., started initial ammonia production. When in full production, the ammonia plant in the Ukraine.[11]
be 500,000 tons.

A contract was signed with a French firm to construct a 400,000-ton-per-year ammonia plant in the Ukraine.[12]

United Kingdom.—Shellstar Ltd., jointly formed by Shell Chemical Corp. (U.K.) and Armour & Co. (U.S.), became fully operational in November and announced plans for erecting a 1,000-ton-per-day ammonia plant and related fertilizer units at Ince Marshes, Ellesmere Port, Cheshire. The new plant was scheduled for operation in 1968.

The largest ammonia-producing project in the world was under construction at the Imperial Chemical Industries, Ltd., (ICI) Billingham Works on the Tees estuary. The project includes three identical single-train units, each having an annual capacity of 300,000 tons and was scheduled for operation in 1966. ICI began producing ammonium nitrate fertilizer at its new 300,000-ton-per-year plant at Severnside near Bristol, and it expected to have a second plant with an annual capacity of 360,000 tons in production by 1967. Also at Severnside, ICI put a new 190,000-ton-per-year ammonium plant on stream early in the year.

Yugoslavia.—Construction was started on a highly automated nitrogenous fertilizer plant at Kutina. The project, scheduled for completion in 1967, included a 100,000-ton-per-year urea unit, a 250,000-ton-per-year ammonium nitrate unit, and a complex fertilizer unit with an annual output of 45,000 tons.

TECHNOLOGY

James E. Carnahan and Leonard E. Mortenson discovered an electron carrier, ferredoxin, which enables bacteria to fix atmospheric nitrogen. Harold J. Evans found that a minute amount of cobalt is essential for bacterial nitrogen fixation. The addition of 0.1 part per billion of cobalt gave a 12-fold increase in the growth of soybean plants. These three

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[7] Chemical Age (London). Spanish Producers May Set Up Nitrogen "Cartel." V. 94, No. 2415, Oct. 23, 1965, p. 620.

[8] Nitrogen. New Plants and Projects. No. 38, November 1965, p. 8.

[9] European Chemical News (London). Nitrogen Fertilizer Plant for S. A. Cros. V. 8, No. 186, Aug. 6, 1965, p. 32.

[10] E&MJ Metal and Mineral Markets. V. 36, No. 37, Sept. 13, 1965, p. 5.

[11] European Chemical News (London). Ensa To Build Fertilizer Complex in Ukraine. V. 8, No. 185, July 30, 1965, p. 8.

scientists shared in winning the 1965 Hoblitzelle National Award in Agricultural Sciences. It was said that the ability to regulate this process will be of inestimable value in the efficient production of food and fiber.[12]

Large capacity, 600- to 1,000-ton-per-day, ammonia plants were being engineered and built. The plants are based on a new integrated design that was said to appreciably lower the production cost. Gas preparation, purification, and ammonia synthesis, previously operated as separate units, were combined into a single-train plant. The use of multistage centrifugal compressors was responsible for much of the cost reduction. A single centrifugal compressor was said to replace several banks of reciprocating compressors, thus reducing equipment costs, floor space, and supporting foundations.[13] Operating cost per ton of ammonia produced in a 1,000-ton-per-day plant using naphtha feed, centrifugal compressors, and steam turbines was estimated at $28.97 compared with $37.06 per ton by three 330-ton-per-day plants using motor-driven reciprocating compressors.[14] Using natural gas as the raw material the cost per ton was $25.58 for the 1,000-ton-per-day plant.

An article was published which discussed basic questions that confront a company about to build a new ammonia plant.[15] The latest improvements in plant design and operation were considered in discussing steam reforming, CO conversion, CO_2 removal, ammonia-synthesis, and costs.

A new process [16] to prepare coke-oven gas for cryogenic processing and ammonia production was being built into the United States Steel Corp. chemical complex at Clairton, Pa. The total ammonia recovery was claimed to reach 99.5 percent. The new process produces a clean gas ready for compression for hydrogen recovery and avoids the production of ammonium sulfate which is currently in over capacity.[17]

A new process for making urea, called the Thermo-Urea hot-gas recycle process, was patented.[18] Because the process requires the use of centrifugal compressors, as in the new large capacity ammonia plants, it cannot be pilot-planted. A huge volume of gas is required for the efficient operation of centrifugal compressors. The proof of the technical and economic advantages of the process will have to wait until someone builds a 1,500-ton-per-day or larger plant using it.[19] Chemical Construction Corp. found that single-train urea plants with capacities up to 2,000 tons per day are technically feasible and more economical both in operating and capital costs per ton of urea produced. It was reported that urea can be made with the new process in a 1,500-ton-per-day or more plant for about $27 per ton using $18-per-ton ammonia.[20]

Dutch State Mines developed an improvement in its well-known recycle urea process. After tests in a 50-ton-per-day pilot plant, construction was started on a 220-ton commercial unit to use the process. The process was expected to lower utilities consumption, decrease capital cost requirements, and result in a simpler, more trouble-free operation.[21]

A paper was published which described the Stengel process for the manufacture of concentrated solutions of ammonium nitrate.[22] The authors stated that the process has two advantages in capital costs. The plants are small in comparison to those required by other processes of the same production rates and the reaction and concentration steps are in one stage, thus saving the cost of separate concentrator.

A new process was developed by Oesterreichische Stickstoffwerke A.G. (OSW) Linz, Austria, whereby melamine can be produced continuously from urea at atmospheric pressures. It was claimed that the product is 99.9 percent pure and does

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[12] Farm Chemicals. "Fixing" Nitrogen Fixation. V. 128, No. 8, August 1965, p. 45.
[13] Chemical Engineering. The New Look in Ammonia Plants. V. 72, No. 24, Nov. 22, 1965, pp. 124–126.
[14] European Chemical News Large Plant Supplement. The Design and Economics of Large, Single-Train Ammonia Plants. V. 8, No. 191, Sept. 10, 1965, pp. 34, 36.
[15] Chemical Engineering. Questions and Answers on Today's Ammonia Plants. V. 72, No. 13, June 21, 1965, pp. 109–118.
[16] Rice, Robert D. Method of Recovering Ammonia From Coke-Oven Gasses. U.S. Pat. 3,024,090, Mar. 6, 1962.
[17] Chemical Week. Cool Gain for Ammonia Recovery. V. 96, No. 9, Feb. 27, 1965, p. 39.
[18] Cook, Lucien H., and Ivo Mavrovic (Chemical Construction Corp.). Urea Synthesis Process. U.S. Pat. 3,200,148, Aug. 29, 1962.
[19] Chemical & Engineering News. Big Urea Plants Make New Process Possible. V. 43, No. 36, Sept. 6, 1965, pp. 120–121.
[20] Chemical & Engineering News. Urea Follows Ammonia in Trend to Huge Plants. V. 43, No. 35, Aug. 30, 1965, pp. 32–33.
[21] European Chemical News (London). Improved DSM Process Reduces Urea Costs. V. 8, No. 194, Oct. 1, 1965, pp. 32–34.
[22] Chemical Trade Journal and Chemical Engineer. The Stengel Process for Ammonium Nitrate. V. 156, No. 4053, Feb. 11, 1965, p. 178.

not require recrystallization. Melamine is an important chemical in the plastics industry and has been relatively expensive because production costs are high using the conventional dicyandiamide route. The new process [23] may lead to much lower production cost.

Several new uses were developed for nitrogen and nitrogen compounds. The Army modified a Chevrolet pickup truck to operate using ammonia as fuel. And research studies were completed in General Motors Corp. laboratories showing that ammonia-fueled engines can be developed to perform as well as the present gasoline-fueled auto engines.[24] A liquid ammonia battery was developed which can operate within a temperature range of minus 65° to plus 165° F for extended periods.[25] The Chowchilla Water District repaired a 75-mile stretch of leaky concrete pipe by a simple method of filling the pipe with ammonia solution. The solution precipitated calcium carbonate which set in the cracks and stopped the leaks. After the ammonia water was drained and the pipe was allowed to dry for several days, it was ready for use.[26] A paper was published suggesting the use of ammonia in the reduction or "poling" process in copper refining. Test data obtained in pilot plant studies showed an average ammonia consumption of 1 kilogram per ton of copper produced. Several advantages in using ammonia instead of the old method of copper poling with wood were cited.[27] Research engineers of Illinois Institute of Technology in Chicago developed a new device for freezing food with nitrogen. Liquid nitrogen is sprayed on the food in a horizontal cylindrical chamber. The new method is more efficient and is capable of processing several times as much food in a unit equal in size to one using the old method of immersion freezing.[28]

[23] Chemical Engineering. A New Route to Melamine From Urea. V. 72, No. 21, Oct. 11, 1965, pp. 180–182.

[24] Steel. Army Discloses Energy Fuel Depot Concept. V. 158, No. 2, Jan. 11, 1965, p. 76.

[25] Missiles and Rockets. Honeywell Building Ammonia Batteries. V. 16, No. 18, May 3, 1965, p. 21.

[26] Chemical Engineering. Treatment With Ammonia Solution Stops Leak in Concrete Pipes. V. 72, No. 2, Jan. 18, 1965, p. 85.

[27] Journal of Metals. Copper Refining by Gaseous Ammonia. V. 17, No. 4, April 1965, pp. 386–388.

[28] Chemical Week. V. 96, No. 8, Feb. 20, 1965, p. 92.

Perlite

By Timothy C. May [1]

The domestic production of both crude and expanded perlite continued to show an annual increase. Production of crude perlite increased 18 percent, and expanded perlite was 7 percent more than 1964. The output of crude perlite sold or used by producers continued to gain in 1965. Perlite sold or used by producers increased 12 percent in quantity and 9 percent in value.

DOMESTIC PRODUCTION

During 1965, there were 17 companies operating 18 mines in nine States, compared with 16 companies operating 17 mines in eight States in 1964. Western Gravel Co., Esmeralda County, Nev., reported perlite production for the first time. New Mexico led in total production with 84 percent. Other producing States in order of output, were Arizona, California, Nevada, Colorado, Idaho, Utah, Texas, and Oregon.

Perlite was expanded by 83 companies at 97 plants; 3 companies and 3 plants less than in 1964. California with 12 plants had the greatest number of expanding plants, but it ranked fourth in output. Illinois with nine expanding plants was the largest producing State of expanded perlite. The 10 largest producing States in order of output with number of plants were the following: Illinois with 9 plants; Texas, 7; Kentucky, 2; California, 12; Colorado, 3; Mississippi, 1; Pennsylvania, 6; Maryland, 3; Ohio, 3; and New York, 4.

[1] Commodity specialist, Division of Minerals.

Table 1.—Crude and expanded perlite produced and sold or used by producers in the United States

(Thousand short tons and thousand dollars)

Year	Crude perlite						Expanded perlite		
	Quantity mined	Sold		Used at own plant to make expanded material		Total quantity sold and used	Quantity produced	Sold	
		Quantity	Value	Quantity	Value			Quantity	Value
1956–60 (average)	394	207	$1,797	101	$798	308	255	253	$13,048
1961	374	196	1,665	114	998	310	240	235	12,605
1962	408	198	1,611	122	1,052	320	238	234	12,536
1963	404	203	1,631	122	1,096	325	272	270	14,497
1964	427	211	1,845	139	1,228	350	320	319	14,533
1965	502	231	1,731	161	1,621	392	343	344	15,391

Table 2.—Expanded perlite produced and sold by producers in the United States

State	1964 Quantity produced	1964 Sold: Quantity (short tons)	1964 Sold: Value	1964 Sold: Average value per ton	1965 Quantity produced	1965 Sold: Quantity (short tons)	1965 Sold: Value	1965 Sold: Average value per ton
California	20,470	20,400	$1,266,000	$62.06	29,650	29,700	$1,568,000	$52.79
Florida	6,590	6,590	405,000	61.46	5,250	5,210	335,000	64.30
Illinois	52,320	52,330	1,930,000	36.88	(1)	(1)	(1)	(1)
Iowa	5,700	5,700	232,000	40.70	5,130	5,140	214,000	41.63
Kansas	570	570	33,000	57.89	660	660	48,000	72.73
Ohio	7,190	7,200	498,000	69.17	9,090	9,090	636,000	69.97
Pennsylvania	13,720	13,650	842,000	61.68	11,990	11,950	775,000	64.85
Tennessee	(1)	(1)	(1)	(1)	1,900	2,930	332,000	113.31
Texas	40,380	40,320	2,492,000	61.80	35,690	35,690	2,313,000	64.81
Other Eastern States [2]	120,750	120,790	5,002,000	41.41	192,350	192,410	7,193,000	37.38
Other Western States [3]	51,840	51,820	1,833,000	35.37	50,790	50,790	1,979,000	38.96
Total	319,530	319,370	14,533,000	45.51	342,500	343,570	15,393,000	44.80

[1] Included with "Other Eastern States."
[2] Includes Georgia, Indiana, Kentucky, Maryland, Massachusetts, Michigan, Mississippi, New Hampshire, New Jersey, New York, North Carolina, Virginia, and Wisconsin.
[3] Includes Arizona, Colorado, Idaho, Louisiana, Minnesota, Missouri, Nebraska, Nevada, Oregon, and Utah.

CONSUMPTION AND USES

The following end-use percentages were reported by producers of expanded perlite: Building-plaster aggregate, 40; filter aid, 17; concrete aggregate, 12; loosefill insulation (including low-temperature and silicone treated), 4; soil conditioning, 2; filler, 1; and other, 24.

PRICES

The average value of crude perlite crushed, cleaned, and sized, f.o.b. producers' plants, sold to expansion plants was $7.49 per short ton compared with $8.74 in 1964. The average value of crude perlite used by producers in their own expanding plants in 1965 was $10.07 compared with $8.83 in 1964. A weighted average of these two categories was $8.55 compared with $8.78 (revised) in 1964.

The average value of all expanded perlite sold in 1965 was $44.80 compared with $45.50 in 1964.

WORLD REVIEW

Associate members of Perlite Institute, Inc., 45 West 45th St., New York, in foreign countries include two firms in England, and one each in Australia, France, West Germany, Greece, Japan, Mexico, and New Zealand.

Canada.—Crude perlite to be expanded in Canada was imported from the United States.

The perlite plants located in Canada in 1964 were as follows:

Company	*Plant location*
Canadian Gypsum Co. Ltd.	Hagersville, Ontario.
Domtar Construction Materials Ltd.	Caledonia, Ontario.
	Calgary, Alberta.
Laurentide Perlite, Inc.	Charlesbourg West, Quebec.
Perlite Industries Reg'd.	Ville St. Pierre, Quebec.
Perlite Products Ltd.	Winnepeg, Manitoba.
Vantec Industries Ltd.	Richmond, British Columbia.
Western Gypsum Products Ltd.	Vancouver, British Columbia.

Production of expanded perlite in 1964 was 92,057 cubic yards valued at $748,000, an increase of 2.8 percent in quantity and 3.5 percent in value over the 1963 figure. Of the 1964 production, 81 percent was used in plaster aggregate, 9 percent in insulating concrete, and the remaining 10 percent in horticulture, insulation, acoustics, and other miscellaneous items. Expanded perlite was sold at 25 to 35 cents per cubic foot, f.o.b. plant, and was marketed in bags of 3 and 4 cubic feet.[2]

Chile.—The newly established Perlita Cia., Ltda., a Chilean-controlled mining group with claims in the Laguna de Maula area, southeast of Talca, announced that it expected to mine perlite.[3]

Greece.—Production of crude perlite was 31,000 tons in 1964, compared with 33,000 tons in 1963.

United Kingdom.—Northern Ireland produced 1,977 tons of crude perlite in 1964, compared with 4,362 tons in 1963.

TECHNOLOGY

At the Perlite Institute annual meeting technical reports and discussions covered concrete certification program, diaphragm roof deck design, perlite insulating concrete, structural perlite concrete, high-speed photography of perlite expansion progress, bulk handling, plaster-machine demonstrations, and perlite masonry mortars.

The Velikii Sholles Ridge, the basin of the Viznitsa River, and the Bergovskoe Hills are three areas of perlite occurrence in the Soviet Carpathians that appear to have the most promising resources and quality of volcanic glasses. Perlite, obsidian perlites, perlite lava breccia, and glassy volcanic tuffs are widely distributed over the Bergovskoe deposits. The volcanic glasses have a composition of 85 to 95 percent glass, and 5 to 10 percent of inclusions of various minerals.[4]

To classify materials as lightweight-aggregates suitable for concrete mixes, bulk density limits were specified by the British Standards Institution. The standards describe requirements for expanded perlite, exfoliated vermiculite, pumice, and expanded shale.[5]

Design values for the thermal conductivity of expanded perlite at reduced pressure were developed based on various literature data. The paper details the prediction of design values of conductivity under evacuated conditions.[6]

The use of expanded perlite along with colloidal attapulgite in high water-loss mud used for recovering lost circulation in well-drilling operations was patented.[7]

The use of expanded perlite as a replacement for silica gel in low-cost powder-in-vacuum thermal insulation applications was patented.[8]

A method was patented for the production of uniformly expanded perlite.[9]

A method for making colored aggregate was patented. An adherent ceramic overglaze composition is applied to closed cellular-bloated inorganic particles, such as expanded perlite, and then the applied composition is fused.[10]

A patent was issued for a method to insulate double-walled storage tanks. While crude perlite expands in a portable apparatus adjacent to the tank, the expanded material is admixed with cool air and blown directly into the space between the tank walls.[11]

A patent was granted for the use of perlite admixed with asphalt as a binder to be used in the collection and disposal of waste oil on garage or shop floors.[12]

[2] Wilson, H. S. Lightweight Aggregates, 1964 (Preliminary). Canada Dept. Mines and Tech. Surveys (Ottawa), April 1965, 6 pp.
[3] Bureau of Mines. Mineral Trade Notes. V. 61, No. 1, July 1965, p. 31.
[4] Soloninko, I. S. Volcanic Glasses in the Soviet Carpathians. Mineralog. Sb. L'vovsk. Gos. Univ., v. 18, No. 4, 1964, pp. 426–432; Chem. Abs., v. 63, No. 11, Nov. 22, 1965, col. 14565F.
[5] British Standards Institution. Specification for Light-Weight Aggregates for Concrete. British Standard 3797, 1964, 8 pp.
[6] Adams, L. Thermal Conductivity of Evacuated Perlite. Cryogenic Tech., v. 1, No. 6, June 1965, pp. 249–251.
[7] Coyle, A. I., and E. W. Sawyer, Jr., (assigned to Minerals & Chemicals, Philipp Corp.). Method of Recovering Lost Circulation in Drilling Wells and Fluid Therefor. U.S. Pat. 3,208,523, Sept. 28, 1965.
[8] Matsch, L. C. (assigned to Union Carbide Corp.). U.S. Pat. 3,169,927, Feb. 16, 1965.
[9] Carpenter, G. Methods of Expending Perlite and Like Materials. U.S. Pat. 3,201,099, Aug. 17, 1965.
[10] Harlan, R. B. (assigned to Colorite Co.). Color Coated Cellular Inorganic Aggregate. U.S. Pat. 3,198,656, Aug. 3, 1965.
[11] Wavering, G. A., and C. Mendius (assigned to Silbrico Corp.). System for Treating and Handling Perlite and the Like. U.S. Pat. 3,206,905, June 21, 1965.
[12] Peterson, W. W., and O. N. Gregg (assigned to Compositions, Inc.). Method and Device for Oil Collection and Disposal. U.S. Pat. 3,195,683, July 20, 1965.

A heating-cooling savings calculator was developed by the Perlite Institute, Inc., New York. The manually operated calculator is carried in the pocket and provides a rapid method for estimating the actual dollars saved by the exterior masonry walls, which are insulated with silicone-treated perlite.

Phosphate Rock

By Richard W. Lewis [1]

Domestic production of marketable phosphate rock has increased for seven consecutive years and indications are that it will continue to do so for several years more. The consistent annual increases were due chiefly to increased demands for fertilizer. The marketable production in 1965 was 15 percent above the 1964 output.

Legislation and Government Programs.—The Bonneville Power Administration's plan to supply low-cost electrical energy into southern Idaho was revived when when Public Works Appropriation Act, H.R. 9220 was introduced containing a $1 million appropriation for planning and constructing a high-voltage transmission line line from the Bonneville area to southern Idaho. However, the following provisions were included: "Provided, that the Bonneville Power Administration shall not supply power, directly or indirectly, to any phosphorus electric furnace plant in southern Idaho, Utah, or Wyoming: Provided further that the Administrator of the Bonneville Power Administration shall cancel contract number 14–03–44107, executed April 9, 1964, with the Monsanto Company." The Act was passed October 28, 1965.

A group of six Florida phosphate rock producers involved in a civil antitrust complaint in 1964 agreed to a judgment by the Department of Justice forbidding them to fix prices. Each company was required to issue new price lists based on independent appraisal. Charges against three other firms in the 1964 suit were dropped completely.

Similar action was taken by the Department of Justice in closing out antitrust charges made in 1964 against several Western phosphate fertilizer producers. In this case fines also were imposed.

The decision by Interstate Commerce Commission authorizing Norfolk Southern Railway Co. to construct a railroad line into the phosphate area of Beaufort County, N.C., was upheld in the Federal Courts after 2 years of litigation. Norfolk Southern's exclusive rights had been contested by the Atlantic Coast Line Railroad.

[1] Commodity specialist, Division of Minerals.

Table 1.—Salient phosphate rock statistics

(Thousand long tons and thousand dollars)

	1956–60 (average)	1961	1962	1963	1964	1965
United States:						
Mine production	49,541	60,535	56,746	61,598	66,494	75,389
Marketable production	15,597	18,559	19,382	19,855	22,960	26,440
Value	$99,021	$130,535	$134,304	$139,861	$161,067	$194,552
Average per ton	$6.34	$7.03	$6.93	$7.04	$7.02	$7.36
Sold or used by producers	15,346	17,842	19,060	19,860	22,081	26,045
Value	$97,762	$125,593	$134,222	$140,642	$156,738	$189,824
Average per ton	$6.36	$7.04	$7.04	$7.08	$7.10	$7.28
Exports [1]	3,086	3,918	3,934	4,547	5,691	6,654
P_2O_5 content	997	1,261	1,269	1,480	1,835	2,100
Value	$20,175	$26,924	$27,567	$31,881	$39,717	$65,632
Average per ton	$6.52	$6.87	$7.01	$7.01	$6.98	$9.86
Imports for consumption	119	134	134	161	156	132
Value	$3,167	$3,629	$3,551	$3,651	$3,329	$2,980
Average per ton	$26.56	$27.08	$26.57	$22.68	$21.68	$22.58
Consumption, apparent [2]	12,380	14,058	15,260	15,474	16,546	19,523
World: Production	36,080	44,780	47,540	50,420	58,130	64,600

[1] As reported to the Bureau of Mines by domestic producers.
[2] Measured by sold or used plus imports minus exports.

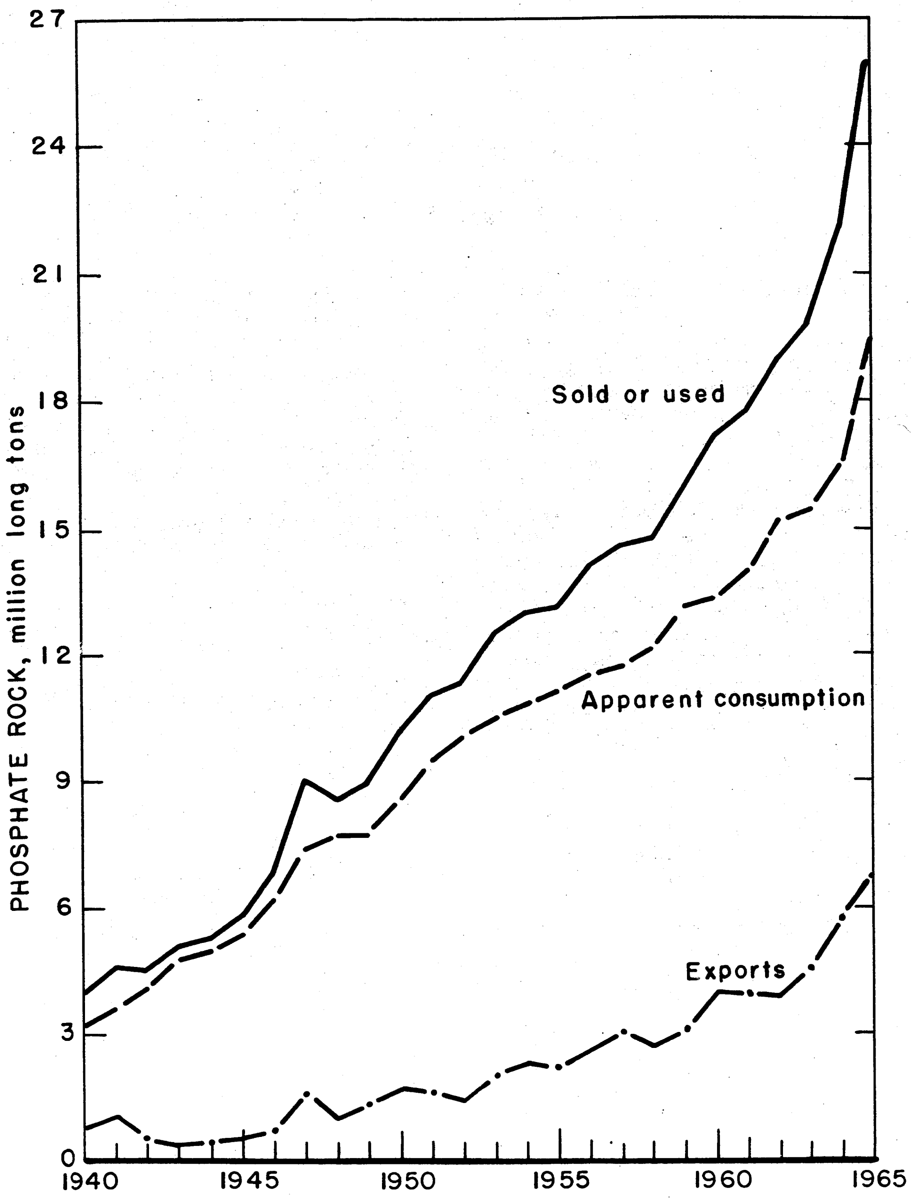

Figure 1.—Phosphate rock (sold or used), apparent consumption, and exports.

DOMESTIC PRODUCTION

The greatest increase in domestic marketable rock production occurred in Florida, with new production facilities as well as expanded existing facilities. Florida's production of 19 million tons accounted for about 73 percent of the total domestic output, the 10 Western States 17 percent and Tennessee 10 percent.

One of the largest fertilizer complexes in Florida was put on stream by The American Agricultural Chemical Co., near South Pierce, Fla. Diammonium phosphate and triple superphosphate output capacities were stated to be 30 and 60 tons per hour, respectively. The phosphoric acid unit is capable of 325 tons per day while 75 tons of hydrofluosilic acid per day can be recovered as a byproduct. A 1,250-ton-per-day sulfuric acid plant also was included in the new facility. A second sulfuric acid and phosphoric acid unit was put into operation about 6 months later. These units were said to have initially produced 1,200 tons of sulfuric acid per day and 325 tons per day of phosphoric acid.

American Cyanamid Co. expanded its Brewster, Fla, plant by installing a 200,000-ton-per-year diammonium phosphate unit. The company announced further expansion of operations with the development of a new mine near Bradley, Fla., construction to begin early in 1966. The new mine, called the Chicora Mine, was expected to be in operation sometime in 1967 and would include modern washing and flotation plants. A 42-cubic yard capacity dragline was ordered to be erected at the mine site and was to be completed in the spring of 1966.

A new phosphoric acid plant was constructed at Bartow, Fla., by Armour Agricultural Chemical Co. The new unit was to replace an old unit and was reported to bring Armour's total phosphoric acid production capacity in Florida to about 700 tons per day. This includes the output of a similar unit at Fort Meade.

Borden Chemical Co., began construcstion on a phosphate fertilizer complex about 9 miles north of Palmetto, Fla. The facility was scheduled for completion in the latter half of 1966. Initial plant capacity was given as 184,000 tons of product annually, the major products being triple superphosphate and diammonium phosphate. A sulfuric acid unit to produce 385,000 tons annually and a 140,000-ton-per-year phosphoric acid unit also was planned for the complex.

Central Phosphates, Inc., a subsidiary of Cherokee Chemical Co., had under construction, facilities for producing high analysis fertilizers. A sulfuric acid plant, a 500-ton-per-day phosphoric acid plant, a triple superphosphate plant, and a diammonium phosphate plant were included in the complex.

Consumers Cooperative Association was having a large fertilizer complex built about 18 miles south of Lakeland, Fla. Principal units of the plant, according to original plans, included a sulfuric acid plant, a 150,000-ton-per-year phosphoric acid unit, a 200,000-ton-per-year diammonium phosphate unit and a plant to produce 80,000 tons of triple superphosphate per year. The entire complex was expected to be in operation by the end of the year.

International Minerals & Chemical Corp. (IMC) completed an expansion program at its Bonnie phosphate complex near Bartow, Fla. Annual production capacity was increased by 33 percent for a total output of 1.2 million tons of product per year. The expansion included a third phosphoric acid unit and a second diammonium phosphate unit. Later in the year, the firm announced another expansion of its phosphate rock producing facilities, involving an investment of about $9 million, which would increase IMC's mineral producing capacity another 33 percent. The new facility, scheduled for operation in September 1966, near Mulberry, Fla., consists of washing, beneficiation, and preparation plant units capable of producing at least 2 million tons of phosphate rock annually.[2]

Kerr-McGee Corp. announced plans for the establishment of a phosphate mining and processing facility near Brewster, Fla. The installation would include a 40-cubic-yard capacity dragline for the mining operation, a washing plant, a flotation plant, and a product drier. The facility, having a production capacity of 1.5 million tons of marketable phosphate rock annually, was scheduled for completion in October 1966.

Occidental Petroleum Corp. formed a new subsidiary, Occidental Agricultural Chemicals Corp. (Oxychem), to consolidate its widespread fertilizer operations into a single operating group. Occidental Corporation of Florida, one of the group in Oxychem, began operations at its new Suwannee River mine in Hamilton County. Fla. The phosphate recovery plant at the mine site, began operations with an initial output capacity of 1.5 million tons of marketable rock. The capacity was to be doubled within the next year. In addition, construction was started of a phosphate fertilizer complex about a mile from

[2] Commercial Fertilizer and Plant Food Industry. V. 111, No. 3, September 1965, pp. 27, 30.

Table 2.—Mine production of phosphate-rock ore in the United States, by States

(Thousand long tons)

Year	Florida Rock	Florida P_2O_5 content	North Carolina Rock	North Carolina P_2O_5 content	Tennessee[1] Rock	Tennessee[1] P_2O_5 content	Western States[2] Rock	Western States[2] P_2O_5 content	Total Rock	Total P_2O_5 content
1956–60 (average)	44,058	5,553			2,784	596	2,699	706	49,541	6,855
1961	54,403	7,552			3,321	734	2,811	740	60,535	9,026
1962	49,600	7,093			3,812	855	3,334	875	56,746	8,823
1963	54,445	8,069			4,131	921	3,022	808	61,598	9,798
1964	58,078	9,410	80	3	4,217	935	4,119	1,020	66,494	11,368
1965	64,660	10,343	(3)	(3)	4,692	980	6,037	1,503	75,389	12,826

[1] Includes brown rock, white rock, and blue rock (1956–58).
[2] Includes Arkansas (1963–65), Idaho, Montana, North Carolina (1965), Utah, and Wyoming.
[3] Included with Western States.

the mine. The complex, when complete, late in 1966, would include a sulfuric acid plant, a phosphoric acid plant, a diammonium phosphate plant, and a triple superphosphate plant. A $3 million rail-water terminal was under construction at Jacksonville, 68 miles from the Suwannee mine, where an estimated 1 million tons of phosphate rock is expected to be exported to foreign markets annually.

V-C Chemical Co., a division of Mobil Chemical Co., began to develop a phosphate mine and erect associated facilities near Fort Meade, Fla., where the firm has 8,000 acres. Additional processing and storage facilities were to be built near Nichols, Fla. The project was expected to double the firm's phosphate production when it goes on stream early in 1967.[3] During the year the company's Harding concentrated superphosphate in Polk County was expanded by the addition of a new sulfuric acid plant and new process equipment for the phosphoric acid unit.

It was reported that Stauffer Chemical Co. would process phosphate ore from its 13,000 acre tract in Hardee County, Fla., in the Victor Chemical Division plant at Tarpon Springs, Fla. The company was said to have an additional 1,800 acres of phosphate land in Polk County and 1,450 acres south of Zolfo Springs, Fla.

The Pamlico River area of Beaufort County, N.C., was well on the way to becoming a major phosphate producing area with the progress made by Texas Gulf Sulphur Co. at its Lee Creek mine near Aurora, N.C. Production of phosphate rock at the rate of 3 million tons per year was expected to begin in 1966. In April, the company announced an additional investment of $32 million was being made in the project and that construction was to begin late in the year on a phosphoric acid plant with a designed capacity of 640,000 tons, a 350,000-ton-per-year triple superphosphate plant, and a 220,000-ton-per-year diammonium phosphate plant. About 415,000 tons of phosphoric acid will be used captively in the production of triple superphosphate and diammonium phosphate.

The North Carolina State Ports Authority announced plans to construct a $9.5 million bulk phosphate handling facility at Morehead City terminal. The facility was to include a 2,500-ton-per-hour loading capacity and a ship berth to accommodate large ocean liners. The project, financed by an Area Redevelopment Administration loan, was expected to begin operation in January 1967.

A contract for building a 30.5-mile rail line from near Washington, N.C., to the Texas Gulf Sulphur Co. phosphate operation was signed in May by the Norfolk Southern Railroad.

Magnet Cove Barium Corp. Ltd., continued to investigate the possibilities of mining phosphate on its leases in the Pungo River area of North Carolina by hydraulic extraction through drill holes. No plans were announced for commercial development.

Two additional requests were made for leases on State-owned river bottoms in Beaufort County, N.C. It was reported that the two companies, New Concept

[3] Commercial Fertilizer and Plant Food Industry. V. 110, No. 6, June 1965, p. 28.

Table 3.—Marketable production of phosphate rock in the United States, by States

(Thousand long tons)

Year	Florida		North Carolina		Tennessee		Western States [1]		Total	
	Rock	P_2O_5 content	Rock	P_2O_5 content	Rock	P_2O_5 content	Rock	P_2O_5 content	Rock	P_2O_5 content
1956–60 (average)	11,349	3,740			1,819	473	2,429	660	15,597	4,873
1961	13,789	4,531			2,235	575	2,535	698	18,559	5,804
1962	13,949	4,543			2,418	638	3,015	823	19,382	6,004
1963	14,592	4,818			2,352	612	2,911	791	19,855	6,221
1964	17,108	5,656	6	2	2,441	640	3,405	932	22,960	7,230
1965	19,253	6,277			2,637	686	4,550	1,223	26,440	8,186

[1] Includes Arkansas (1963–65), Idaho, Montana, Utah, and Wyoming.

Mining Co. of Lakeland, Fla., and North Carolina Phosphate Corp., requesting leases, wished to test the economic feasibility of well-mining methods.

A $45,000 allocation was made by the State of North Carolina for a study to be made of the effects of the phosphate mining operations on the ground water supplies of Beaufort County.[4]

The phosphate industry was expanded also in the Western States. The Bunker Hill Co. at Kellogg, Idaho, began operating a new ammonium phosphate fertilizer plant at Kellogg, Idaho. The new plant was reported to be a joint venture of The Bunker Hill Co. and Staffer Chemical Co.

El Paso Natural Gas Products Co. continued with the modernization of the phosphate plant purchased in 1964 from Central Farmers Fertilizer Co. The project, when completed, will include a sulfuric acid plant, a phosphoric acid plant, and a 21-mile railroad spur between the plant and mine.

Monsanto Co. was to start construction on a 70,000 kilowatt furnace at its Soda Springs, Idaho plant. It was thought that this new furnace would be the largest phosphorus furnace in the world. Monsanto also ordered a 350-foot tubular kiln for installation at the Soda Springs plant. The kiln was stated to be the largest ever to be used in the phosphate industry.

J. R. Simplot Chemical Fertilizer Co. was expanding its Pocatello, Idaho, fertilizer complex by adding a new 1,200-ton-per-day sulfuric acid and a new phosphoric acid plant reported to have a capacity of about 2,000 tons per day. A new $1.5 million beneficiation plant was underway at the Conda, Idaho, mine.

Stauffer Chemical Co. bought mining privileges on 5,500 acres of deposits in Idaho. This addition along with additional land acquired in Florida and Montana, was said to give Stauffer a phosphate rock reserve of more than 1 billion tons. The firm doubled the ammonium phosphate production capacity of its Garfield, Utah, plant. Victor Chemical Division of Stauffer Chemical Co. added a new superphosphoric acid unit to its elemental phosphorus plant at Butte. Early in the year, a $17 million phosphate fertilizer complex was planned by Stauffer for Vernal, Utah, the site of the San Francisco Chemical Co. phosphate mining operation. However, Stauffer postponed these plans reportedly because of the sudden price change of sulfur that affected the economics of the project.

Plans were completed by Susquehanna-Western Inc. for constructing a $17 to $28 million phosphate fertilizer complex in the Riverton-Lander area of central Wyoming. However, development of the complex was not to be started until a partner was acquired. Pittsburgh Plate Glass Co. at one time considered joining Susquehanna but was reported to have decided against exercising its option.

At Geismar, La., Allied Chemical Corp. started construction on a 500-ton-per-day phosphoric acid plant, part of a multimillion-dollar fertilizer manufacturing complex scheduled for completion in 1966.

Arkansas Louisiana Gas Co. began construction on a phosphoric acid plant at Helena, Ark. The acid plant was part of a $33 million fertilizer complex which also

[4] Engineering and Mining Journal. V. 166, No. 12, December 1965, pp. 131, 133.

includes a diammonium phosphate plant. The complex, to be operated by Arkla Chemical Corp., was expected to be finished by the end of 1965.

Coastal Chemical Corp. completed an expansion program at its Pascagoula, Miss., plant which included a new phosphoric acid unit and a diammonium phosphate plant of 40 tons of product per hour capacity. Phosphoric acid production capacity was nearly tripled with the addition of the new acid plant.

Olin Mathieson Chemical Corp. started production at its new 600-ton-per-day phosphoric acid plant at Pasadena, Tex. It was claimed to be the world's largest single-train phosphoric acid plant. The firm's old 350-ton-per-day unit was to be dismantled.

Phosphate Chemicals, Inc., expected to begin production of diammonium phosphate in a newly installed 400-ton-per-day plant in Pasadena, Tex.

One of the world's largest fertilizer plants was put into operation at Hahnville, La., by National Phosphate Corp., a subsidiary of Hooker Chemical Corp. The $35 million chemical producing complex included a 1,000-ton-per-day diammonium phosphate plant, a sulfuric acid unit, and a phosphoric acid unit. Two other plants of the complex, nonfertilizer chemicals, were not expected on stream before 1966.

A new 240,000-ton-per-year ammonium phosphate fertilizer plant was completed and placed on stream at Luling, La., by Monsanto Co.

Davison Chemical Division of W. R. Grace & Co. planned a $4 million chemical complex near Henry, Ill. The proposed plant would have a designed capacity of 100,000 tons per year of plant food as ammonium phosphate fertilizers. Completion of the facility was scheduled for January 1967.

The New Jersey Zinc Co. announced its decision to enter the fertilizer business with the construction of a diammonium phosphate plant at the site of its zinc plant in Depue, Ill. The new phosphate unit was to have an annual capacity of 270,000 tons and was scheduled for completion during the fourth quarter of 1966.

CONSUMPTION AND USES

A preliminary report by the U.S. Department of Agriculture showed that during the fiscal year ending June 30, 1965, fertilizers consumed contained 3,529,164 tons of available P_2O_5. This represents an increase of 5 percent over the preceding 12-month period.

Table 4.—Florida phosphate rock sold or used by producers, by kinds

(Thousand long tons and thousand dollars)

Year	Rock	P_2O_5 content	Value: Total	Value: Average per ton	Rock	P_2O_5 content	Value: Total	Value: Average per ton
	Hard rock				Soft rock			
1956–60 (average)	82	29	$696	$8.52	53	11	$399	$7.55
1961	73	26	672	9.16	39	8	303	7.87
1962	70	25	659	9.34	33	6	275	8.39
1963	76	27	723	9.48	33	7	269	8.11
1964	77	27	747	9.72	28	5	225	8.18
1965	69	24	684	9.92	28	5	221	7.79
	Land pebble				Total			
1956–60 (average)	11,016	3,635	$70,041	$6.35	11,151	3,675	$71,136	$6.37
1961	12,667	4,168	88,395	6.98	12,779	4,202	89,370	6.99
1962	13,624	4,460	93,669	6.88	13,727	4,491	94,603	6.89
1963	14,377	4,722	100,749	7.01	14,486	4,756	101,741	7.02
1964	16,252	5,331	115,513	7.11	16,357	5,363	116,485	7.12
1965	19,096	6,205	138,744	7.26	19,193	6,234	139,649	7.27

Table 5.—Tennessee phosphate rock sold or used by producers
(Thousand long tons and thousand dollars)

Year	Rock	P_2O_5 content	Value	
			Total	Average per ton
1956–60 (average)	1,813	472	$13,279	$7.32
1961	2,291	592	19,099	8.34
1962	2,476	654	20,173	8.15
1963	2,395	625	18,303	7.64
1964	2,458	645	19,074	7.76
1965	2,651	689	22,385	8.45

Table 6.—Western States phosphate rock sold or used by producers
(Thousand long tons and thousand dollars)

Year	Idaho				Montana [1]			
	Rock	P_2O_5 content	Value		Rock	P_2O_5 content	Value	
			Total	Average per ton			Total	Average per ton
1956–60 (average)	1,525	396	$7,179	$4.70	857	254	$6,168	$7.16
1961	1,687	434	8,913	5.28	1,085	323	8,211	7.57
1962	1,744	444	10,164	5.83	1,113	338	9,282	8.35
1963	1,739	432	10,015	5.76	1,240	374	10,583	8.53
1964	1,964	506	9,802	4.99	1,302	393	r 11,377	8.75
1965	W	W	W	W	4,201	1,161	27,790	6.62

r Revised. W Withheld to avoid disclosing individual company confidential data.
[1] Includes Arkansas (1963–65), Utah (1961–65), Wyoming (1956–65), and Idaho in 1965.

Table 7.—Phosphate rock sold or used by producers in the United States, by grades and States
(Thousand long tons)

Year and grade—B.P.L.[1] content (percent)	Florida		Tennessee		Western States		Total United States	
	Quantity	Percent of total	Quantity	Percent of total	Quantity	Percent of total	Quantity	Percent of total
1964:								
Below 60	52	(2)	2,060	86	1,780	55	3,892	18
60 to 66	396	3	326	14	84	3	806	4
66 to 68	2,778	17	29	(2)	80	2	2,887	13
68 to 70	4,558	27	29	(2)	1,211	37	5,798	27
70 to 72	1,185	8	14	(2)	111	3	1,310	5
72 to 75	4,378	26					4,378	19
75 to 77	2,906	18					2,906	14
Plus 77	104	1					104	(2)
Total	16,357	100	2,458	100	3,266	100	22,081	100
1965:								
Below 60	28	1	2,554	96	2,175	52	4,757	18
60 to 66	1,858	9			421	10	2,279	9
66 to 68	3,566	19	40	2	364	9	3,970	15
68 to 70	2,746	14			1,241	29	3,987	15
70 to 72	2,593	14	57	2			2,650	10
72 to 75	3,538	18					3,538	14
75 to 77	3,809	20					3,809	15
Plus 77	1,055	5					1,055	4
Total	19,193	100	2,651	100	4,201	100	26,045	100

[1] Bone phosphate of lime ($Ca_3(PO_4)_2$).
[2] Less than 0.5 percent.

Table 8.—Phosphate rock sold or used by producers in the United States, by uses and States

(Thousand long tons)

State and use	1956–60 (average)		1961		1962		1963		1964		1965	
	Rock	P_2O_5 content	Rock	P_2O_5 content	Rock	P_2O_5 content	Rock	P_2O_5 content	Rock	P_2O_5 content	Rock	P_2O_5 content
Florida:												
Agriculture	7,916	2,627	9,006	2,990	9,746	3,210	10,043	3,305	10,586	3,497	12,730	4,180
Industrial	546	175	377	114	592	183	471	151	685	219	748	243
Exports	2,689	873	3,396	1,098	3,389	1,098	3,972	1,300	5,086	1,647	5,715	1,811
Total	11,151	3,675	12,779	4,202	13,727	4,491	14,486	4,756	16,357	5,363	19,193	6,234
Tennessee:												
Agriculture	274	74	148	46	103	32	127	39	86	25	89	28
Industrial	1,539	398	2,143	546	2,373	622	2,268	586	2,372	620	2,562	661
Total	1,813	472	2,291	592	2,476	654	2,395	625	2,458	645	2,651	689
Western States:												
Agriculture	542	173	664	207	686	215	668	209	399	126	452	141
Industrial	1,443	352	1,586	387	1,626	396	1,736	417	2,262	585	2,810	731
Exports	397	124	522	163	545	171	575	180	605	188	939	289
Total	2,382	649	2,772	757	2,857	782	2,979	806	3,266	899	4,201	1,161
Total United States:												
Agriculture	8,732	2,874	9,818	3,243	10,535	3,457	10,838	3,553	11,070	3,648	13,271	4,349
Industrial	3,528	925	4,106	1,047	4,591	1,201	4,475	1,154	5,320	1,424	6,120	1,635
Exports	3,086	997	3,918	1,261	3,934	1,269	4,547	1,480	5,691	1,835	6,654	2,100
Total	15,346	4,796	17,842	5,551	19,060	5,927	19,860	6,187	22,081	6,907	26,045	8,084

STOCKS

Stocks in the hands of producers at year-end were about 6 percent higher than at the end of 1964.

Table 9.—Producer stocks of phosphate rock, December 31
(Thousand long tons)

Source	1964		1965	
	Rock	P_2O_5 content	Rock	P_2O_5 content
Florida	4,573	r 1,467	4,633	1,509
North Carolina	6	2	6	2
Tennessee	82	23	68	19
Western States	806	r 214	1,109	277
Total	5,467	r 1,706	5,816	1,807

r Revised.

PRICES

The Florida land pebble phosphate rock producers raised prices on all grades of phosphate rock approximately 7 percent in July.

Table 10.—Prices of Florida land pebble, unground, washed, and dried phosphate rock, in bulk, carlots, at mine, in 1965
(Per short ton)

Grade (percent B.P L.)	Jan. 2	Dec. 30
66 to 68	$5.84	$6.25
68 to 70	6.76	7.23
70 to 72	7.38	7.90
74 to 75	8.34	8.96
76 to 77	9.30	9.95

Source: Oil, Paint and Drug Reporter.

FOREIGN TRADE

There was an 18 percent increase in quantity of phosphate rock exported. Japan was again the leading customer for Florida rock, receiving 28 percent of the Florida shipments.

Of the phosphate rock imported, 63 percent came from the Netherlands Antilles, 22 percent from Togo, and 15 percent from Mexico. Canada supplied 95 percent of the imported ammonium phosphates while 95 percent of the dicalcium phosphate imported was shipped from Belgium.

Table 11.—U.S. exports of phosphate rock, by grades and countries

Grade and destination	1964 Long tons	1964 Value	1965 Long tons	1965 Value
Florida phosphate rock:				
North America:				
Bahamas	-----	-----	690	$5,905
Canada	600,710	$6,537,464	623,846	7,227,642
Costa Rica	11,423	101,240	3,547	32,995
Dominican Republic	6,795	62,710	-----	-----
El Salvador	3,649	34,446	11,089	95,118
Guatemala	-----	-----	418	2,680
Jamaica	1,284	11,025	759	14,415
Mexico	200,928	1,639,071	238,049	1,933,909
Netherlands Antilles	1,990	18,328	5,724	54,777
South America:				
Argentina	-----	-----	150	1,695
Brazil	176,150	1,813,029	133,927	1,425,924
Colombia	25,272	211,784	15,155	145,662
Peru	16,153	151,079	16,801	160,556
Uruguay	15,135	156,273	11,325	117,143
Venezuela	286	6,781	19,336	202,042
Europe:				
Belgium-Luxembourg	21,161	204,319	-----	-----
Denmark	17,134	158,492	24,508	247,255
Finland	12,188	158,519	-----	-----
France	25,462	233,482	48,078	578,860
Germany, West	779,103	6,063,651	873,059	7,039,108
Italy	714,700	5,788,245	820,346	6,732,069
Netherlands	77,776	717,472	-----	-----
Norway	15,766	145,835	10,073	98,234
Spain	122,368	1,056,218	116,126	1,113,654
Sweden	18,386	188,462	70,247	718,859
Switzerland	2,358	21,811	2,815	31,757
United Kingdom	233,662	2,005,012	246,800	2,219,425
Asia:				
Hong Kong	749	6,412	-----	-----
India	-----	-----	49,479	485,396
Japan	1,585,779	13,655,797	1,627,201	14,796,666
Korea, South	-----	-----	7,000	63,140
Malaysia	28,643	488,270	18,283	488,516
Philippines	34,513	343,711	69,834	690,327
Viet-Nam, South	22,363	354,035	19,735	569,021
Oceania:				
Australia	211,483	2,179,255	680,494	7,172,825
New Zealand	102,579	1,024,359	138,389	1,497,177
Total	5,085,948	45,536,587	5,903,283	55,962,752
Other phosphate rock:[1]				
North America:				
Bahamas	-----	-----	29	376
Canada	551,709	6,968,127	715,611	9,271,007
Guatemala	23	270	-----	-----
Mexico	14,145	114,729	-----	-----
Panama	62	700	-----	-----
South America: Venezuela	583	6,970	239	11,995
Europe:				
Belgium-Luxembourg	18	200	188	2,500
France	-----	-----	5,254	48,600
United Kingdom	-----	-----	9,806	99,341
Asia:				
Afghanistan	-----	-----	140	1,872
Japan	-----	-----	11,817	108,144
Malaysia	49	1,568	-----	-----
Philippines	36	640	-----	-----
Viet-Nam, South	-----	-----	7,219	125,519
Oceania: New Zealand	-----	-----	16	220
Total	566,625	7,093,204	750,319	9,669,574
Grand total	5,652,573	52,629,791	6,653,602	65,632,326

[1] Includes colloidal matrix, sintered matrix, soft phosphate rock, and Tennessee, Idaho, and Montana rock.

Table 12.—U.S. exports of superphosphates (acid phosphates), by countries

Destination	1964		1965	
	Long tons	Value	Long tons	Value
North America:				
Bahamas	835	$32,609	866	$32,298
British Honduras	80	5,494	18	1,736
Canada	163,404	5,120,380	107,996	3,741,056
Costa Rica	3,695	235,648	664	101,710
Dominican Republic	4,104	250,306	5,568	303,423
El Salvador	6,587	352,445	6,190	339,497
Guatemala	157	9,079	153	11,156
Haiti			14	1,223
Honduras	309	21,313	23	1,814
Jamaica	1,753	95,681	931	63,612
Leeward and Windward Islands	269	15,520		
Mexico	1,140	85,929	56	4,422
Netherlands Antilles	6,513	328,416		
Nicaragua	581	37,332	3,098	190,858
Panama	662	43,407	228	15,420
South America:				
Argentina	1,813	127,383	1,778	117,282
Brazil	57,137	3,252,015	47,929	2,701,496
Chile	86,307	5,089,761	68,864	4,583,333
Colombia	31,180	1,682,891	25,070	1,470,620
Ecuador	2,266	130,991	2,192	146,064
Peru	295	28,417	135	5,758
Uruguay	515	38,731	867	65,229
Venezuela	134	8,187		
Europe:				
France	16,696	943,060	12,807	599,120
Germany:				
East	28,709	509,490		
West	22,974	726,050		
Greece	10,197	569,908		
Italy	1,973	105,149	1,866	101,825
Netherlands	85,718	4,182,257	37,773	2,419,955
Sweden	2,955	141,151		
Africa:				
Nigeria	352	22,918	160	10,527
South Africa, Republic of	11,921	641,691		
Other	29	1,851		
Asia:				
Iran	5,167	349,725		
Japan	8,259	159,334	7,797	443,514
Korea, South	139,189	7,638,468	188,146	11,544,642
Nasei and Nanpo Islands	3,478	233,812		
Pakistan			6,900	482,982
Phillippines	500	35,723		
Viet-Nam, South	45	2,944		
Other	45	3,480	48	3,812
Total	707,943	33,258,946	528,137	29,504,384

Table 13.—U.S. imports for consumption of phosphate rock and phosphatic fertilizers

Fertilizer	1964		1965	
	Long tons	Value	Long tons	Value
Phosphates, crude, and apatite	155,819	$3,329,309	132,263	$2,979,711
Phosphatic fertilizers and fertilizer materials	70,512	4,009,733	51,698	3,138,788
Ammonium phosphates, used as fertilizers	85,845	5,811,974	155,768	12,421,468
Bone ash, bone dust, bone meal and bones, crude, steamed, or ground	10,024	545,238	6,495	369,954
Manures, including guano	3,457	295,516		
Basic slag			146	1,984
Dicalcium phosphate	6,291	394,673	2,683	177,330

WORLD REVIEW

Algeria.—The development of the Djebel Onk phosphate deposits near the Tunisian border continued, and commercial production was expected to begin by the end of the year. The railroad from Djebel Onk to Tebessa was completed.

Angola.—The Government claimed to have verified the existence of 27 million tons of exploitable phosphate reserves, 15 million tons in Cabinda and 12 million on the northwestern coast north of Ambrizete. Four companies were said to have applied for concessions to develop one or both areas.

Australia.—Concern was growing about the future supply of phosphate rock. Deposits on Nauru, one of the main sources, were not expected to last more than another 20 to 25 years at a production rate of 2 million tons per year. Deposits on Christmas Island and Ocean Island were estimated to be exhausted in 30 years. The Commonwealth Government accelerated the search for phosphate deposits and enlisted the aid of two specialists from the United States, Richard Sheldon of the Geological Survey, and Tjeerd Hendrik Van Andel of Scripps Institute of Oceanography.

Several State governments were encouraging the search for phosphate deposits: Western Australia released areas, totaling 20,340 square miles, for phosphate exploration. Four companies were granted leases for a 12-month period.[5] South Australian Department of Mines announced that it would issue rights for phosphate exploration on areas up to 10,000 square miles for 1 year and 4,000 square miles for an additional 6 months. The New South Wales Government decided to offer a reward of 20,000 pounds ($44,800) for discovery of any worthwhile phosphate deposit within the State.

A new deposit was discovered in Northern Territory in a cliff about 5 miles from Darwin. A drilling program was underway to determine the extent of the ore which was reported as containing up to 30 percent phosphate.

Belgium.—A new phosphoric acid plant having an annual capacity of 100,000 tons was being planned for Antwerp by BASF Antwerpen N.V., a new subsidiary of Badische Anilin und Soda Fabrik, A.G.

Brazil.—Companhia Petroquimica Brasileira was planning to erect a phosphoric acid plant to use the Israel Mining Industries hydrochloric acid process. The plant was designed for an annual capacity of 16,500 tons P_2O_5 and was to be in operation before the end of 1966.

Canada.—A new company, Brunswick Fertilizer Corp. Ltd., planned to build a $23 million fertilizer complex at Belledune on Baie des Chaleurs, New Brunswick. Full production of phosphatic fertilizer as ammonium phosphate at a rate of 680,000 tons per year was anticipated early in 1967. The new company was jointly formed by Electric Reduction Company of Canada Ltd. (ERCO) and Brunswick Mining & Smelting Corp. Ltd. It was stated that the phosphate rock would be imported and that 850,000 tons of sulfuric acid per year, recovered from effluent sulfur gas resulting from adjacent metal smelting operations of Brunswick Mining & Smelting Corp. Ltd., would be used.

ERCO planned to build a large electric furnace plant in eastern Canada for the production of elemental phosphorus. The site for the new plant had not been selected when the announcement was made late in the year.

Canadian Industries Ltd. was reported as having awarded contracts for building a phosphoric acid plant at Courtright, Ontario, and a monammonium phosphate plant at Lambton, Quebec. Both plants should be completed in 1966.

Consolidated Mining & Smelting Co. of Canada Ltd. began producing ammonium phosphates at two new plants—one located at Kimberly, British Columbia, and the other on the outskirts of Regina, Saskatchewan. The 100,000-ton-per-year output of fertilizer products from the Regina plant was said to increase the firm's total annual output capacity to 1 million tons.[6]

It was reported that Hudson Bay Oil and Gas Co. Ltd. acquired phosphate rock prospecting permits from the Government covering approximately 1 million acres of land in Alberta.

A new phosphoric acid plant with an annual capacity output of 44,000 tons P_2O_5 went on stream at Fort Sasketchewan, Alberta. The plant was part of a $23 million fertilizer complex completed during the year for Sherritt Gordon Mines Ltd. A

[5] Engineering and Mining Journal. V. 166, No. 5, May 1965, p. 146.
[6] Western Miner (Vancouver, Canada). Regina Fertilizer Operation. V. 38, No. 6, June 1965, p. 54.

Table 14.—World production of phosphate rock by countries [1]

(Thousand long tons)

Country	1961	1962	1963	1964	1965 [p] [2]
North America:					
United States	18,559	19,382	19,855	22,960	26,440
Mexico	29	30	30	27	[e] 28
Netherlands Antilles (exports)	150	129	126	[r] 118	110
Total [1]	18,738	19,541	20,011	[r] 23,105	26,578
South America:					
Brazil:					
Apatite	240	305	212	[r] 192	[e] 200
Phosphate rock	409	251	63	[r] 50	[e] 59
Chile:					
Apatite	14	12	14	[r] 13	13
Guano	19	16	22	15	21
Peru (guano)	157	203	189	202	166
Venezuela	---	---	---	---	[e] 6
Total	839	787	501	[r] 472	465
Europe:					
Belgium	14	12	[r] 13	[r] 22	[e] 22
France	80	66	50	[r] 42	[e] 42
Poland	46	55	64	[r] 88	[e] 88
U.S.S.R.:					
Apatite [e]	5,510	6,500	6,890	7,870	9,350
Sedimentary rock [e]	3,150	3,350	3,940	4,920	5,910
Total [e]	8,800	9,980	10,960	[r] 12,940	15,410
Africa:					
Algeria	433	384	343	72	85
Morocco	7,824	8,033	8,413	9,938	9,669
Rhodesia, Southern	(3)	---	---	2	[e] 4
Senegal:					
Aluminum phosphate	137	139	124	119	133
Calcium phosphate	401	489	463	666	854
Seychelles Islands (guano) (exports)	8	5	7	4	6
South Africa, Republic of	292	302	448	570	600
South-West Africa (guano)	1	1	1	(3)	1
Togo	116	[r] 189	[r] 506	741	958
Tunisia	1,950	2,064	2,333	2,708	2,992
Uganda (apatite)	(3)	1	7	[r] 9	16
United Arab Republic (Egypt)	617	592	634	[r] 604	584
Total [1]	11,779	[r] 12,199	[r] 13,279	[r] 15,433	15,902
Asia:					
China, mainland [e]	500	600	700	800	900
Christmas Island (Indian Ocean) (exports)	694	521	651	775	740
India (apatite)	20	29	13	4	4
Indonesia	[r] 10	[r] 6	[r] 1	[r] 3	[e] 3
Israel	217	207	295	236	382
Jordan	416	[r] 670	[r] 605	[r] 594	815
Korea, North (apatite) [e]	150	200	200	200	200
Philippines:					
Guano	(3)	(3)	1	1	4
Phosphate rock	---	4	[r] 1	3	(3)
Viet-Nam, North:					
Apatite	555	667	[r] 910	[e] 980	[e] 980
Phosphate rock	57	33	[e] 49	[e] 49	[e] 49
Total [e] [1]	2,620	[r] 2,940	[r] 3,430	[r] 3,645	4,080
Oceania:					
Australia	5	4	5	[r] 6	[e] 6
Makatea Island (French Oceania)	375	312	330	[r] 382	[4] 314
Nauru Island (exports)	1,282	1,516	1,547	1,820	1,472
Ocean Island (exports)	338	257	356	323	369
Total	2,000	2,089	2,238	[r] 2,531	2,161
World total [e]	44,780	[r] 47,540	[r] 50,420	[r] 58,130	64,600

[e] Estimate. [p] Preliminary. [r] Revised.
[1] A negligible amount of phosphate rock is produced in Jamaica, Sarawak, Somali Republic and Tanzania.
[2] Compiled mostly from data available June 1966.
[3] Less than ½ unit.
[4] Exports.

125,000-ton-per-year ammonium phosphate plant was included in the new facility

A fertilizer plant, including a phosphoric acid unit and related triple superphosphate and diammonium phosphate units, was being built for St. Lawrence Fertilizers Ltd. at Valleyfield, Quebec. The daily output capacity of the acid plant was stated to be 150 tons P_2O_5. The entire plant was scheduled for completion in July 1966.

Western Cooperative Fertilizers Ltd., formulated plans for developing its own supply of phosphate rock and other raw materials for use in its new $24 million fertilizer complex in Calgary. A program was initiated to develop, if feasible, a source of phosphate rock near Fernie, British Columbia. The company was reported to have 500 claims, each one-quarter square mile in the Fernie area.[7]

Greece.—Phosphate Fertilizer Industry, S.A., nearly completed its $32 million fertilizer plant at Nea Karvali in eastern Macedonia. The phosphoric acid unit was in operation and the ammonium sulfophosphate unit was expected on stream before yearend. The initial annual capacity of the plant was stated to be 250,000 tons of ammonium sulfophosphate.

Chemical Industries of Northern Greece had a $16 million plant under construction at Thessaloniki for the production of ammonium sulfophosphate and mixed superphosphates. This plant also was to be in operation by the end of the year with an initial annual capacity of 200,000 tons of product.

A nitro-phosphate plant was scheduled for erection at Salonica by Société Industries Chimiques du Nord de la Grèce. Output capacity of the fertilizer plant was reported to be 125,000 tons per year.

India.—Albright, Morarji & Pandit Ltd., a new company associated with Albright & Wilson Ltd. (British), which held a 45-percent interest, ordered a phosphoric acid concentration plant to be installed at Am-

[7] Engineering and Mining Journal. Firm To Develop Its Raw Materials. V. 166, No. 11, November 1965, p. 127.

Table 15.—Selected African countries: Exports of phosphate rock in 1965, by countries

(Long tons)

Destination	Algeria	Morocco	Senegal	Togo	Tunisia	Total
North America:						
Cuba	--------	22,889	--------	--------	--------	22,889
United States	--------	--------	--------	13,951	--------	13,951
South America:						
Brazil	--------	--------	--------	10,102	--------	10,102
Chile	--------	18,700	--------	5,905	4,921	29,526
Uruguay	--------	--------	--------	--------	14,763	14,763
Europe:						
Austria	--------	21,841	--------	--------	--------	21,841
Belgium	--------	1,032,696	--------	63,050	--------	1,095,746
Czechoslovakia	--------	125,282	--------	--------	91,335	216,617
Denmark	--------	254,437	--------	--------	34,054	288,491
Finland	--------	136,038	--------	--------	--------	136,038
France	17,800	1,791,026	33,493	218,162	640,917	2,701,398
Germany, West	35,707	571,737	248,551	129,808	245,659	1,231,462
Greece	--------	130,253	--------	--------	94,386	224,639
Ireland	--------	241,691	--------	--------	--------	241,691
Italy	2,608	349,830	--------	89,155	354,512	796,105
Netherlands	--------	521,989	36,622	174,895	41,534	775,040
Norway	--------	52,945	--------	--------	--------	52,945
Poland	--------	444,973	--------	--------	73,324	518,297
Portugal	--------	265,397	--------	--------	--------	265,397
Spain	--------	893,710	--------	--------	127,455	1,021,165
Sweden	--------	331,014	--------	5,905	25,786	362,705
Switzerland	--------	19,664	--------	--------	3,248	22,912
United Kingdom	--------	864,068	151,853	10,800	44,585	1,071,306
Yugoslavia	--------	11,798	--------	--------	192,708	204,506
Asia:						
China	--------	589,585	--------	--------	--------	589,585
India	--------	21,336	--------	--------	256,091	277,427
Japan	--------	267,582	171,007	111,227	25,885	575,701
Taiwan	--------	113,767	--------	--------	--------	113,767
Africa:						
Canary Islands	--------	17,651	--------	--------	--------	17,651
South Africa, Republic of	--------	--------	143,114	--------	--------	143,114
Oceania: Australia	--------	173,527	24,552	133,305	--------	331,384
Other countries	--------	45,932	--------	--------	--------	45,932
Total	56,115	9,331,358	809,192	966,265	2,271,163	13,434,093

barnath, near Bombay. The plant was to produce 25 tons of 54 percent acid per day from 30 percent wet-process acid with operation expected by October 1966. The new firm also had Government approval to establish a $4.2 million wet-process phosphoric acid plant at Ambernath, near the site of a sulfuric acid plant owned by Dharamsi Morarji Chemical Co. Ltd. (a 27-percent owner of the new company). Dharamsi Morarji was granted a license to use phosphoric acid from the new plant to produce 27,000 tons of triple superphosphate annually at the Ambernath plant. Production was expected in 1967 and would be the first triple superphosphate produced in India.

Large reserves of phosphate deposits were reported found along both the eastern and western coasts of India. The deposits, subject to further studies, were estimated to be ample to meet India's phosphatic fertilizer needs for at least 20 years.

Israel.—Swift & Co. and Carl M. Loeb, Rhoades & Co., an investment firm, both of the United States, were reported to have joined Israel-American Phosphates Co. to exploit the phosphate deposits at Ein Yahav. The Israel-American Phosphate Co. has had the concession rights to the phosphate on these deposits for some time, but because of financial difficulties had not gotten into production. Plans were to install a phosphate calcination plant with an initial annual capacity of about 500,000 tons.

The first stage of Israel's new port at Eilat was completed and ready to handle an annual cargo of 500,000 tons. Also the new railroad between Beersheba and Dimona was completed with the extension to Oron expected to be in operation in 1967.

Japan.—Toyo Soda Manufacturing Co. was joined by Stauffer Chemical Co., a U.S. firm, in a 50-50 partnership to form a new company called Toyo Stauffer Chemical Co. The new company planned to erect a dicalcium phosphate plant at Yamaguchi, capable of producing about 8,000 tons per year. Operation was scheduled for 1966.

A 50-ton-per-day phosphoric acid plant was completed for Nihon Suiso Kogyo Co. Ltd. which planned to use the acid to produce 55,000 tons of complex fertilizers annually.

Jordan.—Ralph M. Parsons Co., a U.S. consulting firm, proved the existence of a 30-million-ton phosphate deposit averaging 68 percent B.P.L. at Al Hasa. The Parsons company was completing the second stage of its contract, which included the designing of mining facilities. A 500,000-ton-per-year phosphate rock treatment plant was scheduled to be erected at El Hasa. Contracts for construction and equipment were awarded.

A merger of all phosphate mining operations in Jordan into one company, including those at Ruseifa and Al Hasa, was approved in August by the Government.

Mexico.—Two new phosphate fertilizer plants were scheduled for construction near Coatzacoalcos, Veracruz. Banco Nacional de Mexico, S.A., announced the sponsorship of a new company, Fertilizer Fosfatados Mexicanos, S.A. de C.V., for the development of a large fertilizer complex. Mexican ownership was to be 51 percent with Pan American Sulphur Co., together with two international banking firms owning a 49-percent interest. A $44 million facility with an initial annual capacity of 400,000 tons P_2O_5 was to be established by the new company with completion scheduled for the second quarter of 1966. The second plant, estimated at $18 million, was reportedly being financed by John W. Mecom of Houston, Tex., and a Mexican industrialist, O. L. Longoria. No completion date was announced. A 20,000-ton-per-year elemental phosphorus plant also was to be erected in the State of Veracruz. The plant was to be owned and operated by a new company, Fosfores Industriales, S.A., formed by the Bruno Pagliai industrial group of Mexico with V–C Chemical Co., a division of Mobil Chemical Co., holding a minor interest. The plant was planned for operation in 1967.

Morocco.—An organization, Office des Producteurs de Phosphates, was formed by authorities of Morocco, Tunisia, and Jordan for the purpose of coordinating their international phosphate sales.

The Export-Import Bank of Washington authorized a long-term $25 million capital loan to finance purchases of United States equipment required for expanding phosphate rock production facilities. The loan was made to Office Cherifien des Phosphates (OCP), a corporation wholly owned by the Government of Morocco. The total cost of expansion by OCP was expected to be about $56.6 million.

The Safi chemical fertilizer plant was

completed at a cost of $50 million. The Government-owned complex consists of two production lines, each capable of producing annually either 200,000 tons of triple superphosphate or 150,000 tons of diammonium phosphate.

Occidental Petroleum Corp., a U.S. firm, entered into a joint $100 million venture with OCP on a 50-50 basis to produce phosphatic fertilizers in a new plant. The joint company was set up to operate both the new plant and the one completed at Safi. Occidental's major responsibility to the new complex was to be the construction of a $37.5 million superphosphoric acid plant.

New Zealand.—The growth of the country's chemical fertilizer industry, showing annual capacities of individual plants was published.[8]

Peru.—A contract between Cia. Minera Bayovar, S.A., and the Government for the exploitation of the major phosphate rock deposits in the Sechura Desert was signed. Under the terms of the 25-year contract which covers all phases of the project, Minera Bayovar is committed to produce 1 million short tons of phosphate and/or potash during the preliminary stage, 6 years from the start of construction, and invest about $15 million.[9] The company concluded its first sales agreement with Texada Mines Ltd. of Canada for the delivery of 300,000 tons of phosphate rock concentrate annually over a 10-year period beginning in October 1967.

The Peruvian Government authorized the Banco Minero to seek loans to finance a project which would include a zinc refinery and plants to produce sulfuric acid and superphosphates. The phosphate rock presumably would be supplied by Minera Bayovar.

Poland.—A large phosphatic fertilizer complex, capacity not announced, was under construction at Police near Szezecin. It was reported that the output will completely satisfy the country's total needs for this type of fertilizer. The first units for producing mixed phosphate fertilizers were scheduled for completion late in 1969.

Rhodesia, Southern.—African Explosives & Chemical Industries (Rhodesia), Ltd., had a new phosphatic fertilizer plant at Dorowa in trial operation in September. When the plant reaches full production, Rhodesia will be self-sufficient in the production of superphosphates saving the Government nearly $2 million annually in foreign exchange.

South Africa, Republic of.—The phosphate fertilizer plant of Phosphate Development Corp. Ltd. at Phalaborwa was completed and producing phosphoric acid and triple superphosphate by yearend. The superphosphate plant at Windmill Fertilizers, South Africa, at Sasolburg was completed. The annual capacity output of the plant was given as 500,000 tons of a wide range of fertilizers. African Explosives & Chemical Industries, Ltd., completed a $2.8 million phosphoric acid plant at Modderfontein, near Johannesburg.

Rich and economically recoverable phosphate deposits were reported found off the west coast by the South African branch of Ocean Science & Engineering, Inc., a U.S. firm.

Spanish Sahara.—Five U.S. companies, one Canadian, and several European mining groups were competing for the mining rights to the 1.2-billion-ton high-grade phosphate deposits at El Aioun. The Spanish state-owned mining group, Empresa Nacional Minera del Sahara S.A. (ENMINSA), awarded a provisional contract for the construction of a $21 million port, subject to approval by the foreign partner selected. No announcement of a selection had been made by yearend. Development costs were expected to total about $100 million, including the port facility. Proposals by the U.S. firms were said to provide for the mining of 10 million tons per year, 2 million for U.S. consumption, 1 million to satisfy Spanish requirements, and the remainder for the world market.

It was reported also that ENMINSA had discovered a second phosphate deposit, higher grade than the first discovery. The new deposit in the Bu-Craa district was stated to be 15 feet thick.

Togo.—Compagnie Togolaise des Mines du Benin (CTMB) expanded production facilities and expected an output of nearly 900,000 tons in 1965. A production rate of 1 million tons annually was planned to begin early in 1966. W. R. Grace & Co., a U.S. firm, was reported to be the largest single stockholder in the company with 43 percent of the shares.

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[8] Bureau of Mines. Mineral Trade Notes. V. 60, No. 3, March 1965, p. 18.

[9] Bureau of Mines. Mineral Trade Notes. V. 61, No. 4, October 1965, pp. 17, 18.

Tunisia.—The Forenade Superfosfatfabriker, A.B., plant at Sfax was expected to reach full capacity production of 150,000 tons per year by the end of the year. Expansion of the Société Industrielle d'Acide Phosphorique et d'Engrais superphosphate plant was planned which would increase the total annual capacity of the industry to 350,000 tons by 1968.

U.S.S.R.—Mining operations reportedly were started at the phosphorite deposits of the Kara-Tau mountain range in the Central Asian Republic of Kazakhstan. The processing plants south of Kazakhstan, which were to produce superphosphates and phosphoric acid, were still under construction.[10]

A 41,000-ton-per-year elemental phosphorus plant was under construction at Tschimkent. The plant, being erected by Friedrich Uhde G.m.b.H. of West Germany, would have two electric furnaces and the phosphate rock would be supplied from the Kara-Tau deposits.

United Arab Republic (Egypt).—An agreement between the Rudis Association of Yugoslavia and Safaga Phosphate Co. of Egypt was concluded, in which the Association would conduct geological prospecting for phosphate deposits in the Wassif and Hamrawein areas. The project was to be started near the end of the year by the Ljubljana Geological Institute, a member of the Rudis Association.

A 20,000-ton-per-year ammonium sulfate plant was reported to have been ordered for delivery in 1966.

The Government announced that the production of superphosphate for domestic use was to be increased to 1.3 million metric tons by 1970.

Yugoslavia.—J. C. Carlile Corp., Denver, Colo., completed a feasibility and engineering study on phosphorus production for Tovarna Dusika Ruse of Ruse, Slovenia. The proposed project consisted of a 25,000-kilowatt elemental phosphorus furnace, a nodulizing plant, a phosphoric acid plant, a dicalcium phosphate plant, and a sodium tripolyphosphate plant.

A 100,000-ton-per-year superphosphate plant was reported planned for Subotica on the southern Hungarian border. Construction was to start in 1966 under an economic cooperative agreement between Hungary and Yugoslavia. Hungary was to help in financing the project with repayment in superphosphate.[11]

TECHNOLOGY

The crystallography and chemistry of three sodium-manganese-iron phosphates occurring in pegmatites as the minerals dickinsonite, fillowite, and alluaudite were discussed.[12] The report included chemical analyses, infrared spectrum curves, X-ray diffraction data, and differential thermal analyses (DTA) curves.

A discussion on the origin of bedded deposits of marine phosphates was published.[13] The author claimed the biochemical mode of formation was controlled by the configuration of the sea floor. Organisms decaying on the bottom of depressions in the ocean floor produced ammonia phosphate and ammonia. Bacteria oxidized the ammonia to nitrates that acted as fertilizers for the growth of phytoplanktons on which nektons and planktons live. The sheltered depressions prevented the gradual buildup of soluble phosphates from being dissipated into the open sea. The ammonium phosphate reacted with calcium ions or with precipitating calcium carbonate to form calcium phosphate. Two types of phosphates were discussed: a dark-colored, fine-grained type such as the phosphorite deposits in the Western States and a light-colored coarse-grained type, like the Florida land pebble phosphate.

In another article on the precipitation of marine phosphates, it was concluded that analogies exist between the biochemical precipitation of carbonate apatites and the formation of marine phosphorites and also that carbon dioxide is an essential component of phosphorites.[14]

The Kara-Tau phosphorite deposits in

[10] Phosphorus and Potassium. The Kara-Tau Phosphorite Deposits in Kazakhstan. No. 20, December 1965, pp. 15–17.

[11] Chemical Trade Journal & Chemical Engineer (London). Superphosphate Plant for Yugoslavia. V. 157, No. 4091, Nov. 4, 1965, p. 542.

[12] Fisher, D. Jerome. Dickinsonites, Fillowite and Alluaudites. Am. Miner., v. 50, No. 10, October 1965, pp. 1647–1669.

[13] Youssef, Mourad I. Genesis of Bedded Phosphates. Econ. Geol., v. 60, No. 3, May 1965, pp. 590–599.

[14] McConnell, Duncan. Precipitation of Phosphates in Sea Water. Econ. Geol., v. 60, No. 5, August 1965, pp. 1059–1062.

Kazakhstan U.S.S.R. were described.[15] It was reported that the deposits should provide large reserves for a substantial expansion in Soviet fertilizer production. The Kara-Tau basin contains 45 phosphorite deposits but three-fourths of the reserves were concentrated in the Chulak-Tau, Aksay, Koksu Dzhanitass and Kok-Zhon deposits.

Phosphate deposits and mines of 10 districts covering most of the Montana phosphate field were described in detail.[16] Each district was discussed, and resources and potentials of each district were evaluated.

The pneumatic system used for unloading 50-ton rail cars of pulverized phosphate rock at the Cyanamid of Canada Ltd., Welland fertilizer plant in Niagara Falls, Ontario, was described.[17] It was claimed that a 50-ton carload of phosphate rock could be unloaded and the material conveyed through a 6-inch pipe into an 800-ton capacity storage silo in 1 hour. The initial capital cost of the system was stated to be low and little maintenance required.

Multi Minerals Ltd. of Toronto, Canada, after 2 years of research on a process to produce phosphoric acid from its apatite deposit near Sudbury, contracted for the construction of a semi-commercial pilot plant to evaluate the process. The process, which uses the acid-leach technique, was said to produce a clear, chemically pure phosphoric acid product from either phosphate rock or apatite. Fluorine was reported to be reduced to a negligible amount during the normal course of processing.[18]

Tennessee Valley Authority (TVA) scientists, using new techniques, prepared a wet-process phosphoric acid containing 40 percent P_2O_5. Agglomerates of easily filtered calcium sulfate hemihydrate were produced instead of gypsum as in the usual processes. A slurry of Florida phosphate rock and recycled phosphoric acid (31 percent P_2O_5) was fed into the reactor beneath foam generated by the reaction while sulfuric acid (93 percent) was added to the foam surface. Only 1 hour retention time in the reactor was required with mild agitation at a temperature of 200° to 220° F. A close control of the sulfate concentration in the liquid phase of the reacting slurry was essential.[19]

A process for producing a concentrated (up to 72 percent P_2O_5) pure acid from ordinary wet-process acid, suitable for making sodium tripolyphosphate and other industrial phosphates, was tested in England. Up to 50 percent of the phosphorus content was said to volatilize when wet-process acid (32 to 54 percent P_2O_5) is fed to a submerged flame burner. The strong, pure acid is formed from the condensed vapor.[20]

A process for producing wet-process phosphoric acid containing 50 to 55 percent P_2O_5 without using a concentration step was in the development stage in TVA laboratories. Phosphate rock reacted with fuming sulfuric acid formed in semi-granular acidulate which subsequently was leached with hot water.[21]

Two new processes were developed in Japan for producing wet-process acid. The gypsum produced during the reaction was said to crystallize in large uniform particles which were easily filtered and washed. Both processes claimed recoveries up to 98.5 percent. The gypsum byproduct after washing was pure enough for sale to wallboard manufacturers.[22]

According to a recently patented process (U.S. 3,192,014) gypsum formed during wet-process phosphoric acid manufacture can be easily filtered and washed. The addition of a small quantity of alkyl aryl sulfonate, a surfactant, to the sulfuric acid treatment promotes the growth of hexagonal, easily filtered gypsum crystals instead of the needle-like difficult-to-filter crystals commonly obtained with many types of ores.[23]

At the 15th annual meeting of the Fertilizer Industry Round Table, considerable interest was shown in the discussions of

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15 Phosphorus and Potassium. The Kara-Tau Phosphorite Deposits in Kazakhstan. No. 20, December 1965, pp. 15–17.

16 Popoff, C. C., and A. L. Service. An Evaluation of The Western Phosphate Industry And Its Resources (In Five Parts) 2. Montana. BuMines Rept. of Inv. 6611, 1965, pp. 146.

17 Mining in Canada (Winnipeg, Canada). Pneumatic System Discharges a 50 Ton Car Per Hour. V. 38, No. 12, December 1965, pp. 20–21.

18 Mining Journal (London). Phosphoric Acid Process. V. 264, No. 6772, June 4, 1965, p. 446.

19 Industrial and Engineering Chemistry. Process Design & Development. Wet-Process Phosphoric Acid. V. 4, No. 1, January 1965, pp. 84–88.

20 Chemical Week. V. 97, No. 23, Dec. 4, 1965, pp. 79–80.

21 Mining Journal (London). Direct Production of Phosphoric Acid Without Concentration. V. 264, No. 6771, May 28, 1965, p. 421.

22 Chemical Engineering. Phosphoric Acid Flowsheet Sidesteps Gypsum Woes. V. 72, No. 22, Oct. 25, 1965, pp. 92, 94.

23 Chemical & Engineering News. V. 43, No. 33, Aug. 16, 1965, pp. 37, 77.

nitrophosphates. Four European manufacturing processes were described: DSM (Dutch State Mines), Odda, Kampka-Nitro, and PEC (Potasse et Engrais Chimiques).[24]

A paper was published on a study of the dissolution of phosphate rock in aqueous mixtures of phosphoric acids and sulfuric acids of varying concentrations.[25]

A two-stage method for making ammonium phosphate was developed by TVA and plans were made for pilot plant testing. The process involves two reactors with wet-process phosphoric acid being fed into the first and ammonia being fed into the second. The offgasses from the second reactor, consisting chiefly of ammonia and steam, is passed into the first reactor where the ammonia partially neutralizes the fresh acid. This material is then pumped into the second reactor for final ammoniation. A portion of the orthophosphate formed dehydrates to polyphosphate which is discharged at the bottom of the reactor.[26]

A description of the recently installed TVA rotating phosphorus furnace and its operation was published.[27] The 25,000-killowatt furnace consists of a rotating crucible 26 feet and 6 inches in diameter and 16 feet in depth from the undersurface of the roof to the top of the carbon hearth. The bottom is lined with carbon blocks. The roof is stationary and constructed of monolithic grog. The space between it and the rotating crucible is sealed with water held in a chamber attached to the outside of the furnace shell.

Knapsack A.G., a West German elemental phosphorus producer, adopted a new process for manufacturing 2,000 tons per year of phosphorus pentasulfide. The process was developed by the firm and was based on the reaction between molten yellow phosphorus and molten sulfur at about 350° C in an inert atmosphere.[28] Many safety factors were built into the plant since the danger of explosion of mixtures of air and phosphorus pentasulfide is very great.

A process used by Fertilizers and Chemicals Travancore Ltd., in India to produce ammonium sulfate from waste gypsum resulting from wet-process phosphoric acid manufacture was described.[29]

A crystallographic study, using both optical and X-ray diffraction techniques, was made on tetracalcium phosphate. The results indicated that tetracalcium phosphate has a layer-type structure relationship to hydroxyapatite ($Ca_5(OH)(PO_4)_3$), which accounts, in part, for variations in the compositions of apatite materials having calcium to phosphorus ratio greater than 10 to 6. The hydroxyapatite relationship also suggests that tetracalcium phosphate may be present in tooth and bone mineral.[30]

A report was made on the operation of a newly designed unit which had been installed in July 1964 by FMC Corp. at its Newark, Calif., phosphate plant to reduce air-pollution. The process was reported to be 99.9 percent efficient in preventing droplets of phosphoric acid in the gas stream from entering the atmosphere.[31] Advantages claimed for the unit in addition to its efficiency were its low initial investment and moderate operating costs.

An automatic instrumental method for determining phosphorus in sodium hydrogen carbonate extracts from soils was described.[32] Among advantages claimed for the automatic procedure over the manual techniques were greater accuracy and speed. It was stated that an individual analysis can be made within 6 minutes after aliquots are taken and that the instrument can analyze 192 samples in an 8-hour day.

Patents were granted for new methods and techniques of beneficiating phosphate rock,[33] producing and processing wet-proc-

[24] Fertilizer Industry Round Table 1965. Proceedings of the 15th Annual Meeting, Washington, D.C., Nov. 10–12, 1965. Housden L. Marshall, Baltimore, Md., 1966, 105 pp.

[25] Gilbert, Richard L., and Edgard C. Moreno. Dissolution of Phosphate Rock by Mixtures of Sulfuric and Phosphoric Acids. Ind. and Eng. Chem., v. 4, No. 4, October 1965, pp. 368–371.

[26] Chemical & Engineering News. Ammonium Polyphosphate Made Directly. V. 43, No. 39, Sept. 27, 1965, p. 63.

[27] Marks, E. C., and L. S. Wilson. Operation of a 25,000–Kw Rotating Phosphorus Furnace. J. Metals, v. 17, No. 3, March 1965, pp. 306–312.

[28] Phosphorus and Potassium. Knapsack Process for Phosphorus Pentasulphide Production. No. 18, August 1965, pp. 23–24.

[29] Phosphorus and Potassium. Utilizing Waste Gypsum From Wet-Process Acid Manufacture Using FACT Process. No. 16, April 1965, p. 23.

[30] Brown, Walter E., and Earl F. Epstein. Crystallography of Tetracalcium Phosphate. J. of Res. of NSB, v. 69A, No. 6. November–December 1965, pp. 547–551.

[31] Oil, Paint and Drug Reporter. FMC Goes In For Atmospheric Purity Over San Francisco. V. 188, No. 21, Nov. 22, 1965, pp. 5, 46.

[32] Colwell, J. D. Methods, Apparatus and Technique. Chem. and Ind. (London). No. 21, May 22, 1965, pp. 893–895.

ess phosphoric acid,[34] manufacturing phosphatic fertilizers,[35] utilizing byproducts,[36] and processing industrial phosphorus and phosphates.[37] In addition many patents were issued for the preparation of a large variety of phosphorus compounds.

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Platinum-Group Metals

By Glen C. Ware [1]

The platinum-group metal industry in 1965 was characterized by substantial growth in productive capacity and in United States demand. The growth in capacity was based upon the exploitation of platinum deposits which will support expansion of output to meet any anticipated demand. World capacity was expanded an estimated 400,000 ounces, including 240,000 ounces of platinum and 130,000 ounces of palladium. However, much of this increase was not reflected in market supply owing to delay in refining, which is usually 9 months. Sales of platinum to consuming industries were limited by supply, but sales of palladium increased 21 percent.

The major U.S. suppliers allocated platinum to established customers at $100 per ounce. Nevertheless world prices soared, reaching $170 per ounce in November, when purchases by China could not be filled from free world stocks. Despite record purchases the price of palladium did not change.

Table 1.—Salient platinum-group metals statistics

(Troy ounces)

	1956–60 (average)	1961	1962	1963	1964	1965
United States:						
Mine production [1]	18,676	43,248	28,742	49,750	40,487	35,026
Value	$1,290,577	$2,256,432	$1,591,463	$2,442,840	$2,395,877	$2,041,102
Refinery production:						
New metal	50,927	79,453	54,775	80,208	71,090	61,723
Secondary metal	97,631	85,971	132,102	117,099	120,147	108,525
Imports for consumption	815,460	884,463	720,352	1,003,608	r 882,705	1,167,657
Exports (except manufacturers)	45,270	61,845	60,591	63,012	146,306	103,097
Stocks Dec. 31: Refiner, importer, dealer	515,350	555,445	598,102	699,575	767,264	926,373
Consumption	792,849	823,226	866,459	1,003,194	r 1,117,680	1,186,701
World: Production	1,130,000	1,345,000	1,625,000	1,540,000	2,550,000	2,960,000

r Revised.
[1] From crude platinum placers and byproduct platinum-group metals recovered largely from domestic gold and copper ores.

U.S. requirements for platinum were up sharply due to heavy start-up demands by new plants to refine petroleum. This demand was superimposed upon a rising demand from other industries, notably glass, where expansion was planned contingent upon the availability of platinum. Actual purchases of platinum were short of this projected demand. Since world stocks were believed to have been adequate, limited purchases must be attributed to resistance to high prices on the open market, pending an expected increase in free world supply.

Legislation and Government Programs.—There were no changes in the Government inventories of the platinum-group metals. They remained at 766,000 ounces, 738,00 ounces, and 13,900 ounces of platinum, palladium, and iridium, respectively.

[1] Commodity specialist, Division of Minerals.

However, 316,000 ounces of platinum were credited toward the palladium objective. The objectives for platinum, palladium, and iridium remain 450,000 ounces, 1,300,000 ounces, and 17,000 ounces, respectively. Senate and House bills were introduced to dispose of the 316,000 ounces of platinum in excess of the stockpile objective.

Table 2.—Government inventory of platinum-group metals, December 31, 1965

(Thousand troy ounces)

Metal	National stockpile	Supplemental stockpile	Total
Iridium	14	----------	14
Palladium	90	648	738
Platinum	716	50	766
Rhodium	1	----------	1
Ruthenium	15	----------	15
Total	836	698	1,534

DOMESTIC PRODUCTION

The Goodnews Bay Mining Co. produced platinum-group metals from placer deposits. Recovery from sludge and residue was reported by American Metal Climax, Inc., American Smelting and Refining Company, and International Smelting & Refining Co. Yuba Consolidated Industries, Inc., recovered some crude platinum from its gold placer operation.

Toll refining of platinum-group metals was 7 percent higher than in 1964, despite a decrease of 123,000 ounces in the quantity of palladium. The total output was 1,193,800 ounces including platinum, 942,000 ounces; palladium, 203,000 ounces; iridium, 6,500 ounces; osmium, 1,000 ounces; rhodium, 37,000 ounces; and ruthenium, 4,300 ounces. Spent catalyst from the petroleum industry accounted for the largest part of metal supply for toll refining.

Table 3.—New platinum-group metals recovered by refiners in the United States by sources

(Troy ounces)

Year and source	Platinum	Palladium	Iridium	Osmium	Rhodium	Ruthenium	Total
1956–60 (average)	39,092	6,299	2,538	871	1,207	920	50,927
1961	46,113	28,988	1,903	148	1,993	308	79,453
1962	36,462	16,144	905	100	1,016	148	54,775
1963	40,290	32,799	2,270	189	3,421	1,239	80,208
1964:							
From domestic sources:							
Crude platinum; gold and copper refining	15,608	22,863	2,423	366	2,757	286	44,303
From foreign crude platinum	14,931	4,438	1,558	149	3,517	2,194	26,787
Total	30,539	27,301	3,981	515	6,274	2,480	71,090
1965:							
From domestic sources:							
Crude platinum; gold and copper refining	11,376	22,500	1,414	315	2,156	400	38,161
From foreign crude platinum	13,871	3,839	1,214	884	2,702	1,052	23,562
Total	25,247	26,339	2,628	1,199	4,858	1,452	61,723

Table 4.—Secondary platinum-group metals recovered in the United States

(Troy ounces)

Year	Platinum	Palladium	Iridium	Osmium	Rhodium	Ruthenium	Total
1956–60 (average)	48,834	42,339	1,296	364	3,097	1,701	97,631
1961	51,218	32,451	193	6	1,836	267	85,971
1962	71,817	56,273	767	99	2,570	576	132,102
1963	54,084	59,993	440	273	1,990	319	117,099
1964	66,043	49,879	764	928	2,338	195	120,147
1965	53,562	50,025	960	763	2,590	625	108,525

CONSUMPTION AND USES

There were significant changes in the use patterns of platinum, palladium, and rhodium. The quantity of platinum used by all industries did not change significantly in 1965. However, platinum available to the major suppliers was not enough to meet demand, and neither the glass nor the petroleum industry bought as much as they would have taken had it been available at $100 an ounce. The use of palladium increased 21 percent, and the use of rhodium decreased 28 percent from the 1964 high, when the glass industry had used rhodium to conserve platinum.

Table 5.—Platinum-group metals sold to consuming industries in the United States

(Troy ounces)

Year and industry	Platinum	Palladium	Iridium	Osmium	Rhodium	Ruthenium	Total	Percent of total
1956-60 (average)	346,076	412,935	6,060	819	21,805	5,154	792,849	100
1961	283,088	508,040	6,547	805	19,174	5,572	823,226	100
1962	304,272	519,860	9,251	1,125	26,063	5,888	866,459	100
1963	424,344	526,527	9,832	1,056	37,068	4,367	1,003,194	100
1964:								
Chemical	137,248	117,102	2,659	1,157	13,179	2,636	273,981	24
Petroleum	r 108,691	41,887	88	100	2,121	2,018	r 154,905	16
Glass	49,680	110	6	----------	23,923	----------	73,719	6
Electrical	103,584	350,889	2,288	23	7,687	1,049	465,520	41
Dental and medical	19,376	49,893	198	----------	38	862	70,367	6
Jewelry and decorative	29,576	20,886	4,354	----------	8,296	793	63,905	6
Miscellaneous	3,195	10,665	59	99	182	1,083	15,283	1
Total	r 451,350	591,432	9,652	1,379	55,426	8,441	r 1,117,680	100
1965:								
Chemical	131,599	156,796	3,006	1,479	12,499	3,103	308,482	26
Petroleum	81,200	37,001	6	75	369	----------	118,651	10
Glass	19,846	1,402	8	----------	10,275	----------	31,531	3
Electrical	106,808	430,384	3,483	10	7,924	2,647	551,256	46
Dental and medical	26,511	50,192	294	32	124	142	77,295	7
Jewelry and decorative	35,387	18,203	2,639	----------	7,498	860	64,587	5
Miscellaneous	10,084	23,107	118	38	221	1,331	34,899	3
Total	411,435	717,085	9,554	1,634	38,910	8,083	1,186,701	100

r Revised.

Table 6.—Refiner, importer, and dealer stocks of platinum-group metals in the United States, December 31

(Troy ounces)

Year	Platinum	Palladium	Iridium	Osmium	Rhodium	Ruthenium	Total
1961	255,654	244,910	12,250	3,058	29,258	10,315	555,445
1962	256,755	285,173	13,871	2,762	30,692	8,849	598,102
1963	320,601	315,756	18,907	1,531	32,900	9,880	699,575
1964	378,896	317,691	20,022	1,936	38,388	10,331	767,264
1965	422,804	427,450	18,374	1,502	44,531	11,712	926,373

PRICES

After being raised $10 from $87 to $90 per ounce on January 19, the price of platinum allocated to consumers remained at $97 to $100 throughout the year. Dealers' prices were substantially higher, ranging around $135 to $140 per ounce most of the year. However, in November the free world supply fell short of demand and prices moved up sharply. January 1966 futures sold on December 30 at $169.50 per ounce, up from the year's low of $122.75. The price of osmium rose on February 1 from $190 to $200 per ounce to $230 to $250 and then held steady. The price of iridium rose from $95 to $100 per ounce to $100 to $105 on July 21 and to $110 to $115 on November 1. The prices of palladium, rhodium, and ruthenium remained steady throughout the year at $32 to $35, $182 to $185, and $55 to $60 per ounce, respectively.

FOREIGN TRADE

Exports of platinum declined 42 percent, with large decreases in exports to France, Italy, Japan, and the United Kingdom.

The value of exported platinum-group manufactures was about one-half of the value in 1964. Declines were noted for a large number of importers, but exports to Japan decreased the most.

The United States imported a record quantity of platinum-group metals in 1965. Palladium imports led in quantity at 735,000 ounces, and platinum was second in quantity with imports of 349,000 ounces. The 1965 imports of palladium and platinum exceeded the 483,000 ounces and 282,000 ounces, respectively, imported in 1964. Imports of platinum of origin in the U.S.S.R. and imports attributed to such origin were up sharply, totaling 53,000 ounces. This amount is approximately 11 percent of the estimated output in the U.S.S.R., strengthening the belief of some that there may be as much as 500,000 ounces of platinum in stock in that country.

Table 7.—U.S. imports for consumption of platinum-group metals

Year	Troy ounces	Value (thousands)
1956–60 (average)	815,460	$37,911
1961	884,463	36,840
1962	720,352	32,699
1963	1,003,608	50,376
1964	[r] 882,705	[r] 50,450
1965	1,167,657	69,110

[r] Revised.

Table 8.—U.S. exports of platinum-group metals, by countries

Year and destination	Platinum (ore, concentrates, ingots, bars, sheets, wire, sponge, and other forms, including scrap)		Palladium, rhodium, iridium, osmiridium, ruthenium, and osmium (metal and alloys including scrap)		Platinum group manufactures, except jewelry (value)
	Troy ounces	Value	Troy ounces	Value	
1956–60 (average)	28,831	$1,860,735	16,439	$456,260	$2,367,236
1961	41,385	2,088,753	20,460	819,882	2,983,447
1962	49,651	1,514,082	10,940	458,924	4,105,734
1963	51,236	3,650,354	11,776	507,494	2,255,601
1964:					
North America:					
Canada	946	111,784	8,578	466,509	2,622,011
Mexico	145	15,030	3,193	184,004	208,010
Netherlands Antilles	1,310	176,123	48	9,645	32,137
Other	5	682	28	3,794	68,005
South America:					
Brazil	1,560	255,757	38	6,859	22,841
Chile	13	840	-	-	3,391
Colombia	301	28,325	70	4,552	115,595
Other	32	13,898	151	9,742	104,883
Europe:					
Belgium-Luxembourg	750	86,638	426	22,679	94,265
France	9,051	872,108	248	32,081	153,213
Germany, West	16,097	1,836,392	4,817	274,965	168,737
Italy	5,370	466,113	396	34,999	654
Switzerland	1,599	171,827	104	6,936	181,886
United Kingdom	64,367	2,789,851	752	66,207	169,746
Other	531	57,330	60	6,886	53,632
Africa	-	-	-	-	7,041
Asia:					
India	86	9,450	30	2,244	9,141
Japan	22,924	2,947,723	2,208	226,920	804,059
Other	18	1,332	20	3,580	25,389
Oceania	34	1,114	-	-	238,788
Total	125,139	9,842,317	21,167	1,362,602	5,083,424
1965:					
North America:					
Canada	927	152,083	1,218	117,276	1,737,975
Mexico	419	74,073	2,314	159,080	145,796
Other	38	3,969	98	16,403	112,529
South America:					
Chile	3,452	339,126	34	1,238	2,036
Colombia	415	43,959	11	2,072	4,543
Venezuela	82	5,497	44	3,570	2,903
Other	14	4,145	105	16,180	24,703
Europe:					
Belgium-Luxembourg	737	116,010	3,428	175,539	14,661
France	375	56,210	1,367	198,471	130,054
Germany, West	15,049	2,177,452	13,349	1,904,960	2,103
Italy	2,492	378,918	2,324	270,267	8,379
Netherlands	1,480	258,695	358	57,404	2,319
Switzerland	1,549	230,311	176	28,991	28,764
United Kingdom	29,174	3,430,686	1,969	261,579	111,092
Other	511	7,091	59	12,375	14,152
Africa	-	-	11	1,850	16,932
Asia:					
India	3	592	12	1,549	1,875
Israel	10	520	65	3,710	3,940
Japan	16,056	2,534,512	3,093	500,249	101,281
Philippines	25	512	67	14,130	7,029
Other	117	23,765	29	4,463	11,355
Oceania	-	-	41	6,527	30,095
Total	72,925	9,838,126	30,172	3,757,883	2,514,516

Table 9.—U.S. imports for consumption of platinum-group metals (unmanufactured), by countries [1]

(Troy ounces)

Year and country	Unrefined material		Refined metals					
	Primary	Scrap	Platinum	Palladium	Iridium	Rhodium	Ruthenium	Total
1964:								
North America:								
Canada			112,407	95,084	4,060	24,449	1,465	[r] 237,465
Honduras		132						132
Mexico			954	1,406				2,360
Netherlands Antilles		272						272
South America: Colombia	22,166	1,115		64				23,345
Europe:								
Belgium-Luxembourg		202		8,075				8,277
Czechoslovakia						416		416
France			18	1,179				1,197
Germany, West	432		612	10,271		148		11,463
Italy		84		3,049				3,133
Netherlands	517			45,011		1,003		46,531
Norway	2,600		4,406	7,369	510	1,293	988	17,166
Switzerland			1,011	72,656		9,889		[r] [2] 83,556
U.S.S.R.	1,649	2,095	6,351	126,719		7,092		[2] 145,519
United Kingdom	8,552		[r] 155,693	[r] 99,415	2,045	11,514	7,903	[r] 287.456
Asia:								
Japan		1,227	306	12,720				14,253
Lebanon			164					164
Total:								
Troy ounces	35,916	5,127	[r] 281,922	[r] 483,018	6,615	55,804	10,356	[r] 882,705
Value	$3,341,061	$486,947	[r] $24,101,906	[r] $13,475,096	$488,621	$7,955,125	$403,745	[2] $50,450,160

Table 9.—U.S. imports for consumption of platinum-group metals (unmanufactured), by countries [1]—Continued

(Troy ounces)

Year and country	Unrefined material		Refined metals					
	Primary	Scrap	Platinum	Palladium	Iridium	Rhodium	Ruthenium	Total
1965:								
North America:								
Canada	33		62,543	119,006	5,600	6,600	5,360	199,142
Mexico				727		200		927
Netherlands Antilles			1,202					1,202
Panama			460					460
South America:								
Colombia	19,621	4						19,625
Venezuela	673							673
Europe:								
Belgium-Luxembourg			636			478		1,114
France	103			1,072	37			1,212
Germany, West			2,957	56,495		40		[2] 59,517
Ireland			582	18				600
Netherlands			317	10,599		820		11,736
Norway			6,630	7,699				14,329
Switzerland			8,552	32,156				40,708
U.S.S.R.			40,345	[3] 443,555	2,743	18,169		504,812
United Kingdom			224,886	63,534	2,459	13,448	2,838	[r 2] 311,365
Africa: South Africa, Republic of			3					3
Asia:								
Japan			50					[2] 82
Taiwan				20				20
Oceania: Australia			117			13		130
Total:								
Troy ounces	20,430	4	349,280	734,881	10,839	39,768	8,198	1,167,657
Value	$2,275,237	$429	$36,125,104	$22,381,089	$942,663	$6,762,289	$307,172	$69,109,837

[r] Revised.

[1] Certain items reported by the Bureau of the Census as "sponge and scrap" have been reclassified by the Bureau of Mines and included with "platinum refined metal" in this table.

[2] Includes in 1964, 935 ounces ($34,793) of osmiridium from United Kingdom, and 1,613 ounces ($49,827) from U.S.S.R.; 3,988 ounces ($228,209) of osmiridium from United Kingdom in 1965; and in 1964, 1,399 ounces ($113,039) of osmium from United Kingdom; and 1965, 212 ounces ($64,524) from United Kingdom, 25 ounces ($11,000) from West Germany, and 32 ounces ($12,121) from Japan.

[3] Includes 33,913 ounces ($1,085,224) reported as platinum and believed to be palladium.

WORLD REVIEW

Free world output of platinum-group metals in 1965 was estimated to be about 1,260,000 ounces, including 746,000 ounces of platinum and 394,000 ounces of palladium. The supply of platinum in the free world market is expected to overtake demand when the current expansion of capacity is fully reflected in market supply. Thus, current shortage of platinum may be relieved in 1966.

Canada.—Canada's output of platinum-group metals increased as a result of increased production of nickel. The recovery of osmium was begun on a modest scale.

Japan. — Japan reported imports of 450,495 ounces of platinum-group metals in 1965 compared with 343,816 ounces in 1964 and 373,419 ounces in 1963. Imports of platinum were 183,350 ounces in 1965, 165,701 ounces in 1964, and 183,758 ounces in 1963. Imports of palladium increased steadily. In 1963, 147,055 ounces were imported, 168,273 ounces in 1964, and 260,521 ounces in 1965. Imports of metal whose origin was attributed to the U.S.S.R. were 354,928 ounces compared to 181,551 ounces in 1964 and 198,044 ounces in 1963. Japan produces less than 1 percent of her requirements for platinum-group metals.

Table 10.—World production of platinum-group metals

(Troy ounces)

Country	1961	1962	1963	1964	1965 p 1
North America: [2]					
Canada:					
Platinum and platinum-group metals	418,278	470,787	357,651	r 376,238	452,063
United States:					
Placer platinum and from domestic gold and copper refining	43,248	28,742	49,750	40,487	35,026
South America: [2]					
Colombia:					
Placer platinum (exports) [3]	r 20,160	r 14,100	r 22,983	r 20,647	11,040
Europe:					
U.S.S.R.:					
Placer platinum and from platinum-nickel-copper ores e	500,000	800,000	800,000	r 1,500,000	1,700,000
Africa:					
Congo, Republic of the (Léopoldville):					
Palladium from refineries			3	e 4	
Platinum from refineries			4	e 1	
Ethiopia:					
Placer platinum	180	180	e 180	e 180	353
South Africa, Republic of:					
Platinum-group metals from platinum ores e	350,000	300,000	300,000	600,000	750,000
Osmiridium from gold ores e	7,000	6,000	5,500	6,000	6,000
Asia:					
Japan:					
Palladium from refineries	1,550	1,372	1,326	1,875	3,016
Platinum from refineries	2,247	1,872	1,714	2,199	2,788
Philippines:					
Platinum from refining nickel-platinum concentrates	177	172			
Palladium from refining nickel-platinum concentrates	215	141			
Oceania:					
Australia:					
Placer platinum	2	r 2	r 4		41
Palladium					81
New Guinea [4]	r 2	r 5	5	2	4
World total e	r 1,345,000	r 1,625,000	r 1,540,000	r 2,550,000	2,960,000

e Estimate. p Preliminary. r Revised.
[1] Compiled mostly from data available June 1966.
[2] U.S. imports include platinum from other Western Hemisphere countries which are not listed as producers.
[3] U.S. imports from Colombia are consistently higher than Colombian export data.
[4] Year ended June 30.

South Africa, Republic of.—Mine and mill output of platinum-group metals was increased substantially. A 40-percent increase over the 1963–64 output was scheduled for the completion by April 1966. Its full effect should be reflected in market supply by the end of 1966. All of the 1965 output of refined metal was sold. Although the output increased steadily, total sales were less than in 1964, when stocks were drawn virtually to depletion.

The Bureau of the Census reported the import of 300 tons of nickel matte from the Republic of South Africa. Its platinum-group metal content would be about 15,000 ounces of which 10,000 ounces would be platinum. The imports also include metallic concentrates. These imports were the result of contracts made in 1964 between Rustenburg Platinum Mines Ltd. and a consortium of African mining interests to supply the consortium with platinum in return for rights to mine the neighboring Brakspruit property. The platinum matte and concentrate metallics were shipped to Engelhard Industries International Ltd. through sales to the Platinum Prospecting Co.

U.S.S.R.—Increasing exports and other data indicate that the production of platinum-group metals in the U.S.S.R. has increased steadily since about 1945. It probably reached 1.5 million ounces by 1964 and 1.70 million ounces in 1965. Production of refined metal is reported to be 60 percent palladium, 30 percent platinum, and 10 percent minor metals. About 80 percent of this metal is mined in one area near Noril'sk in Eastern Siberia. One deposit, the Noril'sk-I, is reported to have sufficient proven reserves to maintain the present production rate for 90 years. Possessing the only stocks of platinum not held in the U.S. Government stockpile, the U.S.S.R. was able to sell platinum at about $170 per ounce in the final 2 months of the year, but they offered palladium at prices below the nominal price quoted by U.S. suppliers.

TECHNOLOGY

One reason the platinum-group metals have retained their places among industrial materials, despite their high price, is the ease of reclamation from used material. This allows the special properties of the platinum-group metals to be available at a reasonable cost. The traditional properties upon which their uses depend are noble character; catalytic activity; stable thermal and thermoelectric properties and good mechanical properties at high temperatures; and a high temperature coefficient of electrical resistivity.

The surfaces of the noble metals are hydrophobic, a property which enables engineers to design more efficient and compact stills. A coating of platinum or rhodium can increase the heat-transfer coefficient of a surface by as much as 50 percent, and can increase condensation rates 90 percent above the rates that have been obtained on uncoated surfaces.[2]

Platinum black catalyzes the oxidation of hydrogen in fuel cells, that have been adopted as the source of power to energize instruments carried by space vehicles. Electrodes of a titanium-palladium alloy deliver the energy to the instrument circuits. A solid polystyrene formulation is used as an electrolyte, and potable water is the only substantial product of the reaction. The potential applications for fuel cells far exceed the potential supply of platinum to build them, and extensive use must be based upon other catalysts.

Direct conversion of chemical energy to electrical energy is the object of diligent research, much of which was devoted to the physical chemical reactions that occur at electrodes made of platinum-group metals. Typical reactions are as follows: The diffusion of gases through porous electrodes,[3] the passage of hydrogen through solid palladium,[4] electrocatalytic reactions,[5] carbon-supported platinum-group metal

[2] Chemical & Engineering News. Noble Metals Give Better Condensation. V. 43, No. 15, Apr. 12, 1965, pp. 72–73.

[3] Austin, Leonard G., Mario Ariet, Robert D. Walker, Gwendolyn B. Wood, and Raymond H. Comyn. Simple-Pore and Thin-Film Models of Porous Gas Diffusion Electrodes. Ind. and Eng. Chem., v. 4, No. 3, August 1965, pp. 321–327.

[4] Castellan, G. W., R. A. LaPietra, and P. L. Damour. The Transmission of Electrolytically Deposited Hydrogen Through a Palladium Membrane Electrode. J. Electrochem. Soc., v. 12, No. 6, June 1965, pp. 654–655.

[5] Bianchi, G. Improved Porous Electrode for Studying Electrocatalytic Reactions of Gases and Vapors. J. Electrochem. Soc., v. 112, No. 2 February 1965, pp. 233–235.

electrodes,[6] and the reaction of hydrogen and oxygen at platinum and palladium electrodes in acid solutions.[7] Two solid-electrolyte cells [8] and a cell using conducting porous-Teflon electrodes were described.[9] Fuels other than hydrogen were studied.[10]

Units to separate high-purity hydrogen from mixed-gas streams have been built with multimillion cubic-foot-per-day capacity by supporting large areas of exceedingly thin films of palladium.[11] Resistance to oxidation and to thermal shock approaching that of tungsten may be imparted to graphite by a 2-mil-thick coating of iridium. Molten iridium wets graphite but does not react with it. The coat adheres and adequately protects against oxidation at 3600° F for 1 hour or more.[12]

Engelhard Industries, Inc., published an excellent set of tables giving the physical properties of the noble metals. Osmium, specific gravity 22.61, lost its position as the densest of the platinum-group metals when 22.65 was accepted commercially as the specific gravity of iridium. The difference has no practical significance, and it may be reversed again since the calculated values remain 22.59 for osmium and 22.55 for iridium.[13]

The electrodeposition of rhodium, platinum, and palladium from aqueous solutions is commonplace. Recently they have been electrodeposited from a fused bath onto titanium.[14] The electrodeposition of iridium and ruthenium from aqueous solutions has also been accomplished.[15] Platinum and palladium coats are applied to nonmetallic substrates by firing the dried residues from liquid preparations of the metals.[16]

All of the platinum-group metals are catalysts for hydrogenation and hydrogenolysis reactions. A wide variety of reactions are promoted.[17] Platinum supported on silica gel promotes the dehydrocyclization of aromatic compounds.[18]

Liquid hydrogen in its para form has enhanced heat-sink properties, enabling ram jet engines to be lighter in weight. Ruthenium promotes the conversion of the normal ortho-para mixture into virtually pure para hydrogen.[19]

Zone refining with an electron beam at a vacuum of 10^{-6} torr is now used to prepare single crystals of all the platinum-group metals, except osmium. Single crystals of ruthenium were found to be 99.999 percent pure by interpreting the ratio of their electrical resistance at room temperature to that at 4.2°K.[20] The recovery of platinum and palladium from gold electrolyte is facilitated by precipitating the gold with reductants other than sulfur dioxide and treating the stripped electrolyte

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[6] Hillenbrand, L. J., and J. W. Lacksonen. The Platinum-on-Carbon Catalyst System for Hydrogen Anodes: I. Characterization of the Catalyst and Support. J. Electrochem. Soc., v. 112, No. 3, March 1965, pp. 245–252.
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[7] Hoare, James P. Oxygen Overvoltage Measurements on Bright Platinum in Acid Solutions: I. Bright Platinum. J. Electrochem. Soc., v. 112, No. 6, June 1965, pp. 602–607.
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[8] Chemical Engineering. Gemini Spaceflight Carries Fuel Cells to New Prominence. V. 72, No. 19, Sept. 13, 1965, pp. 107, 110.
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with sodium formate instead of zinc dust.[21]

The anodic dissolution of platinum electrodes was studied in connection with an investigation of the passivity of iron-chromium alloys.[22] The resistance of platinum to dissolution is important in many applications, including the cathodic protection of ships' hulls and tanks and the protection of inert electrodes made of a copper core coated with titanium and platinum.

Platinum-group metals and their alloys may be dispersion strengthened to resist creep at elevated temperatures.[23] The use of ruthenium as a hydrogenation catalyst to prepare selected organic compounds was the subject of several patents; one of these was assigned to Engelhard Industries, Inc.[24] Interest continued in the use of other platinum-group metals as hydrogenation catalysts. The removal of arsenic from platinum-aluminum catalysts represents the efforts made to devise ways to regenerate catalysts.[25] An aluminosilicate zeolite has been modified by incorporating a platinum-group metal in the inner absorption region of the zeolite.[26]

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Potash

By Richard W. Lewis [1]

Increased world demand for fertilizers was reflected in the heavy production and sales of potash, one of the major plant food elements. In the United States the apparent consumption increased 7 percent. Imported Canadian potassium salts, however, supplied the increased demand and sales of domestic potash were slightly less than in 1964.

Legislation and Government Programs.—The U.S. Department of the Interior approved an order revising the special rules governing the development of oil and gas, and potash deposits on certain Federal lands in Eddy and Lea Counties, N. Mex. Some areas considered to have no commercial potash ore were excluded, and other lands having known or indicated commercial ore were made subject to the regulations. The revised potash area, including both public and nonpublic lands contained 420,212 acres, a net increase of 121,867 acres.

The rules permitted, where possible, concurrent prospecting for and the development of oil and gas and potash deposits on these Federal lands. Adequate protection of the deposits in the interest of conservation was also provided.[2]

[1] Commodity specialist, Division of Minerals.
[2] FR 6692, May 15, 1965.

Table 1.—Salient potash statistics

(Thousand short tons and thousand dollars)

	1956–60 (average)	1961	1962	1963	1964	1965
United States:						
Production of potassium salts, marketable ----------quantity--	3,933	4,629	4,167	4,871	4,954	5,401
Approximate K_2O equivalent ------------quantity--	2,321	2,732	2,452	2,864	2,897	3,140
Value ------------------------	$82,358	$104,464	$95,859	$110,164	r $114,095	$129,767
Sales of potassium salts by producers ---------quantity--	3,951	4,226	4,615	4,587	5,201	5,027
Approximate K_2O equivalent ------------quantity--	2,331	2,487	2,722	2,709	3,045	2,931
Value at plant----------------	$82,659	$95,388	$105,608	$103,828	$120,284	$121,161
Average value per ton--------	$20.92	$22.57	$22.89	$22.64	$23.13	$24.10
Imports for consumption of potash materials -----quantity--	377	465	617	1,041	r 1,254	1,867
Approximate K_2O equivalent ------------quantity--	204	262	341	594	r 737	1,108
Value ------------------------	$13,564	$17,315	$21,765	$31,137	r $35,797	$52,675
Exports of potash materials ------------quantity--	555	803	859	722	1,048	1,099
Approximate K_2O equivalent ------------quantity--	308	473	506	425	618	648
Value ------------------------	$19,028	$32,477	$30,731	$25,519	$37,586	$42,494
Apparent consumption of potassium salts [1] -----quantity--	3,773	3,888	4,373	4,906	r 5,407	5,795
Approximate K_2O equivalent ------------quantity--	2,227	2,276	2,557	2,878	r 3,164	3,391
World: Production, marketable: Approximate K_2O equivalent-quantity--	9,000	10,700	10,800	r 11,900	r 13,200	14,800

r Revised.
[1] Measured by sold or used plus imports minus exports.

DOMESTIC PRODUCTION

Production of marketable potassium salts exceeded 5 million short tons in 1965, an increase of 9 percent over that of 1964. New Mexico produced 91 percent of the total production and was responsible for most of the increase.

The calculated average grade of crude salts mined in New Mexico was 18.12 potassium monoxide (K_2O) equivalent, compared with 17.99 percent in 1964.

Estimates from reported deliveries [3] indicated that about 20,000 tons of manure salts (3,800 tons, K_2O equivalent) was produced and sold.

The prospects of producing power and recovering minerals including potash from superheated brines of the geothermal wells in the Imperial Valley, Calif. were still under investigation. Imperial Thermal Products Co., a subsidiary of Morton International Inc. had a pilot plant in operation which successfully generated electricity from the steam. The brines from the plant were processed to two products: A pure sodium chloride and a sodium chloride-potassium chloride mixture. The latter was being shipped to the firm's pilot plant at Saltair, Utah for a study of methods to recover a marketable potash product. Earth Energy, Inc., a subsidiary of The Pure Oil Co., operated a chemical pilot plant to study methods for processing the brines from the geothermal wells. The plant was shut down about 3 months before the end of the year to evaluate the data and for further research.

Table 2.—Production and sales of marketable potassium salts in the United States, in 1965, by product

(Thousand short tons and thousand dollars)

Product	Production			Sales		
	Gross weight	K_2O equivalent	Value [1]	Gross weight	K_2O equivalent	Value
Muriate of potash, 60-percent K_2O minimum:						
Standard	2,395	1,469	$54,772	2,230	1,367	$50,764
Coarse	1,491	909	35,674	1,413	861	33,966
Granular	648	392	16,018	598	362	14,953
Total	4,534	2,770	106,464	4,241	2,590	99,683
Other potassium salts [2 3]	867	370	23,303	786	341	21,478
Grand total	5,401	3,140	129,767	5,027	2,931	121,161

[1] Derived from reported value of "Sold or used."
[2] Figures for refined muriate and manure salts are included with potassium sulfate and potassium-magnesium sulfate to avoid disclosing individual company confidential data.
[3] Includes sulfate manufactured from captive production of muriate.

Plans and studies were continued on methods for extracting minerals from the Great Salt Lake. Salzdetfurth, A.G., of Hanover, West Germany entered into a partnership with Lithium Corporation of America, Inc., to develop the land and mineral rights held by the latter firm. National Lead Co. and partner, Hogle-Kearns Co. (H–K Co.) continued their efforts to develop satisfactory commercial techniques to process the Great Salt Lake brines. After successful processing methods are developed, the companies planned to produce potash, magnesium compounds, and sodium sulfate as the major marketable products.

Foote Mineral Co. continued construction of a plant to process its brine deposit near Silver Peak, Nev. Substantial quantities of potash were expected to be recovered as a byproduct of lithium production. Plant startup was anticipated for sometime in 1966.

American Potash & Chemical Corp. increased potassium sulfate production capacity of its Trona, Calif. plant to 50,000 tons per year.

Kermac Potash Co. began limited production of potash at its new mine and plant 40 miles west of Hobbs, N. Mex. The operation is jointly owned by Kerr-McGee Corp. and National Farmers Union Development Corp. The first product

[3] American Potash Institute, Inc. North American Deliveries of Potash Salts. E-183, Mar. 11, 1966, p. 2.

Table 3.—Production and sales of potassium salts in New Mexico

(Thousand short tons and thousand dollars)

Year	Crude salts [1]		Marketable potassium salts					
	Mine production		Production			Sales		
	Gross weight	K_2O equivalent	Gross weight	K_2O equivalent	Value [2]	Gross weight	K_2O equivalent	Value
1956–60 (average)	13,212	2,495	3,622	2,137	$75,637	3,639	2,147	$75,953
1961	15,653	2,934	4,281	2,523	96,380	3,882	2,281	87,415
1962	14,115	2,619	3,758	2,208	85,124	4,206	2,476	95,851
1963	16,414	3,083	4,504	2,643	100,458	4,213	2,484	94.925
1964	17,356	3,122	4,585	2,675	r 104,861	4,815	2,814	110,772
1965	18,557	3,363	4,919	2,848	117,771	4,607	2,677	110,424

r Revised.
[1] Sylvite and langbeinite.
[2] Derived from reported value of "Sold or used."

from the dryer was reported on November 17. According to reports, Tenneco Oil Co. was contracted to market one-half of the potash output.

Southwest Potash Corp., a division of American Metal Climax, Inc., expanded production facilities at Carlsbad, N. Mex. by 100,000 tons, bringing its total output capacity to about 600,000 tons per year.

On January 13, Texas Gulf Sulphur Co. held official opening ceremonies of its Cane Creek mine near Moab, Utah. The first trainload of potash was shipped from the mine about the first of February. Many of the production problems were overcome and near capacity output rate was expected to be reached during 1966.

A group of New Mexico investors obtained an option to purchase the United States Borax & Chemical Corp. potash property near Carlsbad, N. Mex. The potash firm had announced earlier its intention of closing the facility in 1968 at which time the high-grade ore reserves would be depleted. The investors hoped to interest another company in taking over the facilities and mine the low-grade (16 percent K_2O) reserves which could last another 20 years.

CONSUMPTION AND USES

Adverse weather conditions over much of the United States caused severe flooding in the Midwest and delayed planting in many areas until late in the season, resulting in less than expected apparent consumption. Even so, deliveries of potash for agricultural use increased 6 percent over those in 1964. Nonagricultural potash deliveries were increased by 16 percent over those of 1964.

Illinois, Indiana, Ohio, Georgia, and Florida, in decreasing order, were the leading States in quantities of agricultural potash received. Deliveries and consumption do not necessarily correspond because much of the potash delivered is used in mixed fertilizers and resold in other States.

Table 4.—Deliveries of potash salts in 1965, by States of destination

(Short ton K_2O equivalent)

Destination	Agricultural potash	Chemical potash	Destination	Agricultural potash	Chemical potash
Alabama	96,430	24,882	Nebraska	10,896	173
Arizona	833	23	Nevada	----	1,191
Arkansas	75,418	602	New Hampshire	676	44
California	31,540	11,836	New Jersey	29,541	2,679
Colorado	2,269	27	New Mexico	523	524
Connecticut	5,484	227	New York	64,105	82,841
Delaware	10,399	1,031	North Carolina	114,438	488
District of Columbia	410	----	North Dakota	5,317	----
Florida	169,842	584	Ohio	194,503	6,801
Georgia	177,427	1,106	Oklahoma	18,305	328
Hawaii	26,495	----	Oregon	9,945	406
Idaho	2,425	3	Pennsylvania	46,829	4,464
Illinois	414,438	26,998	Rhode Island	1,464	381
Indiana	273,232	4,215	South Carolina	80,649	----
Iowa	169,694	301	South Dakota	2,460	----
Kansas	8,275	868	Tennessee	95,667	----
Kentucky	58,387	10,137	Texas	129,784	6,695
Louisiana	31,875	987	Utah	401	31
Maine	11,986	88	Vermont	5,834	----
Maryland	86,813	1,657	Virginia	117,750	566
Massachusetts	16,711	574	Washington	16,965	1,606
Michigan	99,912	1,796	West Virginia	2,400	14,895
Minnesota	109,440	128	Wisconsin	123,314	130
Mississippi	65,295	----	Wyoming	117	----
Missouri	114,584	1,589			
Montana	544	----	Total	3,132,041	213,902

STOCKS

The quantity of potassium salts held by producers was increased by 72 percent because of less demand than was anticipated. Yearend stocks on hand included material sold for delivery during the 1966 spring planting season.

Table 5.—Stocks of potassium salts in the United States

(Thousand short tons)

Year	Number of producers	Stocks, Dec. 31: Gross weight	Stocks, Dec. 31: K_2O equivalent
1956–60 (average)	11	658	392
1961	11	927	558
1962	11	475	286
1963	10	762	478
1964	10	519	295
1965	12	892	504

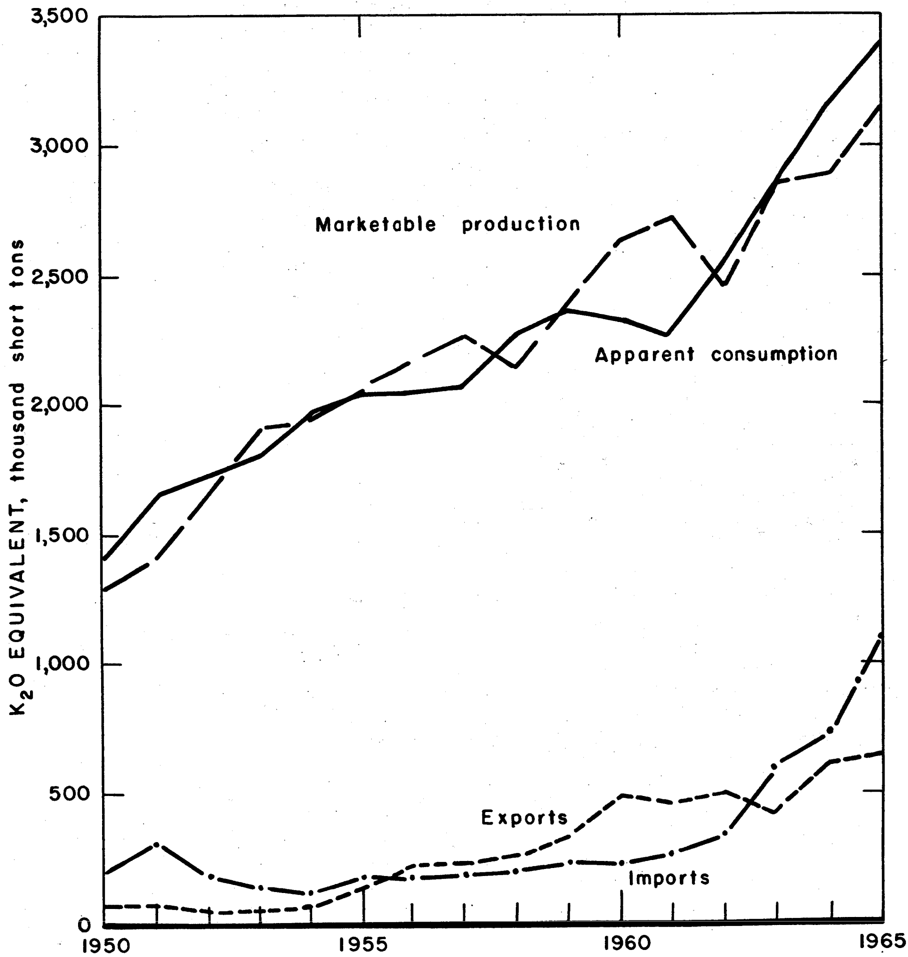

Figure 1.—Marketable production, apparent consumption, exports, and imports, K_2O equivalent.

PRICES

Quoted bulk prices on muriate of potash for the 1965–66 fertilizer year were unchanged from those for the previous 12-month period. However, potassium sulfate was priced 2 cents per unit K_2O higher. One unit of K_2O is defined as equal to 1 short ton of material containing 1 percent K_2O equivalent, or 20 pounds.

Price schedules published by producers, quoted prices for shipments during the months indicated, against contracts made before July 1, 1965. On contracts made after June 30, 1965, some producers increased the prices 2 cents per unit, while others increased the price 5 percent. An additional $5.50 per short ton was charged by most producers for muriate shipped in 100-pound bags.

All producers reserved the right to adjust prices to meet competition.

Table 6.—Bulk prices for New Mexico potash [1]

(Cents per unit K_2O)

Product	1965			1966	
	July–Aug.	Sept.–Oct.	Nov.–Dec.	Jan.	Feb.–June
Muriate, 60-percent K_2O minimum:					
Standard	36	38	40	40	43
Coarse	37.5	39.5	41.5	41.5	44.5
Granular	40	42	44	44	47
Sulfate of potash, standard [2]	72	75	78	78	81
Manure salts	17.65	17.65	17.65	17.65	17.65

[1] Quoted by producers, carlots, f.o.b. Carlsbad on contracts made prior to July 1, 1965.
[2] Coarse and granular when quoted: 3 cents and 5 cents higher respectively.

Table 7.—Bulk prices for California potash [1]

(Cents per unit K_2O,

Product	1965			1966	
	July–Aug.	Sept.–Oct.	Nov.–Dec.	Jan.	Feb.–June
Muriate, 60-percent K_2O minimum:					
Standard	45	46	47	47	49.5
Coarse	46.5	47.5	48.5	48.5	51
Sulfate, 52-percent K_2O minimum	83	85.5	88	88	91

[1] Quoted by American Potash & Chemical Corp. carlots, f.o.b. Trona, Calif. on contracts made prior to July 1, 1965.

FOREIGN TRADE

Total exports of potassium salts increased about 5 percent. Foreign competition for world markets increased and there was evidence to indicate even keener competition among the world suppliers during the next several years.

Imports of muriate of potash from Canada into the United States was 80 percent greater than in 1964, and accounted for 84 percent of the total imported. Crude potassium sulfate imports continued to decrease and the tonnage shipped was about 7 percent less than in 1964.

Table 8.—U.S. imports for consumption of potash materials

Material	Approximate equivalent as potash (K_2O) (percent)	1964 Short tons	1964 Approximate equivalent as potash (K_2O) Short tons	1964 Approximate equivalent as potash (K_2O) Percent of total	1964 Value	1965 Short tons	1965 Approximate equivalent as potash (K_2O) Short tons	1965 Approximate equivalent as potash (K_2O) Percent of total	1965 Value
Used chiefly as fertilizers:									
Muriate (chloride) [1]	60	1,159,702	695,545	94.3	$29,202,170	1,782,668	1,069,601	96.6	$45,834,001
Potassium nitrate, crude	40	3,163	1,265	.2	146,896	3,545	1,418	.1	159,123
Potassium sodium nitrate mixtures, crude	14	r 13,498	r 1,890	.3	r 550,855	7,409	1,037	.1	297,855
Potassium sulfate, crude [1]	50	67,233	33,656	4.6	2,595,297	62,428	31,214	2.8	2,236,140
Other potash fertilizer materials	6	204	12	.0	7,421	788	47	.0	27,136
Total	----	r 1,243,800	r 732,368	99.4	r 32,502,639	1,856,838	1,103,317	99.6	48,554,255
Used chiefly in chemical industries:									
Bicarbonate	46	113	52		11,545	355	163		31,917
Bitartrate: Cream of tartar	25	1,453	363		620,164	1,226	307		553,265
Carbonate	61	272	166		35,233	62	39		8,911
Caustic	80	923	738		186,685	972	778		193,585
Chlorate and perchlorate	36	763	275		160,966	1,105	398		238,885
Cyanide	70	1,055	739	.6	504,063	1,107	775	.4	505,842
Ferricyanide	42	r 531	r 223		r 327,076	647	272		405,326
Ferrocyanide	44	836	368		304,424	1,153	507		465,458
Nitrate	50	2,766	1,383		326,009	1,357	679		154,675
Rochelle salts	22	252	55		96,292	230	51		85,090
All other	31	1,262	391		721,776	1,698	526		1,477,956
Total	----	r 10,226	r 4,753	.6	r 3,294,233	9,912	4,495	.4	4,120,910
Grand total	----	r 1,254,026	r 737,121	100.0	r 35,796,872	1,866,750	1,107,812	100.0	52,675,165

r Revised.
[1] Muriate and potassium sulfate quantity obtained from The American Potash Institute, Inc. reports.

Table 9.—U.S. exports of potash materials, by countries

Destination	Fertilizer 1964 Short tons	Fertilizer 1964 Value	Fertilizer 1965 Short tons	Fertilizer 1965 Value	Chemical 1964 Short tons	Chemical 1964 Value	Chemical 1965 Short tons	Chemical 1965 Value
North America:								
Canada	64,467	$2,209,462	45,005	$1,716,220	7,566	$1,483,869	7,217	$1,874,755
Costa Rica	11,573	353,897	8,716	320,994	4	1,240	10	18,099
Dominican Republic	4,200	166,329	5,064	208,888	17	2,474	4	2,290
Mexico	37,214	987,250	43,933	1,160,022	1,209	224,646	1,370	318,028
Netherlands Antilles	15,292	415,291	13,210	373,746	46	14,135	6	4,251
Other	17,459	671,068	15,375	670,122	121	34,630	122	48,413
Total	150,205	4,803,297	131,303	4,449,992	8,963	1,760,994	8,729	2,265,836
South America:								
Argentina	441	15,498	----	----	460	129,840	709	142,891
Brazil	28,549	1,042,077	52,448	1,968,299	517	135,131	12,638	859,554
Chile	16,371	575,234	17,184	558,253	75	21,444	116	33,132
Colombia	40,143	1,230,558	29,265	920,464	1,201	73,094	82	25,967
Peru	893	37,772	412	21,942	61	23,195	49	27,345
Venezuela	6,674	269,615	18,861	671,999	248	63,640	270	108,014
Other	2,513	93,372	2,599	100,056	158	29,876	128	17,495
Total	95,584	3,264,126	120,769	4,241,013	2,720	476,220	13,992	1,214,398
Europe:								
Belgium-Luxembourg	1,092	32,175	----	----	798	199,689	360	92,254
Germany, West	3,145	28,336	741	31,497	2,352	740,392	1,794	523,454
Ireland	5,544	145,084	----	----	----	----	5	6,872
Italy	2,564	75,767	11,672	353,355	1,261	297,316	418	99,688
Netherlands	(1)	(1)	391	44,235	620	199,979	860	290,985
Sweden	13,779	434,850	15,828	472,224	457	40,790	125	37,794
United Kingdom	727	35,327	1,068	53,832	676	194,141	817	224,685
Other	7,089	211,690	7,204	228,643	1,242	347,276	1,793	550,905
Total	r 33,940	r 963,229	36,904	1,183,786	7,406	2,019,583	6,172	1,826,637
Africa:								
South Africa, Republic of	51,009	1,446,803	41,627	1,199,001	112	32,968	137	47,479
Other	556	21,953	590	26,031	290	89,124	181	43,893
Total	51,565	1,468,756	42,217	1,225,032	402	122,092	318	91,372
Asia:								
India	----	----	2,685	143,642	299	75,856	7	3,354
Japan	r 435,747	r 13,647,660	393,015	12,324,722	918	203,754	18	13,521
Korea, South	55,358	1,797,031	143,704	4,358,308	4	2,068	12,335	2,755,263
Pakistan	----	----	8,118	315,055	299	67,180	(2)	528
Philippines	7,616	239,041	4,445	143,673	73	30,835	879	64,768
Taiwan	11,574	410,739	43,330	1,536,230	23	14,721	1	988
Viet-Nam	1,709	64,128	2,322	109,636	41	9,589	31	17,095

Other	----	----	112	5,056	165	43,749	511	91,731
Total	r 512,004	r 16,158,599	597,731	18,936,322	1,822	447,752	13,782	2,947,248
Oceania:								
Australia	68,353	1,948,888	48,751	1,412,034	545	152,137	3,159	300,610
New Zealand	114,795	3,955,605	74,630	2,360,975	175	44,818	131	36,903
Other	----	----	----	----	----	----	6	1,757
Total	183,148	5,904,493	123,381	3,773,009	720	196,955	3,296	339,270
Grand total	1,026,446	32,562,500	1,052,305	33,809,154	22,033	5,023,596	46,289	8,684,761

r Revised.
[1] Revised to none.
[2] Less than ½ unit.

Table 10.—U.S. imports for consumption of potash materials, by countries

(Short tons)

Year and country	Bitartrate, cream of tartar	Caustic (hydroxide)	Chlorate and perchlorate	Cyanide	Muriate (chloride) [1]	Potassium nitrate, crude	Potassium sodium nitrate mixtures, crude	Potassium nitrate (saltpeter), refined	Potassium sulfate,[1] crude	All others	Total: Quantity	Total: Value
1964:												
Belgium-Luxembourg	----	5	----	----	------	10	----	44	----	r 310	r 369	r $194,682
Canada	----	----	----	35	837,357	51	13	----	202	3	837,661	19,394,361
Chile	----	----	----	----	------	1,500	13,485	----	----	----	14,985	613,002
France	80	48	----	76	170,580	82	----	----	33,525	226	204,617	7,081,810
Germany:												
East	----	----	15	----	------	----	----	320	----	r 81	r 416	r 80,500
West	----	594	11	485	116,787	1,498	----	1,537	18,960	r 1,148	r 141,020	r 5,046,729
Italy	664	----	----	66	------	----	(2)	99	14,546	78	r 15,453	r 959,187
Netherlands	----	13	----	----	------	22	----	44	----	1,093	1,172	374,650
Spain	389	----	28	----	34,978	----	----	573	----	75	36,043	1,200,897
Sweden	----	257	418	----	------	----	----	----	----	----	675	188,067
United Kingdom	1	----	----	189	------	----	----	----	----	r 213	r 403	r 141,951
Other countries	319	6	291	204	------	----	----	149	----	r 243	r 1,212	r 521,036
Total	1,453	923	763	1,055	1,159,702	3,163	r 13,498	2,766	67,233	r 3,470	r 1,254,026	r 35,796,872
1965:												
Belgium-Luxembourg	----	----	----	----	------	----	----	----	----	595	595	337,565
Canada	----	30	----	6	1,503,292	72	----	----	22	194	1,503,616	37,169,540
Chile	----	----	----	----	------	3,307	7,409	----	----	----	10,716	436,587
France	3	110	26	122	113,182	66	----	----	37,338	500	151,347	4,971,200
Germany:												
East	----	----	----	----	------	----	----	143	----	83	226	57,261
West	----	576	----	496	122,905	100	----	638	20,218	891	145,824	5,632,878
Italy	606	----	----	----	------	----	----	352	4,850	503	6,311	551,923
Netherlands	----	4	----	28	------	----	----	----	----	1,326	1,358	449,537
Spain	317	----	----	----	43,239	----	----	152	----	105	43,813	1,461,520
Sweden	----	244	675	----	------	----	----	----	----	----	919	244,489
United Kingdom	----	----	----	196	------	----	----	----	----	103	299	135,337
Other countries	300	8	404	259	50	----	----	72	----	633	1,726	1,227,328
Toal	1,226	972	1,105	1,107	1,782,668	3,545	7,409	1,357	62,428	4,933	1,866,750	52,675,165

r Revised.
[1] Muriate and potassium sulfate quantity obtained from The American Potash Institute, Inc. reports.
[2] Revised to none.

WORLD REVIEW

Brazil.—The Brazilian National Institute of Technology reported the discovery of a carnallite potash bed near Carmopolis, Sergipe. The deposit was approximately 90 feet thick and was first encountered at a depth of 1,500 feet. The Government petroleum monopoly, Petrobraś, discovered the potash while drilling for oil.

Canada.—Saskatchewan continued on its way to becoming the major potash producing area of the world. In 1965, three companies were in production, three were sinking shafts, two were preparing to sink shafts, and at least two additional firms were in the planning stages. In March 1965, 21 companies were known to hold potash permits in Saskatchewan while at least 16 others were involved in exploration projects. Canadian potash production in 1965 was nearly 10 times that of 1962, the first year of production since the ill-fated beginning in 1958 by Potash Co. of America.

In early fall International Minerals & Chemical Corp. (Canada) Ltd., (IMC) increased production capacity from 1.6 to 2.0 million tons per year with the installation of new hoisting equipment. Two 16-ton capacity skips were replaced with skips of 24-ton capacity. This was the second expansion program completed within the year; the first, early in the year, increased capacity from 1.2 to 1.6 million tons per annum. The company also continued sinking a second shaft to the deposit about 6 miles southeast of its first shaft. The construction of a new concentrator at the new mine site was on schedule, with production expected by early 1967. The new plant was designed to have a capacity of 1.5 million tons of product annually, which will increase I.M.C.'s total rated capacity to 3.5 million tons.

Kalium Chemicals, Ltd., announced that The British Metal Corp. (Canada) will represent the company as export sales agent. Kalium expected to begin overseas shipments by midyear.

Potash Co. of America resumed operations at its potash mine near Patience Lake, Saskatchewan after its closure in 1959 because of water seepage in the shaft. It was announced that the production rate by midyear had reached near capacity of 600,000 tons of K_2O annually.

United States Borax & Chemical Corp. joined with Homestake Potash Co., a wholly owned subsidiary of Homestake Mining Co. to form a partnership company called Can-Am Potash Producers. Can-Am Potash Producers, with an 80-percent interest, was then joined by Swift Canadian Co. Ltd., holding a 20-percent interest, and formed Allan Potash Mines to develop and operate mining facilities near Saskatoon, Saskatchewan. Shaft-sinking operations were progressing satisfactorily as well as construction of the surface plant and processing facilities. The completion date was set for 1968. The rated production capacity was given as 1.5 million tons per year of product.

Alwinsal Potash of Canada Ltd., started developing a new potash mine at Lanigan-Guernsey, Saskatchewan with production scheduled for 1968.

Table 11.—World production of marketable potash, by countries
(Short tons K_2O equivalent)

Country	1961	1962	1963	1964	1965 p
North America:					
Canada	------	e 150,000	626,860	r 858,351	1,430,000
United States	2,732,602	2,452,921	2,864,037	2,897,000	3,140,000
South America: Chile (nitrate)	15,504	19,541	e r 20,540	r 14,881	e 15,650
Europe:					
France	1,884,791	1,897,958	r 1,897,661	r 2,059,299	2,071,240
Germany:					
East	1,846,369	1,931,247	2,034,000	r 2,046,990	e 2,000,000
West	2,253,122	2,138,637	2,147,300	r 2,426,184	e 2,645,000
Italy	149,187	170,142	207,565	r 226,866	e 231,000
Spain	289,037	259,156	286,876	r 322,427	e 427,260
U.S.S.R. e	1,455,000	1,650,000	1,700,000	r 2,100,000	2,500,000
Asia: Israel [1]	93,600	100,200	124,560	r 281,640	e 341,700
World total (estimate)	10,700,000	10,800,000	12,100,000	r 13,400,000	14,800,000

e Esimate. p Preliminary. r Revision.
[1] Year ended March 31 of year following that stated.

Contracts were awarded for the sinking of two shafts for the Consolidated Mining & Smelting Co. of Canada Ltd., near Delisle, Saskatchewan, 20 miles southwest of Saskatoon. The two shafts, 18.5 and 16 feet in diameter were to be sunk simultaneously to the deposit and somewhat more than 3,000 feet deep. Production from the mine was scheduled to begin in 1969.

Duval Corp. awarded contracts for sinking two shafts on its potash property 8 miles southwest of Saskatoon. Both shafts were to be 16 feet in diameter and were to be sunk simultaneously to about 3,500 feet. The project, including processing plants and related storage and shipping facilities, was expected to cost about $63 million, and was scheduled for operation in late 1969 or early 1970.

Noranda Mines Ltd., completed arrangements to bring its potash property near Saskatoon into production. A pilot hole was completed at the proposed shaft site and other preparations for the sinking of twin 16-foot-diameter shafts were in progress. First production was scheduled for 1969. Construction of a plant with a rated capacity of 1.2 million tons of product per year was planned. Total cost of the project was estimated at $72 million.

Other companies actively exploring in Saskatchewan included Continental Potash Corp., Mobile Chemical Co., American Metal Climax, Inc., Prime Potash Corp. of Canada Ltd. (name changed from Porcupine Prime Mines), United Comstock Lode Mines, and Canadian Exploration Ltd. (subsidiary of Placer Development Ltd.).

Prairie Potash Mines Ltd., a subsidiary of Metal Mines Ltd., expected to begin sinking a shaft to develop the first potash mine in Manitoba. The property is near St. Lazare in southwestern Manitoba.[4]

Noranda Mines Ltd., did not exercise its option to acquire the potash leases held by Tombill Mines Ltd., in Manitoba; however there appeared to be other interested parties and the prospects for a mine to be developed in the future were good. Tombill Mines acquired additional property in Saskatchewan.[5]

Congo (Brazzaville).—Compagnie des Potasses du Congo finished drilling its high-grade potash ore body and started planning for development. The firm's production goal was set at 500,000 tons of product per year. American Potash & Chemical Corp. was to obtain a 42.5-percent interest in the enterprise, but because of political complications the shares had not been obtained by yearend.

Ethiopia.—One shaft was completed into the potash ore body in the Danakil Depression to a depth of about 300 feet. Ore samples were reported to be of good quality and the total ore body to be minable and refinable. A pilot plant near the shaft began tests on the ore's amenability for refining. Ralph M. Parsons Co. was planning to produce 600,000 tons of potash per year from this deposit at some undetermined date. Some water seepage was experienced in the mine, but it was reported not to be excessive.

Germany, East.—East German Government authorities contracted to supply 1.5 million tons of potash during the next 5 years to Propane Fertilisers Ltd., of the United Kingdom. This exceptionally large contract was expected to promote some expansion of the East German potash industry.[6]

Israel.—Dead Sea Works Ltd., placed on-stream a new 400,000-ton-per-year refining plant, and was completing a series of dikes which would convert nearly all of the Israeli portion of the southern end of the Dead Sea into a potash recovery area. A total potash output of 600,000 tons per year was expected in 1966 upon the completion of the new dikes.[7]

Jordan.—Following the completion of the feasibility study financed by the U.S. Agency for International Development, Arab Potash Company Ltd., naming a U.S. engineering consulting firm to design and evaluate a $60 million potash facility to be built on the southernmost shores of the Dead Sea. The firm expected an eventual production capacity of 600,000 tons of potash per year.[8]

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[4] Northern Miner (Toronto, Canada). Study Drill Results at Prairie Potash. No. 18, July 22, 1965, p. 9.

[5] Northern Miner (Toronto, Canada). Major Tonnage Hike Tombill's Potash. V. 51, No. 6, Apr. 29, 1965, p. 8.

[6] European Chemical News (London). E. Germany Wins Big UK Potash Order. V. 8, No. 192, Sept. 17, 1965, p. 8.

[7] Engineering and Mining Journal. Harvesting More Israel Potash. V. 166, No. 10, October 1965, pp. 84–90.

[8] Bureau of Mines. Mineral Trade Notes. V. 61, No. 5, November 1965, pp. 46–47.

Table 12.—France, Spain and West Germany: Exports of potash by countries
(Short tons)

Country	Exporting countries					
	France [1]		Spain		West Germany [2]	
	1964	1965	1964	1965	1964	1965
North America:						
Canada	9,326	6,553	----	----	7,850	16,346
Cuba	----	----	16,535	----	3,737	987
Jamaica	----	2,313	----	----	6,949	5,799
Martinique	7,158	----	----	----	----	----
United States	185,259	112,689	35,274	53,682	140,063	164,212
South America:						
Brazil	32,123	25,105	----	----	23,058	23,952
Chile	1,359	1,000	8,818	5,512	6,895	10,100
Europe:						
Austria	45,890	52,723	----	----	62,982	79,828
Belgium-Luxembourg	340,474	286,990	22,579	42,263	197,165	350,270
Czechoslovakia	314	882	----	----	882	6,283
Denmark	32,871	28,081	3,775	2,094	181,431	211,162
Finland	11,651	17,951	2,001	12,307	25,916	54,503
France	----	----	----	5,765	8,767	9,336
Germany, West	50,498	56,227	----	----	----	----
Greece	1,517	4,193	----	----	10,485	10,761
Hungary	----	----	----	----	16,634	77
Iceland	----	----	----	2,205	----	6,614
Ireland	52,156	41,631	22,811	13,079	48,178	50,023
Italy	81,925	92,060	50,546	42,307	37,269	41,050
Netherlands	134,913	137,901	24,229	17,113	210,998	235,206
Norway	13,001	9,556	69,600	82,448	19,390	29,723
Poland	1,447	967	----	20,338	35,249	210,915
Portugal	98	----	25,033	33,713		
Sweden	36,536	49,978	6,311	11,541	55,401	62,870
Switzerland	90,921	86,384	----	----	28,658	39,505
United Kingdom	214,762	252,586	48,728	72,130	216,263	211,897
Yugoslavia	2,355	9,992	----	----	22,046	6,338
Africa:						
Algeria	5,697	----	3,549	4,966	551	4,409
Congo (Brazzaville)	5,520	----	----	----	----	110
Ivory Coast	6,213	----	----	----	----	1,323
Reunion	6,084	----	----	----	----	----
Rhodesia, Southern	4,340	4,333	----	2,500	22,095	12,127
South Africa, Republic of	35,987	22,937	----	8,499	51,386	65,822
Asia:						
Ceylon	32,982	17,492	----	----	6,750	40,304
India	20,356	31,412	----	----	15,344	28,054
Korea, North	----	----	----	----	11,023	----
Japan	97,321	45,280	----	----	126,055	99,263
Malaysia	7,242	13,945	----	----	10,104	17,844
Philippines	9,662	14,629	----	----	12,897	14,706
Taiwan	116	----	----	----	11,464	11,023
Oceania:						
Australia	25,053	7,209	----	----	35,342	10,787
New Zealand	33,434	668	----	----	14,927	28,301
Other countries [r]	36,844	25,209	1,979	3,196	43,088	35,560
Total	1,673,405	1,458,876	341,768	435,658	1,727,292	2,207,390

[r] Revised.
[1] Data include salts carbonate, chloride, and nitrate of potash.
[2] Data include crude salts, chloride, sulfte, magnesium sulfate, and beet ash.

Peru.—Minera Bayovar, S.A., proceeded with the construction of brine ponds from which potash and other salts would be extracted. Some large experimental ponds were completed to provide salts for pilot plant studies to determine a refining process. The project is in the Sechura Desert in northwest Peru bordering the ocean, and also is the site of large phosphate deposits being developed.

U.S.S.R.—The Gulf of Kara Bogaz was reported as a possible new source of potash salts. The gulf is separated by a narrow channel from the east shore of the Caspian Sea. By erecting a dike across the channel a natural evaporation pan, over 5,000 square miles in area could be formed, making available for extraction almost unlimited quantities of potash and other salts.[9]

Soviet authorities announced the discovery of a new potash deposit in the Kurluk region of Turkmenistan, a Central Asian republic of the U.S.S.R. The potash-bearing zone was stated to consist of

[9] Phosphorus and Potassium. No. 15, February 1965, p. 32.

five layers of ore covering an area of about 23 square miles. No plans for development were announced.[10]

United Kingdom.—Armour Chemical Industries Ltd., continued to study the possibilities for the economic recovery of potash by solution mining methods from deposits in Yorkshire, England. A small pilot plant was to be established near Whitby to study refining methods.

TECHNOLOGY

Studies made by the U.S. Geological Survey revealed that the Great Salt Lake in Utah contains more than 5,000 million tons of a variety of dissolved minerals. University of Utah scientists estimated the potash content to be about 132 million tons.[11]

The geology of the Saskatchewan potash deposits was discussed in a paper presented by W. J. Pearson at the October Potash Show in Saskatoon, Canada. It was reported in the published paper that the major potash deposits in Saskatchewan are found bedded in the Prairie Evaporite formation of the upper part of the Elk Point group and are of Middle Devonian age. These are the only potash deposits known to exist in this geologic age. The formation extends into southwestern Manitoba, northeastern Montana, and northwestern North Dakota.[12] The potash zones to the south, however, become thinner and deeper and in some areas are partly missing. In Montana and North Dakota the salt beds lie at depths ranging from 8,000 to 12,000 feet.

Another paper given at the Potash Show outlined how over $300 million would be spent by the potash industry in the Saskatoon area within 4 or 5 years. Supply problems resulting from the huge requirements for construction materials over a relatively short period were discussed.[13]

The first high-voltage (4,160 volts) mining machine to be used underground was installed at the working face of a potash mine in New Mexico. New Mexico was the first State in the United States to approve such use of high-voltage mining equipment. More efficient machine performance and the use of smaller and cheaper trailing cables were among the advantages claimed.[14]

Heavy liquid cyclone concentration of potash for three different types of potash ores was investigated and the results published.[15] A 57.5 percent K_2O concentrate was produced with a 93.3 percent recovery from ore containing only sylvite and halite. From an ore containing carnallite 88.5 percent of the potash was recovered to produce a 51.1 percent K_2O concentrate while an ore containing kainite gave a low recovery of 65.4 percent but produced a 58.7 percent K_2O concentrate.

An improved flotation technique developed and patented by Wintershall A.G., a West German potash producer, was described.[16] It was reported that experimental results indicated that ores containing kainite can be successfully treated by flotation to produce a marketable product with good recovery of the potash values.

Complete details were published on the process used by Southwest Potash Corp. in its nitrate of potash plant at Vicksburg, Miss. The plant, although starting up initially in 1963, went into successful continuous operation in 1965.[17]

International Minerals & Chemical Corp. announced at Carlsbad, N. Mex., that it had perfected a new process for growing potassium sulfate crystals. The process resulted from nearly 4 years of concentrated research and development work and the expenditure of over $200,000 for equipment. The company claimed that the new process produced a much larger crystal than the older process and was

[10] Phosphorus and Potassium. No. 20, December 1965, p. 36.

[11] Mines Magazine. Six Billion Tons of Minerals Held By Great Salt Lake. V. 55, No. 3, March 1965, p. 13.

[12] Pearson, W. J. Geology of Saskatchewan Potash Deposits. Western Miner (Vancouver, Canada), v. 38, No. 12, December 1965, pp. 35–41.

——— Geology of Saskatchewan Potash Deposits. Mining in Canada (Winnipeg, Canada), v. 38, No. 12, December 1965, pp. 12–19.

[13] Croome, N. C. Construction Requirements of the Saskatchewan Potash Industry. Western Miner (Vancouver, Canada), v. 38, No. 12, December 1965, pp. 42–46.

[14] Mining Congress Journal. Manufacturers Forum. V. 51, No. 8, August 1965, p. 80.

[15] Tippin, R. B., and James S. Browning. Heavy Liquid Cyclone Concentration of New Mexico Potash Ores. Society of Mining Engineers of AIME, Preprint 65B312, October 1965, 17 pp.

[16] Phosphorus and Potassium. Wintershall Develop Improved Flotation Technique. No. 19, October 1965, p. 30.

[17] Chemical Week. Synthetic Saltpeter Scores. V. 97, No. 4, July 24, 1965, pp. 35–38.

thereby a cleaner and more acceptable product.

Potassium permanganate was evaluated for use in air pollution abatement. Its odor-destroying properties were investigated on a number of malodorus chemical compounds. Odoriferous samples from asphalt and rendering plant process streams were successfully treated by the permanganate method. It was found that, although potassium permanganate does not destroy all odors, its effectiveness warrants its consideration for use in air pollution control.[18]

Oak Ridge National Laboratory of the Atomic Energy Commission announced the successful testing of a potassium vapor turbine, which operated continuously for 2,000 hours driven by the vapor produced from boiling potassium used to cool uranium fuel elements of a reactor. The turbine may have a key role for cooling reactors and generating electricity in space vehicles.

The Alberta Research Council at Edmonton started on a $4.75 million research and development program to study low-cost pipeline techniques for transporting potash and other minerals from mine to markets in Canada. The program was sponsored by the Department of Industry, Government of Canada, the Government of Alberta, and private industry. Plans called for the potash to be placed in protective containers which would be transported through the pipe with a stream of fluid.[19]

Among many patents issued concerning potassium minerals and compounds were two on underground solution mining of sylvinite ores [20], one on processing natural brines for potassium values [21], and seven on the processing of various potassium minerals.[22]

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[18] Industrial and Engineering Chemistry. Product Research & Development: Odor Abatement With Potassium Permanganate Solutions. V. 4, No. 1, March 1965, pp. 48–50.

[19] Phosphorus and Potassium. Pipelining Encapsulated Potash. No. 20, December 1965, p. 39.

[20] Dency, W. B. Solution Mining Using Heat Exchange Tubes. U. S. Pat. 3,205,012, Sept. 7, 1965.

Gunning, H. F. (assigned to Esso Production Research Co., a corporation of Del.). Enhancing Potassium Chloride Dissolution By The Addition of Ferro- And Ferricyanides. U.S. Pat. 3,215,471, Nov. 2, 1965.

[21] Dunseth, M. C., and M. L. Salutsky (assigned to W. R. Grace & Co., New York). Method of Recovering Potassium Values From Brines. U.S. Pat. 3,195,978, Sept. 20, 1965.

[22] Adams, A. (assigned to International Minerals & Chemical Corp., Skokie, Ill.). Leaching Halite Values From Langbeinite. U.S. Pat. 3,215,509, Nov. 2, 1965.

Authenrieth, H. (assigned to Kali-Forschunge-Anstalt G.m.b.H., Hannover, West Germany). Electrostatic Separation of Minerals. U.S. Pat. 3,217,876, Nov. 16, 1965.

Authenrieth, H., G. K. Peuschel, and G. Weichart (assigned to Kali-Forschunge-Anstalt G.m.b.H., Hannover, West Germany). Process for the Electrostatic Separation of Carnallite-Containing Crude Salts. U.S. Pat. 3,225,924, Dec. 28, 1965.

Marullo, G., D. Cadorin, M. Maggiore, and G. Veronica (assigned to Montecatini Soc. gen. per l'Industria Mineraria e Chimica, a corporation of Italy). Process for Producing Potassium Sulfate From Kainite Through The Intermediate Formation of Schoenite and Langbeinite. U.S. Pat. 3,207,576, Sept. 21, 1965.

Scarfi, A., and E. Gugliotta (assigned to Sincat Soc. Industriale Catanese S.p.a., Palermo, Italy). Processing of Kainitic Minerals. U.S. Pat. 3,199,948, Aug. 10, 1965.

Smith, R. E. (assigned to Potash Co. of America, Carlsbad, N. Mex.). Method of Controlling Hydroseparator Operation. U.S. Pat. 3,208,592, Sept. 28, 1965.

Veronica, G., and M. Maggiore (assigned to Montecatini Soc. gen. per l'Industria Mineraria e Chimica, a corporation of Italy). Process for Producing Potassium Sulfate Starting From Kainite. U.S. Pat. 3,198,601, Aug. 3, 1965.

Pumice

By Timothy C. May [1]

The output of pumice and pumiceous materials, pumicite, scoria, lapilli, volcanic cinder, and similar materials, continued to increase as a group in 1965. Pumice and pumiceous materials, sold or used by producers in 1965, increased 25 percent in quantity and 3 percent in value over sales in 1964.

DOMESTIC PRODUCTION

Fourteen States reported production, two States less than in 1964. Production came from 128 companies, individuals, railroads, highway departments, or Government agencies at 137 operations in 1965. Arizona with 11 active pumice operations and 37 percent of the total 1965 production had the greatest output, followed by California with 19 percent from 43 operations, Oregon with 19 percent from 28 operations, Hawaii with 11 percent from 20 operations, and New Mexico with 8 percent from 10 mines. The remaining production was distributed among nine States from 25 mines. In 1965 there was no production reported from Montana and Wyoming.

[1] Commodity specialist, Division of Minerals.

Table 1.—Pumice sold or used by producers in the United States
(Thousand short tons and thousand dollars)

Year	Pumice and pumicite		Volcanic cinder		Total	
	Quantity	Value	Quantity	Value	Quantity	Value
1956–60 (average)	851	$3,087	1,103	$2,132	1,954	$5,219
1961	936	4,203	1,527	2,596	2,463	6,799
1962	533	3,206	1,738	3,095	2,271	6,301
1963	1,050	3,321	1,568	3,257	2,618	6,578
1964	1,165	4,094	1,611	2,349	2,776	6,443
1965	483	2,443	3,000	4,197	3,483	6,640

Table 2.—Pumice [1] sold or used by producers in the United States
(Thousand short tons and thousand dollars)

State	1964		1965		State	1964		1965	
	Quantity	Value	Quantity	Value		Quantity	Value	Quantity	Value
Arizona	880	$1,635	1,273	$1,605	Nevada	W	W	68	$187
California	443	1,937	676	1,744	New Mexico	260	$760	264	915
Colorado	61	114	56	134	Oregon	566	909	657	1,181
Hawaii	365	603	380	624	Other States [2]	142	385	63	171
Idaho	59	100	46	79					
					Total	2,776	6,443	3,483	6,640

W Withheld to avoid disclosing individual company confidential data; included with "Other States."
[1] Includes pumicite and volcanic cinder.
[2] Kansas, Montana (1965), Nebraska, Oklahoma, Texas, Utah, Washington, Wyoming (1964), and State indicated by symbol W.

Table 3.—Pumice[1] sold or used by producers in the United States, by uses

(Thousand short tons and thousand dollars)

Use	1964		1965	
	Quantity	Value	Quantity	Value
Abrasive: Cleaning and scouring compounds	10	$689	10	$201
Concrete admixture and concrete aggregates	925	2,946	1,215	3,016
Railroad ballast	629	543	1,009	831
Road construction [2]	1,008	1,260	1,146	1,292
Other uses [3]	204	1,005	103	1,300
Total	2,776	6,443	3,483	6,640

[1] Includes pumicite and volcanic cinder.
[2] Includes surfacing, ice control, and maintenance.
[3] Includes abrasive uses (miscellaneous), absorbents, filler, insecticides, laboratory, landscaping, paint, roofing aggregate, soil conditioners, and miscellaneous uses.

CONSUMPTION AND USES

Concrete admixture and aggregate used 35 percent of the total output of pumice, compared with 33 percent used in 1964. Road construction consumed 33 percent of the total output of pumice compared with 36 percent used in 1964. Railroad ballast used 29 percent of the total output of pumice compared with 23 percent used in 1964. The remainder was used in cleaning and scouring compounds, absorbents, soil conditioners, roofing aggregate, and other miscellaneous uses.

PRICES

Nominal price quotations, covering domestic and prepared pumice, were carried regularly in trade publications. The Oil, Paint, and Drug Reporter quoted the following average prices for 1964, per pound, bagged, in ton lots: Domestic, fine and coarse, $0.0430; domestic, medium, $0.0480; imported (Italian), silk-screened, coarse, $0.0675; imported (Italian), fine, $0.0450 to $0.0475. Imported (Italian) sundried, coarse and fine, was quoted at $75 to $79 per ton.

The E&MJ Metal and Mineral Markets quoted prices of pumice, f.o.b. New York or Chicago, in barrels, powdered, $0.0350 to $0.0600 per pound, and lump, $0.0600 to $0.0800 per pound, the same as in 1964.

The average value of crude pumice, sold or used in 1965, was $1.12 per ton, 15 percent less than in 1964, and the average for prepared pumice was $2.51, 19 percent less than in 1964. The weighted average for the two categories was $1.91, 18 percent less than in 1964.

The average price per ton for pumice, used as concrete aggregate and admixture, was $2.48; road construction was $1.12; railroad ballast, $0.82; abrasive uses, $20.10; and other uses, $12.62.

FOREIGN TRADE

Exports.—Pumice export data were available for the first time. Exports in 1965 were 282 tons, valued at $56,000. Exports went to 11 countries, with Japan accounting for 42 percent, and Canada accounting for 32 percent.

Imports.—Pumice stone imported in 1965 for use in the manufacture of concrete masonry products, such as building block, brick, and tile, principally from Greece and Italy, was 75 percent more than in 1964. Crude pumice, valued at less than $15 per ton, had an average value of $7.74 per ton compared with $9.01 in 1964; crude pumice, valued at more than $15 per ton, averaged $21.21 per ton, compared with $20.55 in 1964; and wholly or partly manufactured pumice averaged $3.61 per ton, compared with $3.41 in 1964.

Tariff.—Pumice stone to be used in the manufacture of concrete masonry products, such as building blocks, bricks, tiles, and similar forms, was imported duty free. The duty per pound on imported pumice was the following: Crude pumice valued at $15 per ton and under, 0.0425 cent; crude pumice valued at over $15 per ton, 0.08 cent; wholly or partially manufactured, 0.35 cent; millstones, abrasive wheels, and abrasive articles, not specifically provided for (n.s.p.f.), 14 percent ad valorem.

Table 4.—U.S. imports for consumption of pumice, by countries

Country	Crude or unmanufactured				Wholly or partly manufactured			
	1964		1965		1964		1965	
	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value
Italy	5,499	$64,844	9,457	$98,506	3,092	$105,444	3,530	$126,822
Other	------	------	----	------	----	------	1	444
Total	5,499	64,844	9,457	98,506	3,092	105,444	3,531	127,266

Country	Pumice [1]				Manufactured n.s.p.f.	
	1964		1965		1964	1965
	Short tons	Value	Short tons	Value	Value	Value
Greece	60,094	$128,759	141,309	$305,492	------	------
Italy	28,007	100,429	23,417	53,113	$6,229	$10,885
Other	13,251	22,221	12,511	23,403	14,110	15,707
Total	101,352	251,409	177,237	382,008	20,339	26,592

[1] To be used in manufacturing concrete masonry products.

WORLD REVIEW

Table 5.—World production of pumice by countries [1]

(Short tons)

Country	1961	1962	1963	1964	1965 p [2]
Argentina [3]	32,321	12,585	7,790	5,712	e 5,100
Austria: Trass	40,846	30,696	23,349	25,223	22,516
Cape Verde Islands:					
Pozzolan	7,361	7,503	13,035	r 11,296	e 11,000
Chile: Pozzolan	62,790	120,315	142,012	155,885	156,094
France:					
Pumice	1,455	1,876	849	r 1,010	e 1,000
Pozzolan	485,504	521,751	601,488	r 645,547	539,691
Germany, West (marketable)	5,898,461	6,290,883	r 7,043,761	6,416,547	5,617,372
Greece:					
Pumice	77,162	87,938	e 88,000	e 88,000	e 220,000
Santorin	209,439	207,273	e 220,000	e 220,000	e 441,000
Iceland	e 9,000	e 7,200	13,779	11,023	e 11,000
Italy:					
Pumice	310,893	349,862	r 722,917	e 1,025,000	e 1,025,000
Pumicite	161,488	r 160,607	e 309,000		
Pozzolan	3,212,787	r 3,322,318	r 4,765,354	e 4,740,000	e 4,740,000
Kenya	779	1,243	1,245	1,585	1,145
New Zealand	36,637	36,425	18,599	22,980	120,807
Spain: Canary Islands	1,585	1,918	1,685	r 2,528	e 2,540
United Arab Republic (Egypt)	4,335	2,276	9,614	23,779	28,282
United States (sold or used by producers):					
Pumice and pumicite	936,039	[4] 583,716	1,050,178	1,165,379	484,047
Volcanic cinder	1,526,546	1,737,587	1,567,825	1,611,093	2,999,838
World total e	r 13,150,000	r 13,600,000	r 16,730,000	r 16,300,000	16,560,000

e Estimate. p Preliminary. r Revised.
[1] Pumice is also produced in Japan, Mexico, and U.S.S.R. (sizeable quantity), but data on production are not available; no estimates are included in total except for Japan.
[2] Compiled mostly from data available August 1966.
[3] Includes volcanic ash and cinders, and pozzolan.
[4] Includes American Samoa.

TECHNOLOGY

The pumice of the 1915 eruption of Lassen Peak, Cascade Range, Calif., was described. The light bands of dacite and the dark bands of andesite represent two distinct magmas that were imperfectly mixed at the time of eruption.[2]

Modern materials, handling techniques, and equipment used for the removal of volcanic cinders from property in a remote section of Arizona, owned by the Santa Fe Railroad, was described. The residue makes an excellent track ballast material, and it is estimated that at the present rate of production, the area holds a 200-year supply of ballast material.[3]

Investigations indicated that some pumice has a capacity to expand and that the expanded product is competitive, from a weight standpoint, for many of the extra-lightweight aggregate applications.[4]

A method was patented for making hydraulic cement by using a 15 to 85 weight-percent of granulated pumicite, blast furnace slag, fly ash, or other latent hydraulic binder interground with 15 to 85 percent of portland cement clinker. The heat of grinding was utilized for drying the latent hydraulic binder before the latter sets.[5]

A sanding block consisting of a mixture of pumice, gypsum plaster, portland cement, and abrasive grit, sandwiching a block of foam glass, was patented.[6]

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[2] MacDonald, G. A., and T. Katsura. Eruption of Lassen Peak, Cascade Range, California, in 1915–Example of Mixed Magmas. Geol. Soc. Amer. Bull., v. 76, No. 5, May 1965, pp. 475–482.

[3] Construction Methods and Equipment. V. 47, No. 8, August 1965, p. 29.

[4] Wagner, N. S., and L. L. Hoagland. The Residual Expansibility of Pumice. Ore Bin, v. 26, No. 4, April 1965, pp. 73–75.

[5] Frankert, O. P. (assigned to F. L. Smidt & Co., New York). Method of Making Cement. U.S. Pat. 3,183,106, May 11, 1965.

[6] Nichols, E. Smoothing Block and Method of Manufacture. U.S. Pat. 3,171,724, Mar. 2, 1965.

Rare-Earth Minerals and Metals

By John G. Parker [1]

For the first time, apparent domestic industrial consumption of all rare-earth materials exceeded 4,000 tons of equivalent rare-earth oxides (REO). Domestic shipments of concentrate from the large California bastnaesite operation were over two times that of 1964; concentrate containing nearly 3,000 tons of REO was produced.

Production and sales of europium and yttrium oxides needed for color television phosphors showed a large increase. To supply these compounds and other individual high-purity oxides, several chemical-processing companies expanded or planned expansion of facilities.

Legislation and Government Programs.—Of the 15,787 tons equivalent REO held in the various Government inventories, 9,977 tons was in the national stockpile and 5,810 in the supplemental stockpile. Almost 44 percent of the total REO was rare-earth sodium sulfate, 32 percent was monazite, almost 21 percent was bastnaesite, and the remainder was rare-earth chloride and sweepings.

The nonobjective rare-earth residues totaling approximately 3,000 short wet tons, held for a number of years in the Defense Production Act Inventory, were sold in July for $735,000 to Metal Traders, Inc., New York City.

DOMESTIC PRODUCTION

Concentrate.—Shipments of bastnaesite concentrate from the Molybdenum Corporation of America, Mountain Pass, Calif., mining, milling, and concentrating plant totaled over twice as much as those in 1964. The ore-processing plant produced concentrates containing almost 3,000 tons of REO from 37,500 tons of ore. Most of the material required for processing specialized products such as europium oxide was taken from the company's bastnaesite inventory. A $1.7 million plant using solvent extraction to recover 20 pounds per day of europium oxide went on stream in July but exceeded production capacity in December. Byproducts included a technical-grade of cerium oxide, a concentrate of lanthanum, praseodymium and neodymium, and another concentrate containing samarium and gadolinium. A substantial quantity of the bastnaesite concentrate was required by the York, Pa., rare-earth chloride plant. Construction was started on a new mill which will be able to produce 15,000 tons per year of REO concentrates.[2]

The Skinner beach-sand mining and beneficiation facility in Duval County, near Jacksonville, Fla., reportedly ceased operations in the middle of the year and shipped the last of its monazite concentrates, the quantity of which was 45 percent less than those made in 1964.

Compounds and Metals.—In May, when W. R. Grace & Co. acquired the Vitro Chemical Co. plant in Chattanooga, Tenn., the number of major chemical processors of rare-earth and yttrium concentrates was reduced to five. Besides Grace, which had another rare-earth plant at Pompton Plains, N.J., other firms making compounds were as follows: American Potash & Chemical Corp., Rare Earth (Lindsay) Division, West Chicago, Ill., at which capacity was raised; Molybdenum Corporation of America, Nipton, Calif., and York and Washington, Pa.; Research Chemicals, Division of Nuclear Corporation of America, Phoe-

[1] Commodity specialist, Division of Minerals.
[2] Molybdenum Corporation of America. Annual Report. 1965, pp. 1, 7, 15.

nix, Ariz.; and Michigan Chemical Corp., St. Louis, Mich. The latter two concerns and American Potash specialized in refining yttrium oxide by ion-exchange and solvent-extraction methods. High-purity europium oxide was made by Molybdenum Corp. and Michigan Chemical. It was also imported from Germany and sold by Philipp Brothers Corp., New York City, and Ronson Metals Corp., Newark, N.J.; the total shipped to domestic consumers was about four times greater than the quantity shipped in 1964. Production of yttrium oxide by domestic companies was about five times greater than the production in 1964.

Misch metal production increased almost 50 percent. The two major manufacturers were Ronson and American Metallurgical Products Co., Inc., New Castle, Pa., with some small production reported by W. R. Grace & Co. Ronson also produced and sold didymium metal, an alloy mostly of neodymium and praseodymium. Union Carbide Corp., Alloy, W. Va., increased by 50 percent its production of a rare-earth silicide for alloying purposes. Also, a total increase of 50 percent was noted in production of higher purity metals by American Potash, W. R. Grace, Michigan Chemical, Research Chemicals, Ronson, and Vitro. Dresser Products, Inc., Great Barrington, Mass., tripled its fabrication of high-purity metals.

CONSUMPTION AND USES

Sales of europium and yttrium oxides increased greatly. The total of rare-earth and yttrium concentrates, compounds, metals, and alloys consumed industrially apparently exceeded 4,400 tons of REO equivalent. Because of the value of purified products required for color television phosphors and other electronic purposes, the total value of shipments for consumption from chemical processors and metal and alloy producers rose to about $16 million.

Estimates of apparent consumption, derived mostly from shipments destined for various uses, were by value as follows: 39 percent of rare-earth compounds, as yttrium and europium oxides, used for electronic applications, principally for color television phosphors; almost 20 percent consumed in the production of misch metal, ferrocerium, and other rare-earth alloys; 15 to 20 percent for polishing powders or otherwise used by the glass industry; and 5 to 10 percent consumed in the making of petroleum catalysts. Almost 5 percent was used in the production of arc carbons, and several percent each was used in making steels and special cast iron and in the production of high-purity rare-earth metals. The remainder went mostly toward research, nuclear applications, and various miscellaneous uses.

The expanding use of yttrium and europium oxides in color television phosphors is based on its much truer and brighter red color, compared with the conventional sulfide red phosphors. This permits brightening the green and blue phosphors, thereby providing a better color balance. Europium oxide is the activating agent and is mixed with yttrium oxide or yttrium vanadate, the two commercially used host materials.

Yttrium was used also in yttrium iron garnet (YIG) and yttrium aluminum garnet (YAG) which are crystalline ferromagnetic materials useful in microwave devices such as high-frequency pulse generators. A new neodymium-doped, optically pumped YAG operating at room temperature exceeds 40-watts power level and supports continuous-wave laser action. The oxides of gadolinium, lanthanum, and yttrium and yttrium and lanthanum fluorides also show potential in solid-state laser applications. Neodymium also was used as a dopant in glass laser rods. In an erbium oxide crystal doped with thulium, energy is transferred from the host to the laser ion. The threshold value is very low, and the laser can be operated in pulses with a xenon flash lamp or continuously with a 500-watt, quartz-iodide tungsten lamp. Lastly, double dopants, combinations of host and laser rare-earth ions, offer high concentrations of active ions and fluoresce in the visible red portion of the spectrum between 4,900 and 6,100 angstroms.

Phosphors composed of terbium-activated alkaline-earth borates potentially offered an improvement in high-pressure mercury-discharge lamps used in highway and industrial lighting.

A new magnesium-ferrosilicon alloy, which contains a small quantity of cerium, had a lower content of magnesium than the conventional 9 percent magnesium alloy used in ductile iron. Further, improved magnesium recoveries also decrease ductile-iron production costs.

The use of rare-earth silicides in cast iron and stainless steel, indicated by shipments, increased almost 40 percent. Yttrium, used as a deoxidizer and desulfurizer in columbium and tantalum, improves high-temperature tensile strength and inhibits oxygen embrittlement. In nuclear structural applications, it was preferred over most other additives because of its low thermal-neutron cross section. Yttrium hydride was believed to be a cheaper substitute for the yttrium metal tried several years ago as a cast iron nodularizer.

It is estimated that over two-thirds of the misch metal was alloyed with iron to produce ferrocerium lighter flints; most of the remainder was employed in metallurgy to desulfurize and nodularize cast iron, to enhance resistance to creep and improve fatigue properties at intermediate temperature in magnesium and aluminum alloys, and to refine grain size, raise impact strength, and improve hot workability by increasing ductility in the forging of certain steels. It can be used to strengthen nonferrous alloys, such as those of copper, without adversely affecting electrical conductivity. A very small portion was used in vacuum-tube getters and in anodes. Didymium, an alloy composed largely of neodymium and praseodymium, can be used instead of misch metal as an additive to steels. Also, it is added to some magnesium alloys. One of the latter, QE22A, was said to have the highest yield strength of any magnesium casting alloy.

Most of the rare-earth oxide polishing powders were consumed by plate glass manufacturers, the remainder were used making optical instrument and ophthalmic (eyeglass) lenses and mirrors. Certain rare-earth oxides were used as components of special optical glasses, contributing to hardness and chemical stability. In glass, cerium dioxide with titanium dioxide contributes a reddish-yellow color; didymium compounds, neutral gray; neodymium, purple; and praseodymium, green-yellow.

The light-absorptive properties of some rare-earth compounds are important, especially in such elements as neodymium which absorbs yellow light in glassblowers and welders goggles. Cerium oxide absorbs ultraviolet light, thereby protecting food in glass containers; the hydrated form, as a glass component, prevents radiation browning in color television picture tubes. Lanthanum-bearing camera lenses have higher refractive indices, decreased dispersion, and are extremely fast and precise. A new prospective use of some rare-earth elements, especially europium and cerium, is in photochromic or variable transmissability window glass and sun glasses which darken when exposed to certain wavelengths, but quickly regain transparency when the light is removed. In ceramics, cerium and praseodymium oxides are components of an excellent yellow pigment. Cerium-free rare-earth carbonate, lanthanum oxide, and other high-purity rare-earth oxides are used in electronic ceramics. Some rare-earth compounds, especially cerium and samarium sulfides and gadolinium selenide, effectively convert heat to electricity. In enamels, cerium dioxide is a white opacifier three times as effective as tin and zirconium oxides.

Petroleum-cracking catalysts containing rare-earth elements are recent developments which require increasingly larger quantities of rare-earth chlorides. These catalysts have high activity, increase gasoline recovery, and are stable in hot steam and at high temperatures.

Over 20 percent more rare-earth and didymium fluorides and oxides were consumed in 1965 to make carbon-arc electrodes of superior brilliance and white light used in motion picture set lighting and projectors and in searchlights.

Europium oxide is one of the high thermal-neutron absorbing rare-earth elements currently having limited use in control rods for nuclear power reactors.

Because of its high melting point, yttrium oxide served as a protective refractory coating on low-cost graphite crucibles to prevent carbon contamination of the molten contents. Also, yttria additions stabilize the cubic structure of zirconia, allowing it to expand evenly and making it suitable for refractory uses.

Small quantities of rare-earth chloride and cerium nitrate were used by the textiles industry for bleaching and dyeing. Rare-earth chloride and acetate were used in waterproofing and in fungicides, and rare-earth oxalate has been used in nausea prevention. The radioisotope, thulium 170, with low-energy gamma-ray emission, is of value because it can be placed in a small source in portable radiographic units.

Although shipments of higher purity metals increased about 50 percent by weight and 90 percent by value, little information was forthcoming about their application beyond the statements that they were used mostly for research purposes, most of which probably consisted of determining the value of various alloy systems.

STOCKS

Supplies of rare-earth mineral concentrates held by domestic firms, including chemical processors, an integrated mining and processing concern, and a beach-sand mining operation, were depleted considerably during the year. Bastnaesite stocks were only about 17 percent and monazite less than 90 percent of those held at the end of 1964. Stocks of the intermediate material, rare-earth sulfate, were again only about 50 percent of those in the preceding year. The need for yttrium oxide was reflected in the small quantity of year-end stocks, less than 5 percent of that held by companies at the end of 1964. Stocks of purified metals, however, were over three times greater than those at the close of 1964. Misch metal stocks held by producers and some of the principal users were slightly less than the previous year.

PRICES

Beginning in January, new quotations for imported monazite excluded thorium for the first time. According to E&MJ Metal and Mineral Markets nominal prices per pound, c.i.f. U.S. ports, were as follows: Massive, 55 percent rare-earth oxides, 14 cents; sand, 55 percent, 8 cents, 60 percent, 10 cents, and 66 percent, 12 cents. On the London market, c.i.f. prices per ton of Australian monazite rose about 20 percent during the year, from a low of £45 to £55 ($126 to $154) in January to £57½ to £62½ ($161 to $175) in December. This was due, at least partly, to higher packaging costs and freight rates.

With the exception of yttrium oxalate and yttrium oxide, which dropped significantly in price, all production chemicals on a new list from American Potash & Chemical Corp. showed no changes. Another list, issued by W. R. Grace & Co. from Vitro Chemical Co.'s former plant in Chattanooga, indicated a slight rise in prices of rare-earth chloride and fluoride. Rare-earth oxide, in ton-lot sizes from one of these firms, was $0.90 to $1.05 per pound; from the other, in two lot sizes under 100 pounds, it was available at $2.25 and $2.70 per pound. Other price lists were published by these companies and by Gallard-Schlesinger Chemical Manufacturing Corp., Carle Place, N.Y., Michigan Chemical Corp., and Research Chemicals, Division of Nuclear Corporation of America. Quoted prices for cerium hydrate, of two purity designations, remained at $1.40 and $1.74 per pound in lots of 100 pounds or more; cerium oxide of optical grade continued at $1.85 to $1.90 per pound, delivered, in 50-pound bags.[3]

Prices of high-purity rare-earth and yttrium oxides, depending upon purity and quantities purchased, ranged from $4 per pound for 99.9 percent CeO_2 in lots of 500 pounds or over to $4,975 for a 1-pound package of 99.9999 percent Lu_2O_3. Europium oxide in purities from 99.0 to 99.9999 percent, in lot sizes from 1-pound packages to 2- to 99-pound quantities and from different producers, sold for $850 to $2,000 per pound. With the same considerations, yttria prices ranged from $48 to $500 per pound. Prices per pound of 99.9-percent rare-earth chlorides, in lot sizes of 2 to 99 pounds, were $5.40 for that of lanthanum to $3,450 for that of lutetium. In the same lot size and purity, yttrium chlorides sold for $30 to $65 per pound, and a 1-pound package of europium chloride sold for $600 and $850. Similarly, from one company, a 1-pound package of anhydrous yttrium fluoride sold for $80 and one of anhydrous europium fluoride sold for $900, the latter almost 30 percent above the 1964 price.

Domestic prices per pound of high-purity rare-earth metals of 99.5+ to 99.9+ grade, in the form of crystal sponge, ingots, lumps, or turnings, and in lots of 1 pound,

[3] Oil, Paint and Drug Reporter. Current Market Quotations. V. 187, Nos. 1–26, Jan. 4–June 28, 1965. V. 188, Nos. 1–26, July 5–Dec. 27, 1965.

1 to 5 pounds, over 5 pounds, and 1 to 25 pounds, ranged from $75 for cerium to $8,750 for lutetium. Several producers quoted prices only on gram-lots of europium metal but one company had 99.5+ percent metal available at $5,000 per pound, more than double the price listed in 1964. Yttrium metal was listed at $204 to $500 per pound, for double-distilled grade. On the London Market, 99 percent cerium metal was quoted at £18 per pound, and 98 to 99 percent lanthanum at 15 shillings per gram.

Vitrolloy, a rare-earth master alloy with 30 to 33 percent rare-earth metal content, was available at $2.40 to $2.70 per pound, in three lot sizes. In American Metal Market, ingots of misch metal of 99.8-percent purity and cerium-free misch metal were quoted, respectively, at $2.90 and $5.00 per pound in 50- to 100-pound lots.

Rare-earth metal sheet and foil, in 99.9-percent purity, became available in 0.003- to 0.060-inch thicknesses. Prices ranged from $6.10 per square inch of neodymium to $196.50 per square inch of thulium.

FOREIGN TRADE

Exports.—The sole rare-earth export category item, ferrocerium and other pyrophoric alloys, excluded cerium ores. Items in this new class, exported to 24 countries, totaled 54,151 pounds valued at $220,715. The principal recipients were the United Kingdom, Canada, Japan, West Germany, and Hong Kong, with nearly 88 percent of the quantity and 85 percent of the value of the alloys.

Imports.—Only 3 pounds of cerium oxide valued at $303 was received from Switzerland, but cerium chloride imported from Brazil and India totaled 1,763,512 pounds worth $204,708. Other cerium compounds totaling 16,793 pounds valued at $13,228 were shipped to the United States from France, West Germany, and Switzerland. West Germany sent 2,205 pounds of cerium ore worth $810 to the United States. Of six countries from which the United States imported ferrocerium and other pyrophoric alloys, Austria and Japan were the main sources, shipping over 84 percent by weight and nearly 77 percent by value. Other alloys, principally misch metal, received primarily from West Germany and with lesser quantities from Austria and India, totaled 52,433 pounds worth $71,743. An indeterminate quantity of didymium metal also was received from West Germany.

The Bureau of the Census reported that imports of monazite sand concentrate from six countries totaled 2,028 short tons valued at $188,817. Australia shipped the United States almost 1,280 short tons worth $111,251; other sources by importance were Malaysia, Ceylon, Nigeria, Brazil, and Korea. Five domestic firms, including two dealers, reported receiving over 2,450 short tons of monazite from these countries and two others, one of which was reported to be the Republic of South Africa. A small quantity of xenotime also was imported.

WORLD REVIEW

Australia.—During the year Australian beach-sand operations produced over 10 percent more monazite concentrates than in 1964. Sales of monazite were equally divided between the east and west coast producers. Exports of the concentrates for the fiscal year ending June 30, 1965, totaled 2,395 short tons, of which 56 percent was shipped to the United States and 28 percent was shipped to France.

Brazil.—The Industrial and Commercial Department of Comissão Nacional de Energia Nuclear (CNEN) controlled two industrial units, successfully operating on monazitic beach sands. They are the mining and processing plants at Barra de Itabapoana, in the State of Rio de Janeiro, and at Cumuruxatiba, in the State of Bahia. In 1964 and 1965, respectively, the first operation produced 448 and 269 tons of monazite, and the second, 285 and 389 tons. Also the Department controlled the hydrometallurgical monazite-treatment equipment in the Orquima plant in São Paulo. CNEN said that 1,975 tons of monazite sand concentrate was processed in 1964, with production of 2,450 tons of cerium chloride, almost 35 percent of which was sold at $0.20 per pound. Production of cerium chloride at Orquima, S.A. during 1965 was at the rate of 175 tons per month.

Table 1.—World production of monazite concentrates by countries

(Short tons)

Country [1]	1961	1962	1963	1964	1965 [p] [2]
Australia	1,733	912	[r] 2,231	[r] 2,285	2,581
Brazil	[r] 1,263	[r] 4,277	[r] 2,448	[r] 733	658
Ceylon	[r] 83	---	---	25	40
India	NA	[3] 3,233	[r] [3] 2,678	NA	NA
Indonesia	111	153	[r] 169	[r] 154	28
Korea, South [4]	854	755	---	---	---
Malagasy Republic	503	702	678	[r] 1,063	1,196
Malaysia (exports)	779	702	991	340	777
Nigeria	9	10	12	[r] 13	9
South Africa, Republic of	---	5,326	2,300	---	---

[p] Preliminary. [r] Revised. NA Not available.
[1] United States production data withheld to avoid disclosing individual company confidential data.
[2] Compiled mostly from data available June 1966.
[3] Year ended March 31 of year following that stated.
[4] Reported as concentrates containing 45–55 percent of R_2O_3; also reported as 30 percent Ce, which may be high.

A schedule, published by the Brazilian Directorate of Internal Revenue and effective for the first half of 1965, showed the assessed unit values for various rare-earth ore minerals from which the 10-percent mineral commodity tax could be computed. Established values in cruzeiros per metric ton and equivalent U.S. dollars at 1,285 cruzeiros per dollar, per short ton were as follows: Clean monazite sand, 24,000 cruzeiros or $11.76; monazite, 72,000 cruzeiros or $35.29; euxenite, 144,000 cruzeiros or $70.60; and samarskite, fergusonite, and others, 168,000 cruzeiros or $82.36.

Canada.—Rio Algom Mines Ltd., a subsidiary of Rio Tinto-Zinc Corp., Ltd., bebegan producing yttrium oxide concentrate at its thorium extraction plant at Elliot Lake, Ontario. Shipments from the plant to refiners in the United States and in the United Kingdom was expected to begin in late December. Initial capacity of the plant was 100,000 pounds of yttrium oxide.

Ceylon.—Mineral Sands Corp. set up a pilot plant at Katukurunda to separate monazite from sands along the west coast.

India.—It was reported that 483 tons of monazite, valued at $144,900, was exported in 1964.

Malagasy Republic.—Reportedly 1,143 tons of monazite, valued at $243,100, was exported in 1965. About 85 pounds of euxenite, with a value of $350, also was exported.

United Kingdom.—Thorium Ltd. completed expansion of facilities for producing lanthanum, neodymium, and praseodymium in July and expected to install facilities for europium and yttrium by the end of the year.[4]

TECHNOLOGY

Research on potential and actual application of high-purity rare-earth materials continued unabated as scientists sought to extend knowledge on luminescence and fluorescence phenomena characteristic of certain rare-earth elements or of other elements combined with them. The homogeneity of the dopant, divalent samarium, in CaF_2-type single crystals was affected by crystal-growth parameters such as the ratios of the crystal and crucible diameters and of melt surface to melt volume.[5] Trivalent europium was the activator in the lanthana-gadolinia-yttria system, and chromium caused fluorescence in the $LaAlO_3$-$LaGaO_3$ system.[6] Alkaline-earth borate matrices activated with terbium were tested as phosphors. In general, the calcium compounds had a greater efficiency than the corresponding strontium compounds.[7] Zinc bo-

[4] Chemical Age (London). V. 94, No. 2411, Sept. 25, 1965, p. 473.

[5] Weller, P. F., J. D. Axe, and G. D. Pettit. Chemical and Optical Studies of Samarium Doped CaF_2 Type Single Crystals. J. Electrochem. Soc., v. 112, No. 1, January 1965, pp. 74–77.

[6] Mazelsky, R., and R. Ohlmann. Chromium Fluorescence in the $LaAlO_3$–$LaGaO_3$ System. J. Electrochem. Soc., v. 112, No. 6, June 1965, pp. 626–627.

Ropp, R. C. Luminescence of Europium in the Ternary System: La_2O_3-Gd_2O_3-Y_2O_3. J. Electrochem. Soc., v. 112, No. 2, February 1965, pp. 181–184.

[7] Wanmaker, W. L., A. Bril, and J. W. ter Vrugt. Fluorescent Properties of Terbium-Activated Alkaline Earth Alkali Borates. J. Electrochem. Soc., v. 112, No. 11, November 1965, pp. 1147–1150.

rate glasses of high optical perfection, melting at 1,000° C and readily cast or shaped, were doped with the trivalent rare-earth ions of samarium, europium, terbium, dysprosium, and thulium. Having the generic formula, $Ln_xNa_xZn_{1-2x}B_2O_4$, the glasses were inferior to single crystals in laser work because of their lower thermal conductivities, dielectric constants, and refractive indices, but had the advantages of low-thermal expansion and of greater hardness, which makes the polishing of glasses easy.[8]

Other phosphors and luminescent materials were prepared and tested.[9]

Bureau of Mines investigators covered many aspects of rare-earth research. For example, ore beneficiation techniques included an oxidation-precipitation method on bastnaesite and the fusion conversion of bastnaesite and euxenite with subsequent differential leaching of the oxides. Very high separation factors were achieved in solvent extraction and research was continued on ion exchange and related chemical processes. The properties of and reactions in molten salt mixtures were investigated. Electrowinning cells for producing high-purity yttrium-group metals from their oxides were designed and operated. Electromigration of impurities in solid-state electrolysis and electrorefining were used to further purify the metals. Certain properties of the finished metals were examined. Under a cooperative agreement, efforts were made to produce clean, improved, and homogenized low-alloy steel with rare-earth metals, alloys, and fluxes. Publications by Bureau of Mines mineral-research personnel included studies of the effectiveness of certain complexing agents in solvent extraction,[10] compilation of thermochemical data on europium and neodymium compounds,[11] an investigation of the solid-state phase transformations and crystallographic modifications of rare-earth sesquioxides,[12] a report on electron-beam melting of yttrium,[13] and the determination of physical properties and fabricability of stainless steel-gadolinium alloys.[14]

The numerous papers concerning research on and uses of rare-earth materials, presented at a Moscow conference in March 1963 and mentioned in the Minerals Yearbook chapter for that year, were published in English.[15]

Iowa State University, the site of the Atomic Energy Commission Ames Laboratory which may be termed the birthplace of the modern rare-earth industry, played host to scientists attending the Fifth Rare-Earth Research Conference. In attendance were over 200 conferees, representing domestic and foreign Governments, academic institutions, and industrial firms. Many of the presentations concerned basic aspects of solid-state research but current interest in modern practical applications was shown in the increasing number of papers on laser and phosphor materials. Another conference, scheduled in England for the late summer of 1966, will be concerned with theoretical and experimental physics on rare-earth materials and will give some attention to metallurgical problems.

A popularized review of the technologic

[8] Brixner, L. H. On the Luminescent Properties of Some Rare Earth Ions in Zinc Borate as a Host. J. Electrochem. Soc., v. 112, No. 10, October 1965, pp. 984–988.

[9] Anderson, W. W., S. Razi, and D. J. Walsh. Luminescence of Rare-Earth Activated Zinc Sulfide. J. Chem. Phys., v. 43, No. 4, Aug. 15, 1965, pp. 1153–1160.

Borchardt, Hans J. (assigned to E. I. du Pont de Nemours & Co., Inc.). Luminescent Materials. U.S. Pat. 3,207,573, Sept. 21, 1965.

Brixner, L. H., and E. Abramson. On the Luminescent Properties of the Rare Earth Vanadates. J. Electrochem. Soc., v. 112, No. 1, January 1965, pp. 70–74.

Soden, Ralph R., and Le Grand G. Van Uitert (assigned to Bell Telephone Laboratories, Inc.). Rubidium-Rare Earth Tungstate and Molybdate Optical Maser Materials. U.S. Pat. 3,203,902, Aug. 31, 1965.

Wesselink, G. A., and A. Bril. Fluorescent Properties of Trivalent Neodymium in Lanthanum and Yttrium Orthoniobates and Tantalates. Philips Res. Rept. (Eindhoven, Netherlands), v. 20, No. 3, June 1965, pp. 269–277.

[10] Eisele, J. G., and D. J. Bauer. Extraction and Separation of Rare-Earth Elements and Yttrium With Dodecyl Phosphoric Acid-Kerosine Solvent. BuMines Rept. of Inv. 6601, 1965, 30 pp.

Shaw, Van E., and D. J. Bauer. Extraction and Separation of Rare-Earth Elements in Idaho Euxenite Concentrate. BuMines Rept. of Inv. 6577, 1965, 13 pp.

[11] Stuve, J. M. Heat of Formation of Europium Sesquioxide and Europium Trichloride. BuMines Rept. of Inv. 6640, 1965, 9 pp.

———. Heat of Formation of Neodymium Trichloride. BuMines Rept. of Inv. 6697, 1965, 4 pp.

[12] Stecura, Stephan. Crystallographic Modifications and Phase Transformation Rates of Five Rare-Earth Sesquioxides. Lanthanum Oxide, Neodymium Oxide, Samarium Oxide, Europium Oxide, and Gadolinium Oxide. BuMines Rept. of Inv. 6616, 1965, 44 pp.

[13] Anable, W. E., and R. A. Beall. Electron-Beam Melding of Yttrium. BuMines Rept. of Inv. 6661, 1965, 14 pp.

[14] Copeland, M., W. Barstow, C. Armantrout, and H. Kato. Stainless Steel-Gadolinium Alloys. BuMines Rept. of Inv. 6636, 1965, 29 pp.

[15] Savitskii, E. M., and V. F. Terekhova. Problems of the Theory and Use of Rare Earth Metals. U.S. Dept. of Commerce, Clearinghouse for Federal Scientific and Technical Information, JPRS-28,849, Feb. 23, 1965, 361 pp.

and economic aspects of the rare-earth industry appeared.[16]

A very large rare-earth and strontianite deposit in a carbonatite complex in Malawi was described, reserve estimates made, and a process for treating ore to concentrates outlined. The most abundant rare-earth mineral, a green monazite formerly believed to be epidote, is high in cerium but very low in thorium. Ore reserves to 100 feet in depth, believed workable by quarrying, were estimated at over 18,000 tons of monazite. About 70 percent of this was thought to be recoverable by calcining the ore, slaking, sliming, and then tabling and separating monazite magnetically.[17]

The abundance of rare-earth elements and their distribution among minerals were discussed, and the need for studying thoroughly the compositional variance in coexisting minerals in rocks was cited.[18] Little fractionation of rare-earth elements was believed to occur in meteorites compared with that occurring in the more complex terrestrial environment. Collected data indicated that most of the terrestrial rare-earth elements are in or closely associated with the main rock-forming minerals, that there can be a great variation in the rare-earth patterns and contents of the various minerals of a single rock, and that the concentration of rare-earth elements into phosphatic sedimentary materials is common.[19]

Absorption-spectroscopic techniques were adapted to field or laboratory determination of rare-earth elements in rocks and minerals. Cerium-group minerals were characterized by neodymium and praseodymium bands, yttrium-group minerals by erbium and holmium bands. After heating metamict minerals, their characteristic broad, diffuse absorption bands are noticeably sharpened.[20] Other absorption spectra were tabulated, and a polarographic technique for laboratory analysis of rare-earth elements was described.[21]

A new mineral, discovered in waste residues in processing soda ash from trona, was found to contain nearly 8 percent yttrium oxide.[22]

The typical monazite concentration of the Indian Manavalakurichi and Chavara deposits, and methods used for its recovery were given. Various depressants and collectors, such as unsaturated fatty-acid soaps, were used. Under optimum conditions, using a mixture of oleic, linoleic, and linolenic acids as a collector, a 93.8-percent recovery of monazite containing 72.4 percent rare-earth oxides was achieved.[23] A milling method, suitable for grinding bastnaesite ore without the build up of static electricity, was designed.[24] A low-cost chemical method used to produce an oxide concentrate from bastnaesite ore was described. The resulting material was used in the production of rare-earth chloride.[25]

Using X-ray diffraction, the coefficients of expansion of pure and neodymium-doped yttrium aluminum garnet were found to be identical and no phase transformations were noted in the range from room temperature to that of liquid nitrogen.[26] Data were obtained for crystals of Er_2SiO_5 and Y_2SiO_5 and of rare-earth aluminum garnets.[27] A rare-earth garnet was composed

[16] Chemical & Engineering News. Rare Earths: The Lean and Hungry Industry. V. 43, No. 19, May 10, 1965, pp. 78–92.

[17] Holt, D. N. The Kangankunde Hill Rare Earth Prospect. Geol. Survey Dept., Zomba, Malawi, Bull. No. 20, 1965, 130 pp.

[18] Fleischer, Michael. Some Aspects of the Geochemistry of Yttrium and the Lanthanides. Geochimica et Cosmochimica Acta (London), v. 29, No. 7, July 1965, pp. 755–772.

[19] Haskin, Larry A., Fred A. Frey, Roman A. Schmidt, and Richard H. Smith. Meteoritic, Solar, and Terrestrial Rare-Earth Distributions. General Atomic, Division of General Dynamics, San Diego, Calif., GA-6800, Dec. 15, 1965, 250 pp.

[20] Adams, John W. The Visible Region Absorption Spectra of Rare-Earth Elements. Am. Miner., v. 50, Nos. 3–4, March–April 1965, pp. 356–366.

[21] Mittal, M. L., and R. S. Saxena. Polarography of Lanthanum in Tetramethylammonium Chloride Media. J. Less-Common Metals (Amsterdam, Netherlands), v. 8, No. 5, May 1965, pp. 347–351.

Zalubas, Romuald, and Michael Wilson. Atomic Absorption Spectrum of Praseodymium (PrI). NBS J. Res., v. 69A–(Phys, and Crem.), No. 1, January–February 1965, pp. 59–70.

[22] Milton, Charles, Blanche Ingram, Joan R. Clark, and Edward J. Dwornik. Mckelveyite, a New Hydrous Sodium Barium Rare-Earth Uranium Carbonate Mineral From the Green River Formation, Wyoming. Am. Miner., v. 50, Nos. 5–6, May–June 1965, pp. 593–612.

[23] Viswanathan, K. V., T. R. Madhavan, and K. K. Majumdar. Selective Flotation of Beach Sand Monazite. Min. Mag. (London), v. 113, No. 1, July 1965, pp. 17–23.

[24] Mandle, R. M., and T. O. Tongue (assigned to W. R. Grace & Co.). Fluid Energy Mill. U.S. Pat. 3,186,648, June 1, 1965.

[25] Kruesi, Paul R., and George Duker. Production of Rare-Earth Chloride From Bastnasite. J. Metals, v. 17, No. 8, August 1965, pp. 847–849.

[26] Croft, William J. Low-Temperature Thermal Expansion of Yttrium Aluminum Garnet. Am. Miner., v. 50, No. 10, October 1965, pp. 1634–1636.

[27] Harris, L. A., and C. B. Finch. Crystallographic Data for Er_2SiO_5 and Y_2SiO_5. Am. Miner., v. 50, No. 9, September 1965, pp. 1493–1495.

Rubinstein, C. B., and R. L. Barns. Crystallographic Data for Rare-Earth Aluminum Garnets: Part II. Am. Miner., v. 50, Nos. 5–6, May–June 1965, pp. 782–785.

of lanthanum, praseodymium, or neodymium; nine times as much yttrium or rare-earth elements other than lanthanum, praseodymium, and neodymium; iron; and oxygen.[28] A publication of Oak Ridge National Laboratory discussed preparation, purification, and properties of various rare-earth halides.[29]

The first separation of volatile rare-earth complexes by gas chromatography was said to have been achieved. Using 2, 2, 6, 6-tetramethyl-3, 5-heptanedione (Hthd) as the chelating agent, the resulting chelates are thermally stable, anhydrous, and unsolvated. Because of their volatility differences, these rare-earth complexes can be separated by fractional sublimation.[30]

Research was continued on separation methods using ion exchange and solvent extraction. These included a continuous ion-exchange process which continuously regenerates the ion-exchange liquid by passing the complex-free chelating agent from the effluent in reverse flow through the solid medium,[31] and a solvent extraction method which separates individual elements from an aqueous sulfate solution containing 0.005 to 0.05 mole of rare-earth elements per liter.[32] A calculation method used with a multistage-multisolute system which allows selecting processing conditions for any desired separation was also developed.[33]

Numerous studies were made on the relationship of phases in various rare-earth binary and ternary systems. The "enveloping effect" was believed responsible for the extreme atomic-size sensitivity in binary systems of rare-earth elements and manganese, resulting in formation of 10 A_6B_{23}-type compounds.[34] Three intermetallic compounds–YCo_5, YCo_3, and YCo_2–were determined and six intermediate phases–Y_2Co_{17}, YCo_4, Y_2Co_3, YCo, Y_3Co_2, and Y_3Co–were tentatively identified.[35] In an isothermal section from the Y–Al–C ternary system, aluminum was found to be negligibly soluble in the binary Y_3C phase and the system was found to contain a ternary phrase, Y_3AlC, which has a unit cell of the perovskite type.[36]

Binary rare-earth-aluminum systems investigated included those containing lanthanum and samarium. The lanthanum-aluminum system was found to contain six intermediate phases, three hexagonal, two orthorhombic, and one cubic structure;[37] the samarium-aluminum system contains five intermediate phases, two orthorhombic, one cubic, one tetragonal, and one hexagonal.[38] In an attempt to produce single crystals of samarium metal, SmAl needles formed by reaction were deposited on the alumina crucible. The authors concluded that SmAl had a body-centered cubic B_2-type structure, differing from Buschow's finding of an orthorhombic structure.[39] In another study on binary systems containing rare-earth elements and aluminum, five intermetallic compounds were observed in each of the neodymium-aluminum and gadolinium-aluminum systems, only $NdAl_2$ and $GdAl_2$ melting congruently.[40]

Most of the intermetallic compounds of

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28 Schieber, Michael (assigned to The Weizmann Institute of Science, Rehovoth, Israel). Rare Earth Ferrites. U.S. Pat. 3,193,502, July 6, 1965.

29 Oak Ridge National Laboratory. Rare-Earth Halides. U.S. Dept. of Commerce, Clearinghouse for Federal Scientific and Technical Information, ORNL 3804D, May 1965, 61 pp.

30 Chemical & Engineering News. Gas Chromatography Separates Rare Earths. V. 43, No. 47, Nov. 22, 1965, pp. 39–40.

31 Woyski, Mark M. (assigned to American Potash & Chemical Corp.). Ion Exchange Process for Separating the Rare Earths. U.S. Pat. 3,167,389, Jan. 26, 1965.

32 Rice, Andrew C. (assigned to the U.S. Department of the Interior). Process for Separating the Rare Earth Elements by Means of Solvent Extraction. U.S. Pat. 3,192,012, June 29, 1965.

33 Sharp, Brooks M., and Morton Smutz. Stagewise Calculation for the Solvent Extraction System Monazite Rare Earth Nitrates-Nitric Acid-Tributyl Phosphate-Water. I&EC Process Design and Development, v. 4, No. 1, January 1965, pp. 49–54.

34 Wang, Frederick E., and James R. Holden. Size-Factor Limitation in A_6B_{23}-Type Compounds Due to the "Enveloping Effect"; New Compounds Between Manganese and the Lanthanide Elements. Trans. AIME, v. 233 (Met. Soc.), No. 4, April 1965, pp. 731–736.

35 Pelleg, J., and O. N. Carlson. The Yttrium-Cobalt System. J. Less-Common Metals (Amsterdam, Netherlands), v. 9, No. 4, October 1965, pp. 281–288.

36 Rosen, S., and P. G. Sprang. Phase Equilibria in Yttrium-Rich Ternary Alloys Containing Aluminum and Carbon. Trans. AIME, v. 233 (Met. Soc.), No. 7, July 1965, pp. 1265–1269.

37 Buschow, K. H. J. The Lanthanum-Aluminium System. Philips Res. Repts. (Eindhoven, Netherlands), v. 20, No. 3, June 1965, pp. 337–348.

38 Buschow, K. H. J., and J. H. N. van Vucht. On the Intermediate Phases in the System Samarium-Aluminium. Philips Res. Repts. (Eindhoven, Netherlands), v. 20, No. 1, February 1965, pp. 15–22.

39 Runnalls, O. J. C., and G. W. Lorimer. Preparation, Identification and Crystal Structure of SmAl. J. Less-Common Metals (Amsterdam, Netherlands), v. 8, No. 1, January 1965, pp. 75–77.

40 Buschow, K. H. J. Phase Relations and Intermetallic Compounds in the System Neodymium-Aluminium and Gadolinium-Aluminium. J. Less-Common Metals (Amsterdam, Netherlands), v. 9, No. 6, December 1965, pp. 452–456.

formula MX, where M equals a rare-earth element and X equals copper, magnesium, zinc, cadmium, mercury, or thallium, were found to have crystal structures of the cesium chloride type.[41] Binary alloy studies on two heavy rare-earth metals with silver, gold, platinum, aluminum, indium, thallium, or germanium showed the presence of a number of new intermediate phases, four of cubic cesium chloride type structure, eight of cubic $AuCu_3$ type, four of tetragonal MoSi type and two of hexagonal Mn_5Si_3 type.[42] During investigations on binary systems of rare-earth elements and magnesium, it was discovered that in the cerium-magnesium system, three compounds exist in an area where previously one was believed present. One of the three decomposes into the other two compounds in a eutectoid reaction.[43] Two eutectic reactions were found to occur in the ytterbium-magnesium system, one at 496° C and 31.5 atomic percent magnesium and the other at 509° C and 89.3 atomic percent magnesium; the hexagonal intermetallic compound, $YbMg_2$, was found to exist over a wide compositional range and melted congruently at 718° C.[44] Other binary systems studied were of rare-earth elements with tin and indium, with palladium, and with aluminium and cobalt.[45] Three intermediate phases, Gd_2O_3-$2TiO_2$ with a cubic structure and melting congruently at 1,820° C, Gd_2O_3–TiO_2 melting incongruently at 1,775° C, and a face-centered-cubic solid solution melting incongruently over a range of temperatures and compositions, were determined in the binary Gd_2O_3–TiO_2 system.[46] Nine compounds and three eutectics were observed in the cerium-zinc system with three of the compounds melting congruently and the eutectics being at 10 weight-percent zinc and 495° C, at 37 weight-percent zinc and 795° C, and at 56 weight-percent zinc and 810° C.[47]

Intermetallic compounds of aluminum with rare-earth elements, except for europium, thulium, ytterbium, and lutetium, were investigated. In general, the lattice constants of their orthorhombic and tetragonal structures and, therefore, the volume of the unit cells, decreased with decreasing atomic radii as the atomic number increased.[48] Growth of crystals of rare-earth elements was studied. In one method, tapered and cylindrical tensile specimens of 99.9-percent-pure gadolinium metal were annealed in inert atmospheres, strained in tension, and reannealed.[49]

Investigations of properties of rare-earth materials included determining resistivities and lattice parameters in neodymium-dysprosium alloys,[50] and measuring heats of solution of rare-earth metals and alloys in liquid tin.[51] They also included volumetrically measuring coefficients of expansion to determine the densities of cerium and several binary cerium alloys over a wide temperature range,[52] inferring the cause of a greater rate of expansion of one lattice parameter during heating in some rare-earth-ruthenium intermetallic com-

[41] Iandelli, A., and A. Palenzona. Atomic Size of Rare Earths in Intermetallic Compounds. MX Compounds of CsCl Type. J. Less-Common Metals (Amsterdam, Netherlands), v. 9, No. 1, July 1965, pp. 1–6.

[42] Moriarty, J. L., R. O. Gordon, and J. E. Humphreys. Some New Intermetallic Compounds of Holmium and Erbium With Ag, Au, Pt, Al, In, Tl, and Ge. Acta Crystallographica (Copenhagen, Denmark), v. 19, pt. 2, August 1965, p. 285.

[43] Wood, David H., and Eugene M. Cramer. Phase Relations in the Magnesium-Rich Portion of the Cerium-Magnesium System. J. Less-Common Metals (Amsterdam, Netherlands), v. 9, No. 5, November 1965, pp. 321–337.

[44] McMasters, O. D., and K. A. Gschneidner, Jr. Ytterbium-Magnesium System. J. Less-Common Metals (Amsterdam, Netherlands), v. 8, No. 5, May 1965, pp. 289–298.

[45] Harris, I. R., and G. V. Raynor. Rare Earth Intermediate Phases. I. Phases Formed With Tin and Indium. J. Less-Common Metals (Amsterdam, Netherlands), v. 9, No. 1, July 1965, pp. 7–19.

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Harris, I. R., R. C. Mansey, and G. V. Raynor. Rare Earth Intermediate Phases. III. The Cubic Laves Phases Formed With Aluminium and Cobalt. J. Less-Common Metals (Amsterdam, Netherlands), v. 9, No. 4, October 1965, pp. 270–280.

[46] Waring, J. L., and S. J. Schneider. Phase Equilibrium Relationships in the System Gd_2O_3-TiO_2. NBS J. Res., v. 69A, (Phys. and Chem.), No. 3, May–June 1965, pp. 255–261.

[47] Chiotti, P., and J. T. Mason. Phase Relations and Thermodynamic Properties of the Cerium-Zinc System. Trans. AIME, v. 233 (Met. Soc.), No. 4, April 1965, pp. 786–795.

[48] Buschow, K. H. J. Rare Earth-Aluminium Intermetallic Compounds of the Form RAl and R_3Al_2. J. Less-Common Metals (Amsterdam, Netherlands), v. 8, No. 3, March 1965, pp. 209–212.

[49] Peterson, I. M., M. Smutz, and E. H. Olson. Use of Tapered Specimens in Studies on Growth of Single Crystals of Gadolinium. J. Less-Common Metals (Amsterdam, Netherlands), v. 8, No. 5, May 1965, pp. 352–353.

[50] Arajs, S., R. V. Colvin, and H. Chessin. Electrical and X-Ray Studies of Some Neodymium-Dysprosium Alloys. J. Less-Common Metals (Amsterdam, Netherlands), v. 8, No. 3, March 1965, pp. 186–194.

[51] Lundin, C. E., and M. J. Pool. Heats of Mixing in Praseodymium-Neodymium Solid Solutions. J. Less-Common Metals (Amsterdam, Netherlands), v. 9, No. 1, July 1965, pp. 48–53.

[52] Perkins, R. H., L. A. Geoffrion, and J. C. Biery. Densities of Some Low-Melting Cerium Alloys. Trans. AIME, v. 233 (Met. Soc.), No. 9, September 1965, pp. 1703–1710.

pounds,[53] and using an automatic thermobalance to investigate the thermal decomposition of hydrated rare-earth chlorides.[54]

Yttrium metal was obtained as low as 1,000° C in the final distillation stage of yttrium alloys which were first produced by the equilibrium reaction in a fused-salt bath of magnesium and yttrium chloride.[55] Crystals of yttrium were grown epitaxially from vapor on a tungsten field-emitter surface and the symmetry of field-emission patterns was used to identify the crystal planes.[56] The recrystallization temperature for highly cold-worked alloys of 14 to 74 parts per million of yttrium in tantalum was raised 450° to 700° C compared with high-purity tantalum, and grain growth was retarded, both phenomena being caused by segregation of yttrium at grain boundaries.[57]

A 1964 Soviet monograph on the structures, properties, production, and areas of application of rare-earth borides, carbides, nitrides, silicides, and sulfides was published in English.[58]

White scale, identified as yttrium oxide, and black scale, showing diffraction lines of the oxide and the nitride, were spalled from the surface of pure yttrium which had been heated in air at 1,100° C for 1 hour. Fine grinding of the scale surface and X-ray examination indicated the presence of a triple layer: The outer layer was a normal white oxide, the middle layer was a black oxygen-deficient oxide, and the underlying layer was a yellowish nitride.[59] Because of the excellent electrical conductivity of yttria-stabilized zirconia, highly desirable as a single phase, pore-free, and gastight material in fuel cells, studies were made on the fabrication of yttria-zirconia solid-solution tubes and plates. These items were fired at temperatures between 1,500° and 1,900° C to produce high-density material, but in powder compacts with zirconia, yttria tended to evaporate when heated above 1,400° C.[60]

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[53] Gschneidner, K. A., Jr., R. O. Elliott, and D. T. Cromer. Thermal Expansion of $LaRu_2$, $CeRu_2$, and $PrRu_2$ From 20° to 900° C. J. Less-Common Metals, (Amsterdam, Netherlands), v. 8, No. 4, April 1965, pp. 217–221.

[54] Haeseler, Günther, and Franz Matthes. Uber den Thermischen Abbau der Chloridhydrate der Elemente der Seltenen Erden. (On the Thermal Decomposition of the Hydrated Chlorides of the Rare-Earth Elements.) J. Less-Common Metals (Amsterdam, Netherlands), v. 9, No. 2, August 1965, pp. 133–151 (English summary).

[55] Caro, P. La Réduction des Halogénures d'Yttrium par le Magnésium-Méthode d'Obtention d'Alliages Magnésium-Yttrium (The Reduction of Yttrium Halides by the Magnesium Method for Obtaining Magnesium-Yttrium Alloys.) J. Less Common Metals (Amsterdam, Netherlands), v. 8, No. 4, April 1965, pp. 235–255 (English summary).

[56] Melmed, Allan J. Field Emission From Epitaxially Grown Yttrium on Tungsten. J. Less-Common Metals (Amsterdam, Netherlands), v. 8, No. 5, May 1965, pp. 320–326.

[57] Kirkbride, L. D., J. A. Basmajian, D. R. Stroller, W. E. Ferguson, R. H. Perkins, and D. N. Dunning. The Effect of Yttrium on the Recrystallization and Grain Growth of Tantalum. J. Less-Common Metals (Amsterdam, Netherlands), v. 9, No. 6, December 1965, pp. 393–408.

[58] Samsonov, Grigorii Valentinovich. High-Temperature Compounds of Rare-Earth Metals With Nonmetals. Consultants Bureau, New York, 1965, 280 pp.

[59] Evans, E. B. Scaling of Yttrium in Air. J. Less-Common Metals (Amsterdam, Netherlands), v. 9, No. 6, December 1965, p. 465.

[60] Geltman, Gerald. Fabricating Yttria Stabilized Zirconia. Ceram. Age, v. 81, No. 1, January 1965, pp. 58–60.

Rhenium

By Richard F. Stevens, Jr. [1]

World production of rhenium metal powder increased as a result of the interest in the use of rhenium as an addition to tungsten and molybdenum to produce high-termperature, high-strength alloys, and was estimated at 5,000 pounds in 1965. The primary sources of rhenium during the year were the United States, the U.S.S.R., and Chile. In all cases, rhenium was recovered as a secondary byproduct of porphyry copper ores.

DOMESTIC PRODUCTION

Spurred by the continuing demand for rhenium in refractory metal alloys, the production and shipments of rhenium metal, alloys, and compounds continued to increase during 1965; despite this, the reported domestic consumption of rhenium metal powder decreased. Domestic production of recovered rhenium in the form of salts increased in 1965 and continued to exceed the 1,400 pounds, rhenium content, reported in 1963, while production of rhenium metal powder decreased approximately 25 percent.

The only commercial source of rhenium continued to be as a secondary byproduct recovered entirely from the molybdenite associated with southwestern porphyry copper ores. Chase Brass & Copper Co., Inc., Waterbury, Conn., (a subsidiary of Kennecott Copper Corp.) was the only domestic producer of rhenium metal powder. Chase was recently issued a patent covering the production of high purity rhenium metal from a mixed starting material of crude rhenium salts and rhenium scrap.[2] Other patents upon which Chase's original rhenium recovery operation were based were issued to the parent organization, Kennecott Copper Corp. in 1957 and 1959.[3] Rhenium salts were recovered for Chase from the molybdenite obtained from domestic porphyry copper ores by the Shattuck Chemical Co., Denver, Colo., and the Molybdenum Corporation of America (Molycorp), Washington, Pa. Kennecott was installing a molybdenite roasting facility and rhenium recovery circuit at Garfield, Utah. Molycorp planned to recover rhenium from its Questa, N. Mex., molybdenite mine which began operation late in 1965.

CONSUMPTION AND USES

Approximately 1,009 pounds of rhenium metal powder was consumed, primarily in tungsten-rhenium (W-Re) and molybdenum-rhenium (Mo-Re) alloys, representing a 33-percent decrease compared with 1964 consumption. The U.S. Atomic Energy Commission (AEC) continued to be interested in and study the W-25Re and W-30Mo-30Re alloys for use as a structural material in small nuclear space reactors. The distinct advantages offered by alloying tungsten and molybdenum with rhenium are the lowering of the ductile-brittle transformation temperature and the imparting of sufficient ductility to allow

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[1] Commodity specialist, Division of Minerals.

[2] Cooper, James Jr., and Joseph J. Aldrich (assigned to Chase Brass & Copper Co., Inc., Waterbury, Conn.). Process for Producing High Purity Rhenium compounds. U.S. Pat. 3,192,-011, June 29, 1965.

[3] Zimmerley, Stuart R., and John D. Prater (assigned to Kennecott Copper Corp., New York). Process for Producing Pure Ammonium Perrehenate and Other Rhenium Compounds. U.S. Pat. 2,876,065, Mar. 3, 1959.

Zimmerley, Stuart R., and Emil E. Malouf (assigned to Kennecott Copper Corp., New York). Extraction of Rhenium Incidental to Manufacture of Molybdenum Oxide. U.S. Pat. 2,809,-092, Oct. 8, 1957.

these alloys to be formed with standard fabrication equipment at room temperature while still retaining exceptional high-temperature, high-strength properties. Approximately 75 to 80 percent of the rhenium consumed during the year was in refractory alloys, predominately tungsten-rhenium alloys. Other major applications continued to be in electrical contacts, thermocouples, catalysts, and to a lesser degree, in coatings.

Sylvania Electric Products, Inc., Towanda, Pa., developed a fine tungsten-1.5 percent rhenium alloy wire for flashbulb filaments replacing the W-3Re alloy previously used in this application. The addition of rhenium raises resistivity, causes a faster ignition, and allows this tungsten alloy to be readily drawn to filament wire at only slightly elevated temperatures.

General Dynamics Corp., Fort Worth, Tex., developed an electrical conducting solid-film silver lubricant containing small amounts of rhenium which can operate at temperatures from —80° to 1,400° F. This lubricant is particularly well suited for sliding devices which conduct electric currents.

An extensive and comprehensive Soviet report described the history, properties, applications, occurence, recovery, and production of rhenium.[4]

The translation of selected chapters of a second Soviet report on rhenium-refractory metal alloys has just recently become available which discusses the compaction, heat treatment, mechanical properties, weldability, corrosion resistance, catalytic properties, and high-temperature applications of these alloys.[5] The other chapters of the original Soviet language report described commercial sources of rhenium, extraction of rhenium from byproduct sources, production and plastic deformation of Re, chemical, physical, and mechanical properties of Re, and phase diagrams and physical properties of binary and ternary rhenium alloys. A review and evaluation of the chemistry of rhenium and technetium including methods of determining the occurence and of isolating the chemical compounds of these elements was released.[6]

Additional information on the mechanical, oxidation, and thermal properties of rhenium was also recently published.[7]

Chase Brass & Copper Co., Inc., which purchased Cleveland Tungsten, Inc. early in 1966, announced that they would move their Rhenium Division from Waterbury, Conn., to the former facilities of Cleveland Tungsten at Solon, Ohio.

An English translation of the book which originally appeared under the title "Molibdeno" is now available and contains a revised and expanded chapter, Rhenium as a by-Product of Molybdenite. This revision covers the reserves and production of rhenium from the porphyry copper ores of the United States, Chile, Mexico, East and West Germany, and the U.S.S.R. in more detail than the original Spanish language publication.[8] In this chapter, new data are reported on rhenium reserves, various recovery processes used in the United States and the U.S.S.R., and other methods of recovery and metallurgical treatment. A section of the chapter deals with various developments which have occurred in the past 4 years, specifically information on the U.S.S.R. and East German production of rhenium.

PRICES

Chase Brass & Copper Co., Inc., continued to quote the following prices for rhenium materials, minimum order $50. Ammonium perrhenate (NH_4ReO_4), $425 per pound up to 5 pounds and $400 per pound for larger quantities; potassium perrhenate ($KReO_4$), $395 per pound up to 5 pounds, and $370 per pound for larger quantities; rhenium metal powder, grade I, $650 per pound up to 1 pound, and decreasing to $580 per pound for lots of 20 or more pounds; and rhenium sintered bar (melting stock), $800 per pound up to 1 pound and decreasing to $750 per pound for lots of 5 or more pounds.

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[4] Lebedec, K. B. Rhenium. U.S. Department of Commerce, Joint Publications Service, JPRS 23,361, Feb. 25, 1964, 245 pp.

[5] Savitskiy, Ye. M., M. A. Tylkina, and K. B. Povarova. Rhenium Alloys. U.S. Department of Commerce, Joint Publications Research Service, JPRS 34,566, Mar. 15, 1966, 215 pp.

[6] Colton, R. The Chemistry of Rhenium and Technetium. Interscience Publishers, a division of John Wiley & Sons Ltd., New York, 1965, 185 pp.

[7] Tietz, T. E., and J. W. Wilson. Behavior and Properties of refractory Metals. Stanford University Press, Stanford, Calif., 1965, pp. 206–221.

[8] Sutulov, Alexander. Molybdenum Extractive Metallurgy. University of Concepcion, Concepcion, Chile, 1965, 239 pp.

Rhenium rod stock having diameters ranging from 0.2 to 0.025 inches were quoted at \$900 to \$1,260 per pound respectively. Rhenium strip and foil, having thicknesses ranging from 0.06 to 0.001 inches were quoted at \$815 to \$1,580 per pound, respectively. Also available were tungsten-rhenium and molybdenum-rhenium alloys in the form of ingot, rod, wire, sheet, and tubing produced by both powder metallurgy (PM) and arc-melting (AM) techniques.

Also, Chase was reportedly offering from \$280 to \$300 per pound of rhenium content for W-Re and Mo-Re alloy scrap. This material was recycled to recover the rhenium content.

Effective December 12, 1965, Hoskin Manufacturing Co., one of the largest manufacturers of tungsten-rhenium thermocouples, reduced the price for their standard tungsten—5 percent rhenium/tungsten—26 percent rhenium bimetal thermocouples used to measure temperatures up to 5,000° F.

FOREIGN TRADE

During 1965, imports of high-purity rhenium metal powder more than doubled to 469 pounds valued at \$213,085. This material, which was imported from West Germany (98 percent), France (1 percent), and the United Kingdom (1 percent), continued to be used primarily in tungsten-rhenium thermocouple alloys and in electronic applications. The rhenium metal powder imported from West Germany continued to be sold at approximately \$20 per pound less than domestic rhenium. This price differential was for imported rhenium with duty (10.5 percent ad valorem) paid.

WORLD REVIEW

Belgium.—Société Générale Métallurgique de Hoboken announced it would begin commercial production of rhenium metal powder recovered from molybdenite as a secondary byproduct of porphyry copper ores mined in the Democratic Republic of the Congo (Léopoldville). It is believed that Métallurgique-Hoboken has been accumulating significant amounts of rhenium-bearing copper ores over a period of several years and currently is estimated to have an assured supply of several hundred pounds of rhenium. This Belgian firm reportedly will market the recovered rhenium metal powder through Sté Générale des Minerals at a price of about \$454 per pound.

Chile.—The porphyry copper ores of Chile, from which molybdenite (MoS_2) is recovered, are reported to contain about one pound of metallic rhenium per ton of MoS_2.[9] Similar type deposits in the southwestern part of the United States contain from 1 to 3 pounds of rhenium per ton of MoS_2. The majority of this copper and associated molybdenum is recovered by subsidiaries of the Kennecott Copper Corp. and The Anaconda Copper Co. at several mines. Although the rhenium contents have been reported from only the Chuquicamata mine (0.5 pound rhenium per ton of MoS_2) the El Salvalore mine (1.3 pounds per ton), and the El Teniente mine (1 pound per ton), the other copper porphyry ores are believed to contain like quantiues of rhenium. Almost all of this material is exported to Western Europe where the molybdenite is roasted and some of the rhenium is recovered.

China.—Although little information is available on the rhenium production and reserves of mainland China, it is believed that the disseminated (porphyry) copper deposits, reported in the Copper Materials Survey, which are at the Chung-t'iao Shan mine in Shansi and the Te-hsing mine in Kiangsi, probably contain rhenium.[10] It is believed that none of the rhenium in these ores is recovered.

Germany, East.—In the first commercial production of rhenium, the metal was recovered from the residues of potash salt workings at Aschersleben and from Mansfeld copper smelting flue dust in Eisleben. Recovery of rhenium from the Mansfeld flue dust, which contains approximately 0.25 pounds of rhenium per ton of MoS_2, was recently reinitiated. Research on the high-temperature properties of rhenium

[9] Sutulov, Alexander. Growing Output of Molybdenite. Min. Mag. (London), v. 112, No. 2, February 1965, pp. 72–77.

[10] McMahon, A. D. Copper, A Materials Survey. BuMines Inf. Circ. 8225, 1965, 340 pp.

was being conducted in Freiberg and Dresden.

Germany, West.—Rhenium metal powder was recovered and marketed in West Germany by Herman Stark, Goslar, and production in the country during 1965 was estimated at about 500 pounds. This rhenium was recovered from molybdenite imported from Chile which had been recovered from the porphyry copper ores obtained primarily from the El Teniente mine of Braden Copper Co., a subsidiary of Kennecott Copper Corp.

Mexico.—The rhenium content of the prophyry copper ore produced from the Cananea mine, 50 miles southwest of Bisbee, Ariz., is reported to contain 1.5 pounds of rhenium per ton of MoS_2, a grade comparable to several deposits found in the United States from which rhenium is presently recovered.[11] Although, as in the case of Chile, almost all of the rhenium-bearing molybdenite associated with this copper is exported, it is believed that no attempt is currently being made to recover the rhenium from this relatively high-grade source.

Sweden.—The highest reported concentration of rhenium occurs in the Lainedjaur nickel mine North West of Bastuträsk, which was operated during World War II and has been closed since that time. This deposit contains 5.5 pounds of rhenium per ton of MoS_2, almost twice the highest concentration reported in the United States.

U.S.S.R.—At least seven and possibly nine rhenium deposits in the Soviet Union have sufficient rhenium concentrations to justify their recovery. In all nine deposits the rhenium occurs as a secondary byproduct of rhenium-bearing copper ores in concentrations ranging from 0.13 to 2.2 pounds of rhenium per ton of MoS_2. At the recently expanded Balkhas plant in Kazakhstan, rhenium is recovered from the residues of calcium molybdate production that comes from the treatment of the Kounrad porphyry copper ores. A detailed description of the rhenium recovery process used in the U.S.S.R. is reported in the volume on molybdenum extractive metallurgy.[12] These nine deposits and their reported rhenium contents are as follows:

Mine	*Rhenium content (Pounds per ton of MoS_2)*
Kounrad, Kazakhstan	1.12
Almalyk, Uzbekstan	.51
Kalmatyr, Uzbekstan	.64
Kadzharan, Armenia	.66
Dastakert, Armenia	.18
Daragachaisk, Armenia	.62
Aigedzor, Armenia	2.20
Dzhindarinsk, Armenia	.55
Davenda, Transbaikal	.13

In the Soviet Union the first recovery of rhenium was initiated in 1948 at Balkhash and since that time an intensive research program has been conducted. The four potential sources of rhenium in the U.S.S.R. have been reported to be molybdenite concentrate, copper concentrate, flue dusts from different smelters, and overflow waters from mining and milling operations.

Although the volume of rhenium production in the Soviet Union is not known, it is believed to be comparable or perhaps even slightly higher than that in the United States because only about half of the molybdenite in the United States is treated to recover rhenium while most of the molybdenite obtained in the U.S.S.R. is relatively impure and requires an additional hydrometallurgical treatment, in which operation the rhenium content can be recovered.

TECHNOLOGY

The Bureau of Mines, in cooperation with the Atomic Energy Commission (AEC), continued studies of the tungsten-25 percent rhenium (W-25Re) alloy to evaluate its high-temperature, high-strength properties, and room temperature ductility.[13] During the year studies were initiated on the W-Mo-Re alloy system to determine its properties and optimum methods of consolidating and fabricating this ternary alloy into small diameter, thin-wall tubing.

Bureau studies were also conducted on

[11] Page 77 of work cited in fotnote 9.
[12] Pages 176 and 177 of work cited in footnote 8.
[13] Bureau of Mines. Metallurgical Progress Report, Nos. 26–29 (Quarterly reports, March-December 1965). U.S. Dept. of Commerce, Clearinghouse for Federal Scientific and Technical Information, USBM-RC-1158, 1199, 1205, 1220.

the engineering properties of the W-25Re alloy to determine the suitability of fabricating extruded bars to sheet.

Studies were also conducted by Bureau scientists to develop methods of preparing ultra-fine homogenous tungsten-rhenium alloy powders by the hydrogen coreduction of their freeze-dried ammonium compounds.[14]

The tungsten-rhenium alloys which have excellent high-temperature, high-strength properties, and room temperature ductility continued to be studied as a structural and cladding material in nuclear and aerospace applications.[15]

In order to determine the effect of prolonged exposure of tungsten-rhenium alloys to the operating conditions in nuclear reactors, the influence of neutron irradiation on the creep-rupture, tensile, hardness, and resistivity properties of W-25Re was evaluated.[16]

A processing procedure was developed for tungsten-rhenium base alloys which produced high-purity W-25Re sheet and extended the high-temperature application beyond that of presently available commercial alloys.[17]

The stress-rupture strength and creep resistance of the Mo-50Re alloy were evaluated in the temperature range from 1,600° to 2,200° C and were found to be an order of magnitude greater than pure molybdenum.[18]

In the stress range from 4,250 to 8,500 pounds per square inch at 1,600° C in a hydrogen atmosphere, rhenium and W-25Re had less stress-rupture strength and creep-resistance than tantalum-10 tungsten (Ta-10W).[19]

Tungsten-25 rhenium sleeves were prepared by powder-metallurgy, arc-melting, and skull-casting techniques from stoichiometric proportions of W and Re metal powder isostatically compacted at 30,000 pounds per square inch and sintered at 2,200° C by electron-beam heating.[20] These sleeves were subsequently extruded and drawn to small diameter W-25Re tubing.

W-Re-Mo alloys were developed which offer a wide selection of elevated-temperature properties.[21] W-30Re-30Mo, an inherently fine-grained alloy which exhibits complete resistance to loss of room-temperature bend-ductility, has been successfully fabricated and used as a prototype reactor component. W-30Re and W-30Re-10Mo can be age-hardened to develop high creep-rupture strength.

Tungsten-25 rhenium tubing was successfully produced by extruding W-25Re sleeves consolidated by powder-metallurgy and arc-melting at 1,600° C. and at extrusion ratios of 16 to 1 and 25 to 1.[22] Using this fabrication technique W-25Re tubes were extruded and then drawn at 510° C to ⅜-inch diameter. The reextrusion of W-25Re tubing to smaller diameters, below 0.1-inch, required the use of a filler material, such as molybdenum, which was removed chemically following reextrusion.

Dense adherent rhenium electrodeposits were successfully applied on Mo and W when these substrate surfaces were etched in a 15-percent sodium hydroxide solution with an alternating current density of 30 amperes per square decimeter.[23]

Rhenium alloys studied for use in the brazing of tungsten-base materials included W-10Re-20Ru, W-15Re-25Ru, W-20Re-10Ru, W-40Re-15Ru, Mo-50Re-15Pd and Mo-30Re-30Pd.[24] Although none of these alloys were cold workable, the W-20Re-10Ru alloy had the highest brazing temperature of 2,825° C.

The fabrication of tungsten-rhenium alloys is difficult and expensive because of the high temperatures required, 1,800° C for extrusion, the tendency to form a brittle "sigma" phase during alloying, and the poor recovery of expensive rhenium.[25] To avoid these difficulties the Oak Ridge National Laboratory (ORNL) produced tungsten-rhenium alloy tubing by the vapor coreduction of tungsten and rhenium hexafluorides (WF_6 and ReF_6 with hydrogen

[14] Lansberg, A., and T. T. Campbell. Freeze-Dry Technique for Making Ultra-Fine Powder. J. Metals, v. 17, No. 8, August 1965, pp. 856–860.

[15] Rice, William L. R. Nuclear Fuels and Materials Development. AEC, U.S. Dept. of Commerce, Clearinghouse for Federal Scientific and Technical Information. TID-11295, 4th ed., June 1965, 145 pp.

[16] Pages XIV. 4 and XIV. 5 of work cited in footnote 15.

[17] Page XIV. 4 of work cited in footnote 15.

[18] Page XIV. 3 of work cited in footnote 15.

[19] Page XIV. 3 of work cited in footnote 15.

[20] Pages VIII. 1 and VIII. 2 of work cited in footnote 15.

[21] Pages XIV. 4 of work cited in footnote 15.

[22] Pages XVIII. 1 and XVIII. 3 of work cited in footnote 15.

[23] U.S. Atomic Energy Commission. Reactor Materials. V. 8 Nos. 1–4, (published quarterly), 1965, 249 pp.

[24] Pages 229 and 230 of work cited in footnote 23.

[25] U.S. Atomic Energy Commission. Fundamental Nuclear Energy Research—1965, December 1965, 338 pp.

at 450° to 700° C. A 7-inch length of uniform W-12Re tubing was prepared at 600° C from the fluoride gases diluted with argon.

Processing data on the W-5Re-2.2-ThO_2 alloy indicated that better alloy ductility was achieved using thorium oxide obtained from a fluid colloidal solution instead of from thermally decomposed thorium nitrate.[26]

Low pressure oxidation studies of rhenium and tungsten silicides conducted at high temperatures indicated that these intermetallic compounds were promising protective coatings for pure rhenium and tungsten at elevated temperatures.[27]

Tungsten and tungsten-rhenium alloys were evaluated as structural materials for use in space-power liquid metals service.[28] W-10Re, W-25Re, and W were not attacked by molten lithium after 1,000 hours exposure at 2,500° F. W-10Re, W-25Re, W-15Mo, and W were not attacked by cesium vapor after 1,000 hours exposure at 2,500°, 2,800°, and 3,100° F, but all of these materials were subject to surface dissolution at 3,400° F. Of these tungsten-base materials, the W-25Re alloy was the most resistant to attack by cesium vapor.

Because W-Re alloys are being evaluated as a structural and cladding material for use in graphite-moderated nuclear reactors, the reactions between graphite and W-25Re were studied in the temperature range between 1,500° and 1,900° C.[29] This study indicated that the rapid growth of carbide layers in W-25Re may seriously inhibit the alloys usefulness in structural applications involving graphite.

The metallurgical properties of tungsten and rhenium for thermionic emitters were studied.[30] The use of vapor-deposited rhenium on curved surfaces was found to have significant advantages in nuclear applications where only a thin film of rhenium can be tolerated.

Dilute additions of rhenium to tungsten caused significant improvement in low-temperature ductility, particularly in the worked condition.[31]

Extrustion studies were made on the W-3Re alloy.[32] A combination of low deformation speeds, glass lubricants, and 60-degree die angle furnished the lowest deformation loads.

Fully dense rhenium and rhenium-base alloy parts can be produced by isostatic pressing (solid state bonding) metal powder at 2,900° to 3,000° F and 10,000 to 15,000 pounds per square inch (psi) for 1 to 3 hours.[33] The best rhenium products were prepared by initially compacting the Re powder at room temperature and 100,000 psi prior to subsequent isotatic pressing. Although initial results indicate that W-Re alloys can be prepared in the same way, it may be necessary to use explosive compaction techniques for green pressing.

Magnetic susceptibility measurements conducted on the Mo-Re system indicated that a localized magnetic moment continued to exist in the Mo_6Re_4 alloy when the resistance minimum had vanished.[34]

Technetium (Tc), a radioisotope found in the fission products of nuclear reactors, is a sister element to rhenium and has similar properties. Because of its similarity and potentially more abundant supply, technetium continued to be studied as a replacement for rhenium.[35] The series of tungsten-technetium (W-Tc) alloys containing 0, 2.5, 5, 10, 20, 30, 40, 50, and 60

[26] Holden, F. C., and F. W. Boulger. Third Status Report of the U.S. Government Metalworking Processes and Equipment Program. Battelle Memorial Inst., Columbus, Ohio, DMIC Rept. 218, June 16, 1965, 65 pp.

[27] Bartlett, R. W. Investigation of Mechanisms for Oxidation Protection and Failure of Intermetallic Coatings for Refractory Metals. Aeronutronic Applied Research Laboratories, Newport Beach, Calif., ASD-TDR-63-753, pt. III (U.S. Air Force Contract No. AF 33 (657)-9170), September 1965, 104 pp.

[28] Stang, J. H., E. M. Simmons, and J. A. DeMastry. Materials for Liquid-Power Metals Service. Battelle Memorial Inst., DMIC Memorandum 209, Oct. 5, 1965, 9 pp.

[29] Fackelmann, J. M., R. W. Getz, and D. P. Moak. Reactions of Graphite With Tungsten —25 w/o Rhenium. Paper pres. at 4th symp. on Refractory Metals, Met. Soc., AIME, French Lick, Ind., Oct. 3–5, 1965.

[30] van Someren, Laurence. Tungsten and Rhenium Materials for Therionic Emitters. Paper pres. at 4th Symp. on Refractory Metals, Met. Soc., AIME, French Lick, Ind., Oct. 3–5, 1965.

[31] Klopp, William D., Walter R. Witzke, and Peter L. Raffo. Ductility and Strength of Dilute Tungsten-Rhenium Alloys. National Aeronautics and Space Administration, NASA TM X–52131, October 1965, 20 pp.

[32] Carnahan, D. R., and V. DePierre. The Primary Working of Refractory Metals. Air Force Materials Lab., Res. and Tech. Div., Air Force Systems Command, USAF Wright Patterson Air Force Base, Ohio, Tech. Rept. AFML-TR-64-387, pt. II, October 1965, 150 pp.

[33] Hodge, Edwin S. Hot Isostatic Pressing Improves Powder Metallurgy Parts. Mat. in Design Eng., v. 61, No. 5, May 1965, pp. 92–97.

[34] Clogston, A. M. Localized Magnetic Moments. J. Metals, v. 17, No. 7, July 1965, pp. 728–734.

[35] Battelle Memorial Institute, Pacific Northwest Laboratory. Quarterly Progress Report, A Study of Tungsten-Technetium Alloys. U.S. Department of Commerce, Clearinghouse for Federal Scientific and Technical Information, BNWL —141, —142, —162, —196, January 1965—January 1966.

atomic percent Tc were cast into buttons by arc- and electron-beam melting. All of these alloys exhibited significant amounts of porosity, were irregular in shape, and were difficult to fabricate. During melting, losses of 10 percent occurred because of splatter rather than evaporation. In an attempt to remove the porosity these buttons will be remelted.

Arc-melted tungsten alloys containing 50 and 60 atomic percent (a/o) Tc were examined with an electron-beam microprobe in attempts to determine compositions of the second phase region of these alloys. These measurements, together with observations of the structure, indicated that the nonequilibrium structure of both alloys were alpha solid solution plus a region of alpha and sigma. The configuration of this second region appeared eutectic and was the last region to solidify. This interpretation would place the 60 a/o Tc alloy as hypoeutectic.

Results of cold forging the high technetium alloys (50 and 60 a/o Tc) to about 40 to 50 percent reduction have indicated that, like rhenium, technetium does impart significant room temperature ductility to tungsten.

Additional research conducted on technetium-aluminum (Tc-Al) and technetium-silicon (Tc-Si) compounds evaluated intermediate phases stable at elevated temperatures.[36]

[36] Darby, J. B., Jr., J. W. Downye, and L. J. Norton. Intermediate Phases in the Technetium-Aluminum and Technetium-Silicon Systems. J. Less-Common Metals (Amsterdam, Netherlands), v. 8, No. 1, January 1965, pp. 15–20.

Salt

By William H. Kerns [1]

Increased consumption of salt (sodium chloride) in the expanding chemical industries resulted in a record high U.S. salt production in 1965. Two-thirds of the total salt output was used to manufacture chlorine-caustic, soda ash, and other chemicals. Production of salt was more than 3 million tons above the 1964 figure, a gain of 10 percent.

Legislation and Government Programs.—A Bill was introduced in the U. S. Congress in October 1965 proposing that containers of salt of foreign origin be marked with the English name of the source country. The Bill, H.R. 11575, was referred to the Committee on Interstate and Foreign Commerce, but was not reported out of committee by yearend.

DOMESTIC PRODUCTION

Ninety-eight percent of the domestic salt output came from eight States; the remainder was produced in nine other States.

Salt was produced by 58 companies at 97 plants. Ten companies, each producing more than 1 million tons, operated 39 plants, which together accounted for 84 percent of the U. S. total salt output; 15 companies, each producing less than 1 million but more than 100,000 tons of salt, operated 22 plants and in aggregate supplied 14 percent of the total; and 33 companies, each producing less than 100,000 tons, operated 36 plants and produced the remaining 2 percent.

Nine plants, each with an output of over 1 million tons of salt, together accounted for 48 percent of the total U.S. salt production; 16 plants, 500,000 to 1 million tons, 31 percent; 29 plants, 100,000 to 500,000 tons, 18 percent; 24 plants, 10,000 to 100,000, 3 percent; and 19 plants, less than 10,000 tons, less than 0.5 percent.

More than half of the advance in U.S. salt output resulted from an increased production of salt as artificial brine (produced as brine and used as such) for use in the chemical industry. Most of the remaining advance resulted from an increased output of rock salt of which nearly half was used for highway deicing and roadbed stabilization.

[1] Commodity specialist, Division of Minerals.

Table 1.—Salient salt statistics

(Thousand short tons and thousand dollars)

	1956–60 (average)	1961	1962	1963	1964	1965
United States:						
Sold or used by producers	24,120	25,707	28,807	30,641	31,623	34,687
Value	$148,713	$160,223	$174,841	$184,589	$200,706	$215,699
Exports	387	642	671	781	594	688
Value	$2,507	$3,876	$3,638	$4,140	$3,373	$4,285
Imports for consumption	742	1,050	1,374	1,516	r 2,261	2,410
Value	$3,833	$3,755	$5,097	$5,112	$5,677	$6,505
Consumption, apparent	24,475	26,115	29,510	31,376	r 33,290	36,409
World: Production	83,680	93,660	100,760	104,700	109,720	118,590

r Revised.

Table 2.—Salt sold or used by producers in the United States

(Thousand short tons and thousand dollars)

State	1964		1965	
	Quantity	Value	Quantity	Value
California	1,525	W	1,638	W
Kansas [1]	930	$11,799	1,053	$12,376
Louisiana	6,401	36,056	8,126	41,812
Michigan	4,345	35,711	4,171	36,087
New Mexico	62	559	64	572
New York	4,816	34,216	5,002	35,771
Ohio	4,537	31,092	5,026	34,816
Oklahoma	6	41	9	65
Texas	6,410	28,797	6,964	30,771
Utah	371	3,848	384	3,591
West Virginia	1,033	3,666	1,153	5,539
Other States [2]	1,187	14,921	1,097	14,299
Total	31,623	200,706	34,687	215,699
Puerto Rico	5	74	8	138

W Withheld to avoid disclosing individual company confidential data; included with "Other States."
[1] Quantity and value of brine included with "Other States."
[2] Includes Alabama, Colorado, Hawaii, Kansas (brine only), Nevada, North Dakota, Virginia, and States indicated by symbol W.

Table 3.—Salt sold or used by producers in the United States, by methods of recovery

(Thousand short tons and thousand dollars)

Method of recovery	1964		1965	
	Quantity	Value	Quantity	Value
Evaporated:				
Bulk:				
Open pans or grainers	301	$8,024	303	$8,077
Vacuum pans	2,422	53,262	2,547	56,156
Solar	1,592	10,107	1,700	9,803
Pressed blocks	387	8,659	375	8,701
Total	4,702	80,052	4,925	82,737
Rock:				
Bulk	8,489	50,565	9,742	55,943
Pressed blocks	65	1,725	68	1,767
Total	8,554	52,290	9,810	57,710
Salt in brine (sold or used as such)	18,367	68,364	19,952	75,252
Grand total	31,623	200,706	34,687	215,699

International Salt Co. officials announced plans to construct a $6-million salt refinery at its salt mine at Whiskey Island, Cleveland, Ohio. The new facility will use the company's patented recrystallizer process to produce high-purity evaporated granulated salt primarily for industrial use from rock salt at the rate of 150,000 tons annually. Completion of the plant was scheduled for midyear 1967.

Morton Salt Co., a division of Morton International, Inc., announced plans for a $250,000 expansion in its granulated salt plant at Rittman, Ohio. Multiple-effect vacuum pans are to be installed to evaporate brine and produce a high-purity product. The installation was expected to be completed by spring 1966.

The Goldfield Corp. announced plans for an operation producing 500 tons per day of salt from property leased from the U.S. Government covering 4,159 acres at Detrital Valley near Lake Mead, Ariz.

Solar Salt Co. opened a new $320,000 salt refinery northwest of Grantsville, Utah, in midyear. The new plant increased the drying and screening capacity to 30 tons per hour of salt compared with the 8-ton-per-hour output of the old plant. Solar Salt produces and markets some 40 varieties and packs of salt, none of it the common table salt variety.

Hardy Salt Co. purchased the Leslie Salt Co. salt plant at Salt Lake City, Utah, late in the year. In the past, Hardy's only production facilities were its vacuum-evaporating salt plant at Manistee, Mich. The Salt Lake City solar-evaporating plant, utilizing the salty brine of the Great Salt Lake, was reported to have a capacity for producing 100,000 tons per year of salt.

Flooding of the Carey Salt Co. mine near Winnfield, La., in November forced complete evacuation. All workings and equipment were under water, and specialists were obtained to see if the mine or any part of it could be saved.

Table 4.—Evaporated salt sold or used by producers in the United States

(Thousand short tons and thousand dollars)

State	1964		1965	
	Quantity	Value	Quantity	Value
Kansas	438	$9,485	453	$9,828
Louisiana	251	6,080	256	6,293
Michigan	941	20,597	970	21,498
New York	628	14,501	676	15,471
Ohio	603	13,315	626	13,707
Oklahoma	3	33	6	57
Utah	360	3,776	W	W
Other States [1]	1,478	12,265	1,938	15,883
Total	4,702	80,052	4,925	82,737
Puerto Rico	5	74	8	138

W Withheld to avoid disclosing individual company confidential data; included with "Other States."
[1] Includes California, Hawaii, Nevada, New Mexico, North Dakota, Texas, and States indicated by symbol W.

Table 5.—Rock salt sold by producers in the United States

(Thousand short tons and thousand dollars)

Year	Quantity	Value	Year	Quantity	Value
1956–60 (average)	5,799	$39,131	1963	8,345	$51,648
1961	6,439	42,950	1964	8,554	52,290
1962	7,726	46,874	1965	9,810	57,710

Table 6.—Pressed-salt blocks sold by original producers of salt in the United States

(Thousand short tons and thousand dollars)

Year	From evaporated salt		From rock salt		Total	
	Quantity	Value	Quantity	Value	Quantity	Value
1956–60 (average)	291	$6,357	55	$1,325	346	$7,682
1961	357	7,866	63	1,661	420	9,527
1962	366	8,034	61	1,576	427	9,610
1963	362	7,914	60	1,589	422	9,503
1964	387	8,659	65	1,725	452	10,384
1965	375	8,701	68	1,767	443	10,468

CONSUMPTION AND USES

Salt sold or used in the chemical manufacturing industry accounted for 66 percent of the U.S. total salt output; 41 percent for producing chlorine and its coproduct (caustic soda), 19 percent for sodium carbonate (soda ash), and 6 percent for other chemicals. Of the total salt used by the chemical industry, 87 percent was produced as brine and used as such.

The next highest use of salt was for snow and ice removal and for roadbed stabilization. This use, as shown in table 7 under the "States, counties, and other political subdivisions (except Federal)" category, accounted for 13 percent of the total salt output. Salt assumed to be used as table salt, as shown under "Grocery Stores," represented 3 percent of the total; and salt used in water softening a growing use of salt, accounted for 2 percent of the total U.S. salt output.

Table 7.—Salt sold or used by producers in the United States, by classes and consumers or uses

(Thousand short tons)

Consumer or use	1964				1965			
	Evaporated	Rock	Brine	Total	Evaporated	Rock	Brine	Total
Chlorine	W	W	10,369	12,293	W	W	12,136	14,257
Soda ash	W	W	7,073	7,083	W	W	6,462	6,464
Soap (including detergents)	24	6	------	30	25	9	------	34
All other chemicals	326	548	713	1,587	326	701	1,144	2,171
Textile and dyeing	89	101	1	191	W	141	W	242
Meatpackers, tanners, and casing manufacturers	324	412	------	736	306	458	------	764
Fishing	W	W	------	29	17	5	------	22
Dairy	42	3	------	45	42	4	------	46
Canning	181	54	------	235	177	37	------	214
Baking	105	4	------	109	103	4	------	107
Flour processors (including cereal)	56	8	------	64	59	10	------	69
Other food processing	116	15	------	131	127	30	------	157
Ice manufacturers and cold-storage companies	17	21	------	38	14	22	------	36
Feed dealers	626	420	------	1,046	661	W	W	1,067
Feed mixers	290	116	------	406	289	142	------	431
Metals	54	83	------	137	56	89	------	145
Ceramics (including glass)	6	9	------	15	4	9	------	13
Rubber	W	W	55	77	W	W	53	86
Oil	60	64	92	216	63	62	90	215
Paper and pulp	W	147	W	201	W	137	W	196
Water softener manufacturers and service companies	236	330	4	570	W	287	W	540
Grocery stores	607	298	------	905	595	387	------	982
Railroads	7	33	------	40	6	26	------	32
Bus and transit companies	W	W	------	45	3	45	------	48
States, counties, and other political subdivision (except Federal)	W	3,755	W	3,975	201	4,332	3	4,536
U. S. Government	24	70	------	94	24	71	------	95
Miscellaneous	911	396	18	1,325	1,086	615	17	1,718
Undistributed [1]	601	1,661	4[illegible]	------	741	2,187	47	------
Total	4,702	8,554	18,367	31,623	4,925	9,810	19,952	34,687

W Withheld to avoid disclosing individual company confidential data; included with "Undistributed."
[1] Includes some exports and consumption in overseas areas administered by the United States, and items indicated by symbol W.

Table 8.—Distribution (shipments) of evaporated and rock salt produced in the United States, by destination

(Thousand short tons)

Destination	1964		1965	
	Evaporated	Rock	Evaporated	Rock
Alabama	29	283	30	433
Alaska	3	----	4	----
Arizona	W	15	W	7
Arkansas	16	67	15	65
California	790	W	802	W
Colorado	82	29	85	24
Connecticut	16	53	17	W
Delaware	7	8	8	W
District of Columbia	4	40	4	W
Florida	23	92	25	99
Georgia	45	84	49	127
Hawaii	4	----	4	----
Idaho	32	2	31	W
Illinois	236	503	243	658
Indiana	130	283	132	293
Iowa	143	205	147	232
Kansas	74	173	68	193
Kentucky	42	220	41	227
Louisiana	28	204	30	255
Maine	W	111	31	W
Maryland	63	143	75	W
Massachusetts	61	283	79	270
Michigan	198	346	189	W
Minnesota	122	169	127	231
Mississippi	19	86	18	87
Missouri	83	151	84	192
Montana	36	1	33	1
Nebraska	76	80	83	100
Nevada	21	W	15	W
New Hampshire	4	140	5	131
New Jersey	146	404	154	W
New Mexico	12	56	13	55
New York	229	W	244	W
North Carolina	101	133	113	140
North Dakota	29	6	38	5
Ohio	255	724	260	815
Oklahoma	31	59	32	61
Oregon	48	----	57	W
Pennsylvania	169	529	184	593
Rhode Island	9	W	10	W
South Carolina	32	20	34	18
South Dakota	37	22	37	24
Tennessee	122	238	125	268
Texas	94	242	99	232
Utah	102	7	106	W
Vermont	7	87	7	56
Virginia	78	118	89	130
Washington	159	----	184	W
West Virginia	25	69	25	61
Wisconsin	126	155	137	288
Wyoming	18	11	20	3
Other [1]	486	1,903	483	3,436
Total	4,702	8,554	4,925	9,810

W Withheld to avoid disclosing individual company confidential data; included with "Other."

[1] Includes shipments to overseas areas administered by the United States, Puerto Rico, exports, some shipments to unspecified destinations, and States indicated by symbol W.

PRICES

Quotations for rock and table salt in carlots, f.o.b. New York, by Oil, Paint and Drug Reporter were $1.09 per 100 pounds for rock salt in paper bags and $1.34 per 100 pounds for vacuum common fine table salt. The average value of salt sold or used by producers in 1965, f.o.b. mine, as reported to the Bureau of Mines was $5.88 per ton for rock salt (total of bulk and pressed block), compared with $6.11 per ton in 1964; $16.80 per ton for evaporated salt (open pans or grainers, vacuum pans, solar, and pressed block), $17.02 in 1964; and $3.77 per ton for salt in brine, $3.72 in 1964. Solar salt in bulk was valued at an average of $5.77 per ton, compared with $6.35 per ton in 1964.

FOREIGN TRADE

U.S. salt exports and imports for consumption were minor factors in the U.S. salt industry economics. Total U.S. salt exports to 75 countries was about one-quarter of the imports for consumption. Exports to three countries accounted for most of the total; 55 percent went to Japan, 24 percent to Canada, and 20 percent to Brazil. Imports came from six countries and was about 7 percent of the total U.S. salt production. Most of the U.S. imports of salt were produced in one nearby and two bordering countries; 59 percent came from Canada, 20 percent from Mexico, and 14 percent from the Bahamas, respectively. The remainder came from Spain, United Kingdom, and Tunisia. Nearly one-half of the imports from Canada was produced as artificial salt brine from wells at Sandwich, Ontario, transported from Canada to Detroit, Mich., through pipelines running under the Detroit River, and used as brine in a Detroit chemical plant.

Table 9.—Salt shipped to the Commonwealth of Puerto Rico and overseas areas administered by the United States

(Thousand short tons and thousand dollars)

Area	1964		1965	
	Quantity	Value	Quantity	Value
American Samoa	[1]	$5	[1]	$11
Guam	[1]	12	[1]	14
Puerto Rico	14	1,142	16	1,220
Virgin Islands	[1]	15	[1]	18

[1] Less than ½ unit.

Table 10.—U.S. exports of salt by countries

(Thousand short tons and thousand dollars)

Destination	1964		1965	
	Quantity	Value	Quantity	Value
North America:				
Canada	196	$1,370	163	$1,414
Mexico	1	48	1	61
Netherlands Antilles	1	37	1	43
Other	4	86	2	110
South America:				
Argentina	3	20	([1])	4
Brazil	([1])	1	137	632
Venezuela	4	26	([1])	6
Other	2	25	1	31
Europe:				
Greece	3	20	1	38
Italy	3	23	([1])	31
Netherlands	4	23	([1])	17
Spain	4	20	([1])	32
Other	3	19	([1])	37
Africa:				
South Africa, Republic of	3	27	([1])	13
Other	2	21	([1])	18
Asia:				
Hong Kong	3	15	([1])	1
Japan	349	1,456	379	1,601
Saudi Arabia	1	44	1	46
Other	2	47	1	65
Oceania:				
Australia	5	29	1	67
Other	1	16	([1])	18
Total	594	3,373	688	4,285

[1] Less than ½ unit.

Table 11.—U.S. imports for consumption of salt, by countries [1]

(Thousand short tons and thousand dollars)

Country	1964		1965	
	Quantity	Value	Quantity	Value
North America:				
Bahamas	292	$1,155	344	$1,305
Canada	r 1,280	3,434	1,432	4,017
Dominican Republic	23	46	----	----
Jamaica	4	11	----	----
Mexico	527	679	480	744
Europe:				
Spain	27	72	45	135
Other	(2)	1	(2)	(2)
Africa:				
Tunisia	84	222	109	304
United Arab Republic (Egypt)	24	57	----	----
Total	r 2,261	5,677	2,410	6,505

r Revised.
[1] Includes salt brine from Canada through the Michigan customs district for 1964, 590,120 short tons valued at $161,670; 1965, 645,481 short tons valued at $179,350.
[2] Less than ½ unit.

Table 12.—U.S. imports for consumption of salt, by classes

(Thousand short tons and thousand dollars)

Year	In bags, sacks, barrels, or other packages (dutiable)		Bulk (dutiable)[1]	
	Quantity	Value	Quantity	Value
1956–60 (average)	32	$429	711	$3,404
1961	9	144	1,041	3,610
1962	15	254	1,359	4,843
1963	10	158	1,506	4,954
1964	11	158	r 2,250	5,519
1965	14	241	2,396	6,264

r Revised.
[1] Includes salt brine from Canada through the Michigan customs district 1964, 590,120 short tons valued at $161,670; 1965, 645,481 short tons valued at $179,350.

Table 13.—U.S. imports for consumption of salt, by customs districts [1]

(Thousand short tons and thousand dollars)

Customs district	1964		1965	
	Quantity	Value	Quantity	Value
Buffalo	41	$179	23	$92
Chicago	140	666	198	986
Connecticut	56	274	21	95
Duluth and Superior	42	206	23	119
Georgia	110	406	178	657
Los Angeles	80	125	105	217
Maine and New Hampshire	98	366	83	359
Maryland	105	345	65	200
Massachusetts	112	371	88	323
Michigan	r 809	1,244	944	1,693
New York	30	137	40	143
North Carolina	7	16	12	31
Ohio	91	380	87	361
Oregon	123	151	130	161
Philadelphia	---	---	18	49
Puerto Rico	6	29	6	30
Rhode Island	14	69	14	60
Rochester	7	27	16	103
Vermont	13	56	9	35
Virginia	7	26	9	34
Washington	324	408	280	498
Wisconsin	46	194	61	258
Other	(2)	2	(2)	1
Total	r 2,261	5,677	2,410	6,505

r Revised.
[1] Includes salt brine from Canada through the Michigan customs district for 1964, 590,120 short tons valued at $161,670; 1965, 645,481 short tons valued at $179,350.
[2] Less than ½ unit.

WORLD REVIEW

NORTH AMERICA

Mexico.—Exportadora de Sal, S.A., has expended $16 million in the development of saltworks at Guerrero Negro in the Territory of Baja California, Mexico, and planned to invest an additional $20 million to expand operations. Salt output was expected to reach 1.75 million tons in 1965, and company officials forecast an annual production of 3.25 million tons by 1967. Salt produced by solar evaporation of sea water is supplied to chemical industries in Japan and Pacific Coast areas of the United States and Canada. [2]

Netherlands Antilles.—Negotiations with the Government of Bonaire relating to the development of a solar evaporation plant on the island of Bonaire were underway and progress was made on the first phase of engineering by International Salt Co. This operation will be the company's first venture in the production of solar salt. Potential salt production was expected to be more than 400,000 tons per year. The company had acquired by a combination of purchase and lease in mid-1964 approximately 9,000 acres of land on Bonaire for producing salt.

SOUTH AMERICA

Brazil.—Salt for domestic, agricultural, and industrial uses in Brazil is produced entirely by solar evaporation principally in the Rio Grande do Norte and Cabo Frio areas. A detailed report on the salt industry in Rio Grande do Norte area was published. [3] A shortage, partly attributed to climatic conditions that lowered production, necessitated increased imports to supply the country's growing requirements.

Peru.—The Minera Bayovar S. A. was incorporated in midyear and received an exploitation contract from the Peruvian Government for mining concessions for salt, phosphate, potash, and other nonmetallics in the Sechura Desert in northern Peru. The company is authorized to produce salt and may export it after fulfilling the needs of the domestic market. Work was underway on port facilities, a powerplant, and evaporation pond systems.

EUROPE

Denmark.—A new salt plant was being built at the mouth of the Mariager Fjord in North Jutland, Denmark, by Dansk Salt I/S, a joint venture of KZK of Holland and the Danish company, Kryolit-selksabet Oresund A/S. The plant, which will have an annual capacity of 165,000 short tons, was scheduled for completion in mid-1966. Most of the salt output is intended for domestic Danish consumption with the remainder going to other Scandinavian countries.

U.S.S.R.—Work was begun near Tyret in the Irkutsk region of Eastern Siberia on what was reported to be the largest Soviet salt mine. The designated capacity of the plant was 2 million tons per year, and reserves of salt were estimated to be sufficient for 100 years of mining at this rate.

United Kingdom.—The quantity of salt used in England and Wales for the ammonia-soda process or for electrolysis to chlorine and caustic soda rose from 2 million tons pre-World War II to about 4.5 million tons per year in 1965. Production of common salt by the open-pan process dropped from 600,000 tons per year to 125,000 tons per year; output by the vacuum pan process increased from about 300,000 tons per year to 1,250,000 tons per year; and production of rock salt increased substantially from 20,000 tons per year before World War II to 500,000 tons per year in 1965.

By the close of the year, the Irish Salt Mining Exploratory Co., associated with U.S. interests, had expected to complete the reopening of the old Tennent salt mine at Carrickfergus, Northern Ireland. Most of the salt output was to be exported to the United States.

Yugoslavia.—Exploitation of the only underground rock salt deposit in Yugoslavia, at Tusanj, near Tuzla, was delayed because of water seepage into the main shaft. The Tusanj mine was planned for an exceptionally high degree of mechanization in all phases of operations. The loaders, shuttle cars, compressors, and rock drills will be of U.S. manufacture.

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[2] Bureau of Mines. Mineral Trade Notes. V. 61, No. 1, July 1965, pp. 38–40.

[3] Bureau of Mines. Mineral Trade Notes. V. 60, No. 2, February 1965, pp. 32–34.

Table 14.—World production of salt by countries [1]

(Thousand short tons)

Country [1]	1961	1962	1963	1964	1965 p [2]
North America:					
Canada	3,304	3,665	r 3,701	r 3,982	4,579
Costa Rica	e 13	e 10	7	22	2
El Salvador	17	20	r 79	r 180	e 180
Guatemala (sales)	18	19	21	r 20	e 20
Honduras	17	11	e 11	e 11	e 11
Mexico	1,172	1,424	1,350	1,965	2,425
Nicaragua	13	10	18	19	20
Panama	9	11	11	12	e 11
United States (including Puerto Rico):					
Rock salt	6,439	7,726	8,345	8,554	9,810
Other salt:					
United States	19,268	21,081	22,296	23,069	24,877
Puerto Rico	------	------	8	5	8
West Indies:					
British:					
Bahamas	230	222	283	370	e 524
Leeward Islands	[3] 1	[3] 1	r 7	r [3] 3	8
Turks and Caicos Islands	33	23	r 30	r 9	e 9
Cuba	e 66	e 77	e 88	NA	NA
Dominican Republic:					
Rock salt	r 2	35	25	84	1
Other salt	e 11	11	e 11	22	e 11
Haiti	11	e 11	e 11	e 11	11
Netherlands Antilles	(4)	(4)	(4)	(4)	e 2
Total	30,717	34,357	r 36,302	r 38,245	42,509
South America:					
Argentina:					
Rock salt	2	2	r 3	2	e 2
Other salt	459	r 613	r 300	r 431	e 430
Brazil	r 1,014	1,367	1,315	831	1,238
Chile	51	56	53	r 101	110
Colombia:					
Rock salt	294	293	r 292	319	309
Other salt	77	43	37	56	51
Ecuador	r 29	29	e 39	e 39	e 39
Peru	96	104	96	r 147	137
Venezuela	147	160	84	r 224	e 110
Total [1]	r 2,169	r 2,667	r 2,219	r 2,150	2,426
Europe:					
Austria:					
Rock salt	3	6	6	1	1
Other salt	280	313	r 373	r 370	445
Bulgaria	139	164	116	r 90	e 88
Czechoslovakia	207	201	206	203	215
France:					
Rock salt and salt from springs	3,260	r 3,297	3,405	r 3,573	e 3,373
Other salt	979	1,397	667	r 872	e 882
Germany:					
East	2,204	e 2,200	e 2,200	e 2,200	e 2,200
West (marketable):					
Rock salt	4,791	5,027	r 5,769	r 5,957	6,318
Brine salt	376	381	r 400	r 440	565
Greece	131	127	r 91	r 112	e 99
Italy:					
Rock salt and brine salt	r 1,791	r 1,908	r 2,086	r 2,240	2,347
Other salt	1,340	1,293	r 1,022	r 1,218	1,221
Malta	2	2	2	e 2	3
Netherlands	1,228	1,391	1,630	1,759	1,882
Poland:					
Rock salt	670	671	711	728	2,533
Other salt	1,591	1,616	r 1,639	1,743	
Portugal	r 375	429	383	r 354	e 353
Rumania	1,466	1,628	1,804	1,994	2,222

See footnotes at end of table.

Table 14.—World production of salt by countries[1]—Continued

(Thousand short tons)

Country[1]	1962	1961	1963	1964	1965 p[2]
Europe—Continued					
Spain:					
Rock salt	677	690	771	r 808	750
Other salt[5]	1,086	1,118	1,101	r 2,121	1,213
Switzerland	173	185	211	201	249
U.S.S.R. e	8,300	9,400	9,650	r 10,150	10,500
United Kingdom:					
Rock salt	320	535	842	776	810
Other salt	6,031	6,164	6,317	6,659	6,906
Yugoslavia	177	237	184	203	192
Total e 1	r 37,600	r 40,380	r 41,590	r 44,775	45,370
Africa:					
Algeria	r 142	r 130	r 137	r 128	e 128
Angola	74	66	76	89	65
Cape Verde Islands	26	30	32	r 35	e 35
Chad, Republic of (Natron) e	13	28	28	8	11
Congo, Republic of the (Kinshasa, formerly Léopoldville)	1	1	(4)	r 1	1
Ethiopia (including Eritrea)[8]	166	218	281	290	207
Ghana	20	21	------	34	30
Kenya	25	21	r 19	r 30	56
Libya	13	17	21	14	------
Malagasy Republic	e r 154	e r 154	r 220	r 320	160
Mauritius	4	4	4	4	4
Morocco	23	31	41	67	37
Mozambique	r 24	31	r 44	------	------
Senegal, Republic of (including Mauritania)	49	53	66	62	e 50
Somali Republic	2	e 2	2	7	6
South Africa, Republic of	229	281	218	331	365
South-West Africa:					
Rock salt	4	4	6	r 6	6
Other salt	56	78	66	r 103	101
Sudan	58	r 64	41	r 66	57
Tanzania	36	33	37	36	e 39
Tunisia (sales)	r 179	r 187	r 340	236	392
Uganda	8	3	3	3	3
United Arab Republic (Egypt)	570	r 371	432	744	545
Total	r 1,876	r 1,828	r 2,114	r 2,614	2,298
Asia:					
Aden	94	86	95	r 100	79
Afghanistan:					
Rock salt	r 25	r 34	23	14	20
Other salt			13	13	22
Burma	138	170	177	140	e 150
Cambodia	60	e 44	------	------	------
Ceylon	39	51	25	r 57	86
China, Mainland e	12,100	11,000	11,600	r 11,000	14,300
Cyprus	2	7	8	------	6
Goa	e 8	11	e 11		5,184
India:				5,122	
Rock salt	4	6	5,003		
Other salt	3,833	4,278			
Indonesia	493	335	e 335	e 335	e 331
Iran[6]	160	297	380	e 380	e 380
Iraq[7]	42	42	r 34	e 44	e 66
Israel	49	50	57	e 55	61
Japan	r 936	969	r 823	r 984	935
Jordan	21	21	20	22	22
Korea:					
North	432	464	e 500	e 440	e 550
South	134	428	254	425	737
Lebanon	19	e 18	21	22	26
Mongolia e	8	9	9	9	9
Pakistan:					
Rock salt	222	r 215	267	217	299
Other salt	207	r 280	234	r 204	240
Philippines	103	106	77	52	248
Ryukyu Islands	4	4	4	r 6	4
Saudi Arabia	------	------	11	e 11	e 11
Syrian Arab Republic	8	20	17	r 20	e 17
Taiwan	480	656	690	664	631
Thailand	r 214	r 284	r 293	e 275	e 110

See footnotes at end of table.

Table 14.—World production of salt by countries[1]—Continued

(Thousand short tons)

Country [1]	1961	1962	1963	1964	1965 [p 2]
Asia—Continued					
Turkey:					
Rock salt	33	31	33	36	39
Other salt	r 499	r 462	406	355	505
Viet-Nam:					
North	117	159	141	e 165	e 165
South	110	213	141	r 99	e 105
Yemen	132	165	e 110	e 39	-----
Total e	r 20,725	r 20,915	r 21,810	r 21,305	25,340
Oceania:					
Australia	570	600	r 651	r 611	e 610
New Zealand	6	10	12	24	39
Total	576	610	r 663	r 635	e 650
World total e	r 93,660	r 100,760	104,700	r 109,720	118,590

e Estimate. p Preliminary. r Revised. NA Not available.
[1] Salt is believed to be produced in Albania and Bolivia, data not available. No estimates included in the total.
[2] Compiled mostly from data available July 1966.
[3] Exports.
[4] Less than ½ unit.
[5] Includes an average annual production in the Canary Islands of 15,000 metric tons of sea-salt.
[6] Year ended March 20 of year following that stated.
[7] Year ended March 31 of year following that stated.
[8] Year ended September 10 of year stated.

ASIA

Saudi Arabia.—A mile-wide pool of hot salty water was discovered at the bottom of the Red Sea between Jidda, Saudi Arabia, and Port Sudan, Sudan. The hot brine taken at a depth of 7,200 feet was eight times more salty than normal Red Sea water. British scientists who discovered the pool believe that the dissolved salt acts as a baffle, holding the heat that usually escapes from the center of the earth in the form of upward and outward convection currents.

Syrian Arab Republic.—Ibrahim al-Lahham, Director of the Authority for the Execution of Industrial Projects of the Ministry of Industry, announced in May that tenders would be issued within several months for the exploitation of rock salt deposits in Syria. No further announcement was made by the close of the year.

Yemen.—Negotiations were reported underway to resume exports to Japan from a rock salt deposit at Salif in the northern Tihama of Yemen. Virtually no salt has been exported from Salif since a Japanese contract was terminated in early 1964 and since an agreement was made in mid-1964 to establish a $1.8 million salt-producing and marketing company, which was to be owned 51 percent by Yemen and 49 percent by the United Arab Republic (Egypt).

OCEANIA

Australia.—Leslie Salt Co. announced plans for constructing a 2-million-ton-per-year solar-salt-producing facility near Port Hedland adjacent to the iron ore project in the Hamersley Range in the northwest of Australia. The output of the salt plant will be exported from Port Hedland to Japan as will the iron ore and will double the annual salt production in Australia.

Leakage of brine from ponds causing a loss of salt output at its 400,000 ton-per-year solar-salt-producing operation at Dry Creek in South Australia caused concern to the Imperial Chemical Industries of Australia and New Zealand (ICIANZ). A determination was made that shellgrit in the 6-foot-high earth banks separating the salt ponds causes them to become porous and allows a significant loss of salt solution each year. ICIANZ was conducting field and laboratory tests to determine ways to rectify this problem.

TECHNOLOGY

The "Second Symposium on Salt", sponsored by the Northern Ohio Geological Society, was held in Cleveland, Ohio, May 3 to 5. More than 350 persons from the United States; 50 from Canada; and 25 from 12 other countries including Australia, South Africa, West Germany, and Israel shared technical information on salt. Papers were presented on the geology of salt deposits, mining rock salt, solution mining of salt, underground storage of hydrocarbons in salt caverns, evaporating salt, and rock mechanics in mining salt. The most advanced salt-mining and salt-processing techniques such as long room section mining in salt domes, salt haulage by electric versus diesel truck, and methods for developing predetermined shaped cavities in solution mining were described. Publication of the proceedings of the symposium was scheduled for 1966.

A new process proved successful in cementing a large-diameter casing in a salt stock in the Tatum Salt Dome near Hattiesburg, Miss. The process showed possible application to sinking salt mine shafts and to solution mining salt.[4] The process involved the use of expanding cement and chemical grout to seal the salt stock from overlying aquifers in the primary cementing of a 20-inch diameter casing in a 28-inch hole for Project Dribble, code name for a series of tests being conducted by the Atomic Energy Commission. As the casing size increases the usual problems in cementing casing in a drilled hole increase greatly. Expansion and contraction of the casing caused by pressure and temperature changes become critical with large-diameter casing and must be controlled to some degree if satisfactory bonding is obtained. Careful preplanning and engineering, as well as use of the new materials, led to the success of this operation.

An epoxy compound capable of curing on wet surfaces was used effectively to stop water flowing through damaged concrete liners in shaft sinking operations by Carey Salt Co. a Cote Blanche. La., near the Gulf of Mexico.[5] The damaged areas were covered with an epoxy layer that varied from ¼ to ½ inch in thickness. According to the manufacturer of the epoxy, 1 inch of the hardened compound is equal in strength and water resistance to 10 inches of concrete.

Based on 3 years of field tests, one company reported that additives to rock salt for use on highways to remove ice and snow reduced the rusting of automobiles by as much as 84 percent and cost only $4.00 more per ton than untreated salt.[6] The additives, comprising less than 1 percent of the weight of the product, were reported to inhibit rust by hampering the electrochemical reaction that is the key to the corrosion of iron. In the presence of moisture, cathodic and anodic areas are set up on the surface of the metal that trigger corrosion. The additives were reported to protect these areas separately—the cathodic areas with a film, the anodic areas by a catalytic reaction.

Pilot production tests were made by the Canadian Rock Salt Co. on color separators to sort and reject anhydrite waste from salt to upgrade the product from its Ojibway salt mine near Windsor, Ontario.[7] The color sorting principle was widely used in the food-processing industry, but it was only recently introduced as a potential tool for the mineral-processing industries. The impure salt going to the pilot plant machines was sized to minus ⅝ inch and plus ½ inch and fed onto a grooved belt, which threw the material in a steady stream through the optical box's viewing zone. Here the particles were uniformly illuminated by diffused light and inspected from four sides by photomultiplier units. The quantity of light reflected from the salt particles was compared with that of a standard reflection. Since impurity darkened the color of halite and caused it to have diminished reflectivity, the falling

[4] Dellinger, Thomas B., and L. D. Boughton. Unique Materials Mix Used to Seal Large Diameter Casing in Borehole. Eng. and Min. J., V. 166, No. 6, June 1965, pp. 114–118.

[5] Engineering News-Record. Epoxy Seals Leaking Salt Mine Shaft. V. 175, No. 21, Nov. 18, 1965, p. 119.

[6] Chemical & Engineering News. Treated Salt Removes Snow While Reducing Auto Corrosion. V. 43, No. 10, Mar. 8, 1965, pp. 70, 72.
Chemical Week. Balm for Salt's Sting? V. 96, No. 10, Mar. 6, 1965, pp. 33–34.

[7] Engineering and Mining Journal. Canadians Try Color Sorter for Upgrading Rock Salt. V. 166, No. 12, December 1965, p. 86.

contaminated particles changed the output voltage of at least one of the photomultipliers. This electronically amplified signal finally triggered a high-speed air valve, and the impure particles were blasted from the falling stream of material. This resulted in a final concentrate that, according to the company, was 99.98-percent soluble and was an 80-percent recovery of the pure halite pieces.

A process was patented for preventing blue coloration of sodium chloride treated with ferrocyanide or ferricyanide compounds, anticaking agents. The color-inhibiting agents selected were hydroxides of alkaline earth metals, magnesium and aluminum.[8]

A patent was issued for a process for the production of sodium chloride of relatively low-bulk density from salt of high-bulk density by foaming a stabilized solution of granular salt and drying and grinding the foam.[9]

Another process was patented for the preparation of sodium chloride that has a low-bulk density. An aqueous mixture of sodium chloride and a binding agent are inflated. The binding agent is a gelatin or a gluten with an inflating gas, like carbon dioxide, which is chemically inert with respect to the mixture. The foamed mass is then dried.[10]

An apparatus and method were patented for dissolving rock salt and separating calcium sulfate and other impurities therefrom in the production of brine. In this process, the salt is washed with a high-velocity free-flowing solvent to remove the impurities.[11]

A process was patented to produce culinary salt that has reduced prooxidant properties. The process involves treating a sodium chloride brine, from which the salt is recovered, with a small percentage of ethylenediaminetetracetic acid.[12]

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[8] Schultze, Martin, and Karl-August Hölscher (assigned to Deutsche Solvay-Werke Gesellschaft mit beschrankter Haftung, Solinger-Ohligs, West Germany). Process of Preventing Blue Colouration in Sodium Chloride Treated with Ferro- or Ferricyanide Compounds. U.S. Pat. 3,188,172, June 8, 1965.

[9] Saunders, James (assigned to Cerebos Limited, London). Method of Producing Foamed Sodium Chloride of Low Bulk Density. U.S. Pat. 3,196,024, July 20, 1965.

[10] Cooke, Edward Graham (assigned to Imperial Chemical Industries Ltd., London). Preparation of Sodium Chloride Having Very Low Bulk Density. U.S. Pat. 3,197,277, July 27, 1965.

[11] Miller, H. C. (assigned to Morton Salt Co., Chicago, Ill.). Apparatus and Method of Producing Brine. U.S. Pat. 3,168,379, Feb. 2, 1965.

[12] Miller, F. G., and E. A. Dittmar (assigned to Morton Salt Co., Chicago, Ill.). Process for Preparing Culinary Salt. U.S. Pat. 3,197,608, Aug. 3, 1965.

Sand and Gravel

By William R. Barton [1]

Production of sand and gravel increased again in 1965. Output gained 5 percent and total value 7 percent compared with 1964 figures. Industrial use of higher priced sands burgeoned as sales increased 9 percent over those of 1964.

For the first time in 1965, more than 900 million tons of sand and gravel was sold or used by United States producers.

[1] Commodity specialist, Division of Minerals.

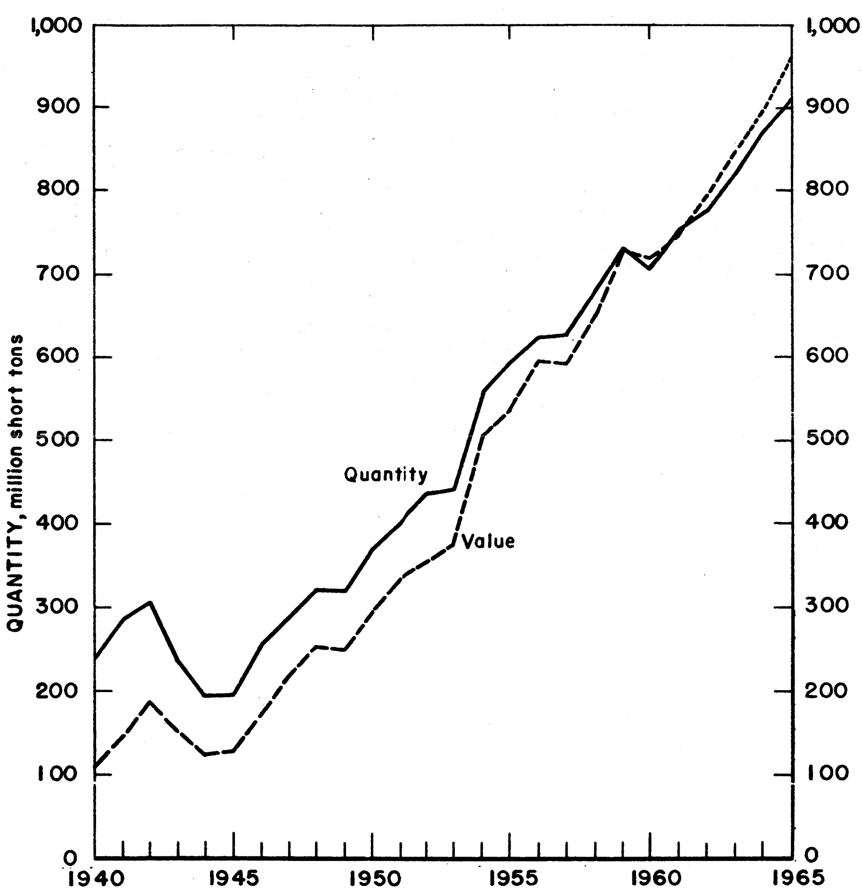

Figure 1.—Production and value of sand and gravel in the United States.

Legislation and Government Programs.—Laws affecting development of sand and gravel deposits on public lands were the subject of discussion and several congressional bills.[2] A Public Land Law Review Commission Advisory Council was organized to study existing public land law, its administration and interpretation. Legal problems concerning the public land sand and gravel deposits will be included in the scope of this study.

Homeowners and farmers continued to institute actions against sand and gravel operators in some areas. However, the courts and zoning bodies are increasingly finding in favor of the aggregate producers.[3] Increased awareness of civic responsibility on the part of aggregate producers has also helped alleviate potential zoning or land use conflicts. An example of sand and gravel production being not only acceptable but beneficial was an agreement signed in Illinois where waste overburden and tailings from an aggregate operation will be used to cover an adjacent city dump.[4]

[2] Stearn, E. W. New Hope for Aggregate Producers: Unlocked Public Lands! Rock Products, v. 68, No. 10, October 1965, p. 97.
[3] Rock Products. Board Finds Quarrying Operations Safe. V. 68, No. 2, February 1965, p. 125.
———. Ohio Sand Firm Wins Zoning Dispute. V. 68, No. 9, September 1965, p. 136.
[4] Rock Products. Martin Marietta Gets O.K. for Chillicothe Quarry. V. 68, No. 11, November 1965, p. 18.

Table 1.—Sand and gravel sold or used by producers in the United States, by classes of operations and uses
(Thousand short tons and thousand dollars)

Classes of operations and use	1964 Quantity	1964 Value	1965 Quantity	1965 Value
Construction:				
Building:				
Sand	144,045	$148,821	149,920	$158,296
Gravel	120,274	153,703	123,671	158,052
Paving:				
Sand	119,930	110,797	124,730	118,465
Gravel	r 344,460	r 330,984	341,351	338,351
Fill:				
Sand	30,575	16,896	43,612	23,076
Gravel	61,267	33,602	74,747	55,014
Railroad ballast:				
Sand	379	291	302	194
Gravel	3,544	2,838	2,640	2,062
Other:				
Sand	8,429	6,989	8,782	7,679
Gravel	6,194	7,398	7,997	9,580
Total construction	r 839,097	r 812,319	877,752	870,769
Industrial sand:				
Unground:				
Glass	7,638	24,414	8,228	26,154
Molding	8,988	24,240	9,831	26,319
Grinding and polishing	989	1,798	958	1,744
Blast sand	1,087	4,517	1,071	3,991
Fire or furnace	584	1,190	592	1,337
Engine	869	1,780	905	1,927
Filtration	163	438	261	520
Oil hydrafrac	384	2,219	259	1,830
Other	1,395	3,577	1,650	5,283
Total unground	22,097	64,173	23,755	69,105
Ground [1]	1,186	10,162	1,636	11,238
Total industrial	23,283	74,335	25,391	80,343
Miscellaneous gravel	5,828	6,721	4,911	6,310
Grand total	r 868,208	r 893,375	908,054	957,422
Commercial:				
Sand	283,283	325,912	297,413	348,878
Gravel	r 337,538	r 373,422	358,471	397,780
Government-and-contractor: [2]				
Sand	43,358	32,217	55,324	39,175
Gravel	204,029	161,824	196,846	171,589

r Revised.
[1] See table 10 for use breakdown.
[2] Approximate figures for operations by States, counties, municipalities, and other Government agencies under lease.

Table 2.—Sand and gravel sold or used by producers in the United States [1]
(Thousand short tons and thousand dollars)

Year	Sand Quantity	Sand Value	Gravel Quantity	Gravel Value	Total Quantity	Total Value
1956–60 (average)	249,542	$264,823	427,107	$394,753	676,649	$659,576
1961	283,336	303,549	468,448	447,752	751,784	751,301
1962	299,757	328,563	476,944	466,162	776,701	794,725
1963	313,978	338,500	507,872	508,772	821,850	847,272
1964	326,641	358,129	r 541,567	r 535,246	r 868,208	r 893,375
1965	352,737	388,053	555,317	569,369	908,054	957,422

r Revised.
[1] Includes possessions and other areas administered by the United States (1956 only).

DOMESTIC PRODUCTION

The 1965 output of 908 million tons of sand and gravel valued at $957 million represented an increase of 5 percent in tonnage and 7 percent in value over that of 1964. California's production of 118 million tons made it the leading producer State followed in order of rank by Michigan, Ohio, New York, and Wisconsin. The sand and gravel produced in these five leading States represented 32 percent of the total U.S. production. The high rate of sustained sand and gravel production has caused increased interest in adequacy of United States reserves.[5] In general, insufficient detail is available to fully evaluate the resource posture of these commodities. However, the record 1965 production of more than 900 million tons for sand and gravel caused concern about the rate of resource depletion. The first billion ton–billion dollar year will be realized soon, possibly by 1968.

Sand and gravel production was distributed 72 percent by commercial operators and 28 percent by Government-and-contractor, the same as in 1964. In 1965, 84 percent of sand and gravel was reported as processed, compared with 85 percent in 1964. The degree of processing was not specified, but the trend has been toward continually more complex treatment to meet more demanding product specifications. Numerous modern plants, stressing efficiency and flexibility were described in the literature.[6]

The trend toward more efficient production equipment was paralleled in transportation equipment. One new rig for highway hauling of aggregates weighs 77 tons loaded and features 11 axles, 42 tires, and a 12-speed transmission. Aggregate producers shipping their product by barge were concerned over proposals for a 2-cent-per-gallon fuel tax on vessels using inland waterways. It was feared that resultant cost increases would have to be passed on to consumers.[7]

Employment and Productivity.—In 1965, productivity was 9.1 tons per man-hour compared with 8.6 tons in 1964. This continued the trend of improved production efficiency reported each year.

[5] Davison, E. K. Are the Sand and Gravel Reserves of the United States Adequate for Future Needs? National Sand and Gravel Association, Report PR–018, Mar. 30, 1965, 4 pp.

[6] Bergstrom, J. H. Con Rock's New Durbin Plant Is Tops in Efficiency. Rock Products, v. 68, No. 4, April 1965, pp. 44–51.

———. Arvin Rock: A Gravel Plant Designed for Expansion. Rock Products, v. 68, No. 10, October 1965, pp. 68–70.

Herod, B. C. Small Plant Reflects Big Plant Capability. Pit and Quarry, v. 58, No. 3, September 1965, pp. 97–100.

Pit and Quarry. New Arizona Sand & Rock Operation—An Industry Pacesetter. V. 58, No. 5, November 1965, pp. 94–99.

Rock Products. Plant Design Ideas. V. 68; No. 9, September 1965, pp. 66–84, 88–92, 94, 117, 120, and 122.

[7] Dorland, G. M. Threatened Water-Ways Fuel Tax Would Have Far-Reaching Effects. Rock Products, v. 68, No. 4, April 1965, pp. 70–71, 108, 110.

Table 3.—Sand and gravel sold or used by producers in the United States, by States and classes of operations

(Thousand short tons and thousand dollars)

State	1964						1965					
	Commercial		Government-and-contractor		Total		Commercial		Government-and-contractor		Total	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Alabama	5,650	$6,120	190	$71	5,840	$6,191	6,422	$7,195	--------	--------	6,422	$7,195
Alaska	4,401	4,121	21,688	14,367	26,089	18,488	5,256	5,600	25,010	$28,867	30,266	34,467
Arizona	10,244	12,138	7,872	8,730	18,116	20,868	7,554	9,229	7,364	7,392	14,918	16,621
Arkansas	8,637	10,990	3,157	3,846	11,794	14,836	9,559	12,001	3,247	3,835	12,806	15,836
California	96,871	113,337	16,124	15,996	112,995	129,333	97,270	115,804	21,040	20,423	118,310	136,227
Colorado	9,006	10,809	11,740	11,418	20,746	22,227	11,189	12,751	9,621	9,290	20,810	22,041
Connecticut	7,377	8,375	2,711	1,062	10,088	9,437	7,320	8,067	2,620	1,039	9,940	9,106
Delaware	1,282	1,280	--------	--------	1,282	1,280	1,545	1,441	--------	--------	1,545	1,441
Florida	6,911	6,039	509	388	7,420	6,427	6,863	6,094	435	283	7,298	6,377
Georgia	r 3,588	r 3,594	--------	--------	r 3,588	r 3,594	3,675	3,588	--------	--------	3,675	3,588
Hawaii	400	971	7	8	407	979	745	2,225	6	12	751	2,237
Idaho	2,871	3,111	6,711	5,580	9,582	8,691	2,811	3,520	9,340	9,678	12,151	13,198
Illinois	33,469	39,094	1,411	872	34,880	39,966	35,260	39,880	968	600	36,228	40,480
Indiana	23,683	21,400	733	411	24,416	21,811	24,159	21,817	708	403	24,867	22,220
Iowa	12,112	12,551	1,778	995	13,890	13,546	14,379	14,810	3,826	2,342	18,205	17,152
Kansas	10,227	7,788	2,741	1,320	12,968	9,108	9,960	7,494	2,584	979	12,544	8,473
Kentucky	6,184	6,040	376	257	6,560	6,297	6,316	6,025	426	307	6,742	6,332
Louisiana	13,228	14,959	366	294	13,594	15,253	14,024	16,306	274	99	14,298	16,405
Maine	2,276	1,636	11,276	4,827	13,552	6,463	2,210	1,694	15,084	6,137	17,294	7,831
Maryland	14,531	17,932	510	139	15,041	18,071	16,047	21,129	153	59	16,200	21,188
Massachusetts	14,782	14,781	6,559	2,013	21,341	16,794	13,091	13,452	9,050	2,720	22,141	16,172
Michigan	40,577	38,164	11,344	6,241	51,921	44,405	43,423	42,059	9,745	5,117	53,168	47,176
Minnesota	22,937	18,220	12,880	7,687	35,817	25,907	26,816	20,919	10,729	6,377	37,545	27,296
Mississippi	7,479	7,871	346	698	7,825	8,569	7,192	7,785	1,255	932	8,447	8,717
Missouri	10,761	12,762	722	618	11,483	13,380	11,229	12,954	839	781	12,068	13,735
Montana	2,764	2,883	13,253	14,957	16,017	17,840	3,333	3,344	8,715	10,243	12,048	13,587
Nebraska	10,234	11,416	4,407	4,332	14,641	15,748	10,421	12,174	1,572	1,523	11,993	13,697
Nevada	4,790	7,018	9,352	7,409	14,142	14,427	5,508	8,847	3,947	2,949	9,455	11,796
New Hampshire	2,883	2,925	5,885	2,071	8,768	4,996	3,421	3,043	7,163	2,516	10,584	5,559
New Jersey	17,658	27,077	3	2	17,661	27,079	17,387	28,645	2	1	17,389	28,646
New Mexico	4,660	6,000	4,121	4,160	8,781	10,160	5,696	6,445	6,067	5,685	11,763	12,130
New York	26,611	28,792	12,671	9,791	39,282	38,583	25,064	29,172	14,161	11,198	39,225	40,370
North Carolina	7,413	8,119	3,737	2,285	11,150	10,404	7,263	8,272	3,236	1,804	10,499	10,076
North Dakota	2,840	3,280	7,680	6,862	10,520	10,142	2,989	3,546	4,585	4,349	7,574	7,895
Ohio	37,521	45,475	250	92	37,771	45,567	40,724	49,218	128	87	40,852	49,305
Oklahoma	5,032	6,031	1,648	972	6,680	7,003	4,570	5,614	648	409	5,218	6,023
Oregon	9,355	11,660	8,898	13,498	18,253	25,158	10,253	12,817	11,547	20,032	21,800	32,849
Pennsylvania	16,169	26,357	30	57	16,199	26,414	18,470	29,540	32	66	18,502	29,606

See footnote at end of table.

Table 3.—Sand and gravel sold or used by producers in the United States, by States and classes of operations—Continued

(Thousand short tons and thousand dollars)

State	1964						1965					
	Commercial		Government-and-contractor		Total		Commercial		Government-and-contractor		Total	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Rhode Island	1,647	$1,613	--------	--------	1,647	$1,613	1,691	$1,811	--------	--------	1,681	$1,811
South Carolina	4,622	5,262	--------	--------	4,622	5,262	5,248	6,688	--------	--------	5,248	6,688
South Dakota	2,559	2,474	11,211	$11,167	13,770	13,641	2,610	3,027	11,388	$11,128	13,998	14,155
Tennessee	7,222	9,631	750	614	7,972	10,245	7,373	10,031	820	659	8,193	10,690
Texas	25,249	30,896	3,906	2,498	29,155	33,394	27,488	33,572	5,161	2,503	32,649	36,075
Utah	5,899	6,338	4,319	4,067	10,218	10,405	5,583	6,232	4,454	4,238	10,037	10,470
Vermont	1,210	1,312	554	182	1,764	1,494	1,417	1,437	667	233	2,084	1,670
Virginia	10,334	13,467	254	255	10,588	13,722	15,301	18,013	21	6	15,322	18,019
Washington	14,637	15,015	17,283	10,956	31,920	25,971	15,399	15,321	15,902	11,913	31,301	27,234
West Virginia	5,472	11,555	--------	--------	5,472	11,555	5,253	11,480	--------	--------	5,253	11,480
Wisconsin	22,378	18,174	11,970	6,521	34,348	24,695	25,669	20,552	13,082	7,155	38,751	27,707
Wyoming	2,178	2,481	3,454	3,455	5,632	5,936	3,448	3,978	4,548	4,395	7,996	8,373
Total	r 620,821	r 699,334	247,387	194,041	r 868,208	r 893,375	655,884	746,658	252,170	210,764	908,054	957,422
American Samoa	--------	--------	22	20	22	20	--------	--------	60	55	60	55
Panama Canal Zone	84	82	--------	--------	84	82	83	85	--------	--------	83	85
Puerto Rico	7,001	10,697	815	795	7,816	11,492	7,265	11,554	882	851	8,147	12,405

r Revised.

Table 4.—Sand and gravel sold or used by producers in the United States in 1965, by States, uses and classes of operations

(Thousand short tons and thousand dollars)

State	Sand, construction							
	Building				Paving			
	Commercial		Government-and-contractor		Commercial		Government-and-contractor	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Alabama	2,348	$2,266	-------	-------	717	$656	-------	-------
Alaska	147	408	10	$32	38	81	72	$252
Arizona	1,207	1,601	-------	-------	491	591	1,274	1,429
Arkansas	1,734	1,990	-------	-------	1,599	1,803	1,241	1,091
California	22,323	26,291	19	21	12,598	13,820	6,930	7,729
Colorado	2,087	2,444	4	4	775	896	963	934
Connecticut	1,975	2,309	-------	-------	1,578	1,497	108	38
Delaware	349	409	-------	-------	207	200	-------	-------
Florida	5,650	4,373	-------	-------	295	240	170	150
Georgia	2,854	2,231	-------	-------	304	263	-------	-------
Hawaii	649	2,004	-------	-------	29	59	4	10
Idaho	305	647	-------	-------	58	89	406	441
Illinois	6,149	5,532	-------	-------	5,184	4,583	293	165
Indiana	4,933	4,172	-------	-------	3,577	2,887	14	6
Iowa	2,609	2,559	-------	-------	2,470	2,446	474	248
Kansas	4,065	3,138	65	45	2,768	1,937	1,314	485
Kentucky	2,104	2,119	-------	-------	1,471	1,294	28	14
Louisiana	2,717	2,643	-------	-------	1,708	1,593	1	2
Maine	331	254	3	2	255	193	792	600
Maryland	4,094	5,390	-------	-------	2,157	3,277	5	2
Massachusetts	2,952	2,808	-------	-------	2,024	1,877	13	5
Michigan	6,469	4,726	74	33	5,377	4,697	1,699	790
Minnesota	4,454	3,461	7	4	1,670	1,111	2,036	1,083
Mississippi	889	783	7	7	1,245	1,094	35	10
Missouri	4,265	3,763	-------	-------	859	821	79	92
Montana	308	497	-------	-------	87	172	244	279
Nebraska	2,267	2,606	-------	-------	981	1,179	483	482
Nevada	700	1,484	27	27	238	402	72	63
New Hampshire	650	455	-------	-------	501	406	3,169	1,117
New Jersey	4,940	5,911	-------	-------	2,906	2,790	-------	-------
New Mexico	949	1,105	-------	-------	480	556	682	679
New York	8,418	10,073	92	138	4,644	5,004	618	433
North Carolina	2,551	2,133	-------	-------	913	858	1,498	768
North Dakota	325	392	-------	-------	202	224	1,702	1,462
Ohio	6,407	6,974	-------	-------	7,917	8,347	-------	-------
Oklahoma	1,758	1,628	-------	-------	812	785	263	119
Oregon	1,184	1,710	2	7	328	433	421	823
Pennsylvania	5,566	7,575	-------	-------	3,374	4,902	-------	-------
Rhode Island	401	435	-------	-------	204	184	-------	-------
South Carolina	2,628	1,713	-------	-------	418	199	-------	-------
South Dakota	420	503	([1])	1	200	249	2,772	2,773
Tennessee	2,344	3,372	-------	-------	1,040	1,550	22	31
Texas	9,376	9,873	2	2	3,096	3,709	475	231
Utah	1,101	1,234	5	5	407	414	215	233
Vermont	172	128	-------	-------	257	163	230	87
Virginia	2,046	2,518	-------	-------	4,476	4,009	-------	-------
Washington	2,138	2,201	1	2	1,099	993	1,302	884
West Virginia	1,505	1,947	-------	-------	444	772	-------	-------
Wisconsin	3,495	2,842	-------	-------	2,424	2,031	3,459	1,777
Wyoming	294	336	-------	-------	368	434	1,882	1,878
Undistributed	------	-------	-------	-------	-------	-------	-------	-------
Total	149,602	157,966	318	330	87,270	88,770	37,460	29,695
American Samoa	------	-------	60	55	-------	-------	-------	-------
Panama Canal Zone	------	-------	-------	-------	-------	-------	-------	-------
Puerto Rico	2,074	3,970	-------	-------	1,572	1,964	234	263

[1] Less than ½ unit.

Table 4.—Sand and gravel sold or used by producers in the United States in 1965, by States, uses and classes of operations—Continued

(Thousand short tons and thousand dollars)

State	Sand, construction—Continued									
	Railroad ballast (commercial)		Fill				Other [2]			
			Commercial		Government-and-contractor		Commercial		Government-and-contractor	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Alabama	-----	-----	17	$14	-----	-----	-----	-----	-----	-----
Alaska	-----	-----	5	4	16	$10	-----	-----	4	$4
Arizona	-----	-----	153	105	92	84	11	$9	-----	-----
Arkansas	-----	-----	W	W	-----	-----	W	W	-----	-----
California	2	$2	4,251	3,188	574	548	442	400	71	84
Colorado	-----	-----	127	87	24	29	-----	-----	-----	-----
Connecticut	-----	-----	302	152	-----	-----	W	W	18	13
Delaware	-----	-----	W	W	-----	-----	-----	-----	-----	-----
Florida	-----	-----	220	144	265	133	12	25	-----	-----
Georgia	36	37	32	14	-----	-----	-----	-----	-----	-----
Hawaii	-----	-----	-----	-----	-----	-----	-----	-----	2	2
Idaho	W	W	7	10	133	96	W	W	-----	-----
Illinois	W	W	W	W	-----	-----	W	W	-----	-----
Indiana	W	W	2,193	969	-----	-----	W	W	-----	-----
Iowa	-----	-----	1,064	632	22	8	W	W	-----	-----
Kansas	15	12	940	425	92	28	117	88	64	20
Kentucky	-----	-----	800	475	-----	-----	-----	-----	-----	-----
Louisiana	-----	-----	W	W	-----	-----	W	W	-----	-----
Maine	-----	-----	277	121	4,629	1,622	50	38	227	178
Maryland	-----	-----	W	W	-----	-----	W	W	1	(1)
Massachusetts	-----	-----	478	193	-----	-----	W	W	21	27
Michigan	W	W	3,265	1,484	1,224	400	W	W	102	41
Minnesota	5	5	855	317	123	42	W	W	36	12
Mississippi	-----	-----	23	4	999	426	W	W	-----	-----
Missouri	W	W	405	358	-----	-----	W	W	-----	-----
Montana	-----	-----	45	51	8	5	13	17	129	171
Nebraska	W	W	W	W	-----	-----	-----	-----	-----	-----
Nevada	W	W	22	16	5	5	W	W	-----	-----
New Hampshire	-----	-----	271	95	20	7	W	W	-----	-----
New Jersey	-----	-----	720	354	-----	-----	706	754	2	1
New Mexico	48	16	40	34	60	41	-----	-----	6	6
New York	-----	-----	649	356	2,851	1,177	644	561	502	243
North Carolina	W	W	231	119	387	241	24	17	694	277
North Dakota	-----	-----	186	194	-----	-----	-----	-----	-----	-----
Ohio	-----	-----	1,556	937	16	21	221	206	-----	-----
Oklahoma	-----	-----	525	209	61	45	W	W	-----	-----
Oregon	W	W	188	178	206	151	22	21	558	844
Pennsylvania	-----	-----	42	43	-----	-----	185	269	-----	-----
Rhode Island	-----	-----	W	W	-----	-----	W	W	-----	-----
South Carolina	-----	-----	27	17	-----	-----	-----	-----	-----	-----
South Dakota	-----	-----	39	30	-----	-----	-----	-----	7	6
Tennessee	-----	-----	29	19	-----	-----	W	W	-----	-----
Texas	-----	-----	523	204	40	20	205	185	40	7
Utah	-----	-----	68	43	-----	-----	1	2	-----	-----
Vermont	-----	-----	93	33	-----	-----	55	57	47	15
Virginia	W	W	2,129	788	-----	-----	W	W	-----	-----
Washington	-----	-----	777	499	2,486	1,821	W	W	9	15
West Virginia	-----	-----	31	41	-----	-----	-----	-----	-----	-----
Wisconsin	W	W	1,325	623	491	152	W	W	182	72
Wyoming	-----	-----	W	W	-----	-----	W	W	-----	-----
Undistributed	196	122	3,858	2,385	-----	-----	3,352	2,992	-----	-----
Total	302	194	28,788	15,964	14,824	7,112	6,060	5,641	2,722	2,038
American Samoa	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Panama Canal Zone	-----	-----	-----	-----	-----	-----	83	85	-----	-----
Puerto Rico	-----	-----	592	524	502	450	-----	-----	-----	-----

W Withheld to avoid disclosing individual company confidential data; included with "Undistributed."

[1] Less than ½ unit.

[2] Includes unspecified.

Table 4.—Sand and gravel sold or used by producers in the United States in 1965, by States, uses and classes of operations—Continued

(Thousand short tons and thousand dollars)

State	Sand, industrial (commercial)									
	Glass		Molding		Grinding and polishing		Blast		Fire or furnace	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Alabama	-----	-----	W	W	-----	-----	-----	-----	-----	-----
Alaska	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Arizona	-----	-----	-----	-----	-----	-----	W	W	-----	-----
Arkansas	W	W	W	W	-----	-----	W	W	-----	-----
California	869	$4,138	87	$399	-----	-----	225	$942	W	W
Colorado	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Connecticut	-----	-----	2	2	W	W	-----	-----	-----	-----
Delaware	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Florida	W	W	W	W	-----	-----	W	W	-----	-----
Georgia	W	W	W	W	-----	-----	W	W	-----	-----
Hawaii	-----	-----	-----	-----	-----	-----	11	23	-----	-----
Idaho	4	23	-----	-----	-----	-----	2	17	-----	-----
Illinois	1,861	4,041	1,029	3,075	W	W	W	W	-----	-----
Indiana	W	W	W	W	-----	-----	W	W	W	W
Iowa	-----	-----	W	W	-----	-----	W	W	-----	-----
Kansas	-----	-----	-----	-----	-----	-----	W	W	-----	-----
Kentucky	-----	-----	W	W	-----	-----	-----	-----	-----	-----
Louisiana	-----	-----	-----	-----	-----	-----	W	W	-----	-----
Maine	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Maryland	W	W	-----	-----	-----	-----	-----	-----	-----	-----
Massachusetts	-----	-----	W	W	-----	-----	W	W	-----	-----
Michigan	W	W	3,298	5,903	W	W	-----	-----	-----	-----
Minnesota	W	W	W	W	-----	-----	W	W	-----	-----
Mississippi	-----	-----	W	W	W	W	-----	-----	-----	-----
Missouri	511	1,259	W	W	W	W	W	W	-----	-----
Montana	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Nebraska	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Nevada	W	W	W	W	-----	-----	-----	-----	W	W
New Hampshire	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
New Jersey	843	3,139	1,740	5,454	-----	-----	151	699	W	W
New Mexico	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
New York	-----	-----	184	757	-----	-----	-----	-----	-----	-----
North Carolina	-----	-----	-----	-----	-----	-----	11	11	-----	-----
North Dakota	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Ohio	W	W	525	2,198	W	W	W	W	W	W
Oklahoma	W	W	W	W	-----	-----	W	W	-----	-----
Oregon	-----	-----	1	6	-----	-----	-----	-----	-----	-----
Pennsylvania	W	W	234	581	W	W	W	W	140	$406
Rhode Island	-----	-----	W	W	-----	-----	-----	-----	-----	-----
South Carolina	W	W	W	W	-----	-----	10	45	W	W
South Dakota	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Tennessee	W	W	301	906	W	W	-----	-----	26	51
Texas	W	W	W	W	-----	-----	W	W	3	5
Utah	-----	-----	3	7	-----	-----	1	4	W	W
Vermont	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Virginia	W	W	-----	-----	-----	-----	-----	-----	-----	-----
Washington	W	W	W	W	-----	-----	W	W	-----	-----
West Virginia	W	W	W	W	-----	-----	W	W	W	W
Wisconsin	W	W	879	2,251	-----	-----	15	44	-----	-----
Wyoming	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Undistributed	4,140	13,554	1,548	4,780	958	$1,744	645	2,206	423	875
Total	8,228	26,154	9,831	26,319	958	1,744	1,071	3,991	592	1,337
American Samoa	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Panama Canal Zone	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Puerto Rico	38	53	-----	-----	-----	-----	-----	-----	-----	-----

W Withheld to avoid disclosing individual company confidential data: included with "Undistributed."

Table 4.—Sand and gravel sold or used by producers in the United States in 1965, by States, uses and classes of operations—Continued

(Thousand short tons and thousand dollars)

State	Sand, industrial (commercial)—Continued									
	Engine		Filtration		Oil (hydraulic fracturing)		Other		Ground sand	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Alabama	W	W	56	$56	-----	-----	W	W	-----	------
Alaska	-----	-----	-----	-----	-----	-----	-----	-----	-----	------
Arizona	W	W	-----	-----	18	$196	12	$16	-----	------
Arkansas	-----	-----	-----	-----	-----	-----	W	W	W	W
California	42	$131	12	56	-----	-----	78	236	W	W
Colorado	W	W	W	W	-----	-----	W	W	-----	------
Connecticut	-----	-----	W	W	-----	-----	-----	-----	-----	------
Delaware	W	W	-----	-----	-----	-----	-----	-----	-----	------
Florida	W	W	W	W	-----	-----	97	95	-----	------
Georgia	-----	-----	W	W	-----	-----	W	W	W	W
Hawaii	-----	-----	-----	-----	-----	-----	3	17	-----	------
Idaho	-----	-----	2	14	-----	-----	1	8	-----	------
Illinois	W	W	W	W	W	W	W	W	W	W
Indiana	W	W	-----	-----	-----	-----	W	W	W	W
Iowa	-----	-----	-----	-----	-----	-----	-----	-----	-----	------
Kansas	40	65	W	W	W	W	2	3	-----	------
Kentucky	W	W	-----	-----	-----	-----	3	11	-----	------
Louisiana	-----	-----	-----	-----	-----	-----	-----	-----	W	W
Maine	4	6	-----	-----	-----	-----	1	2	-----	------
Maryland	-----	-----	-----	-----	-----	-----	W	W	-----	------
Massachusetts	-----	-----	W	W	-----	-----	W	W	-----	------
Michigan	W	W	-----	-----	-----	-----	W	W	W	W
Minnesota	W	W	-----	-----	W	W	-----	-----	W	W
Mississippi	-----	-----	-----	-----	-----	-----	-----	-----	-----	------
Missouri	W	W	W	W	-----	-----	W	W	W	W
Montana	-----	-----	-----	-----	-----	-----	-----	-----	-----	------
Nebraska	-----	-----	-----	-----	-----	-----	-----	-----	-----	------
Nevada	-----	-----	-----	-----	-----	-----	W	W	-----	------
New Hampshire	W	W	W	W	-----	-----	-----	-----	-----	------
New Jersey	W	W	W	W	-----	-----	138	608	191	1,513
New Mexico	-----	-----	-----	-----	-----	-----	2	1	-----	------
New York	23	34	9	15	-----	-----	-----	-----	3	$5
North Carolina	-----	-----	W	W	-----	-----	-----	-----	-----	------
North Dakota	-----	-----	-----	-----	-----	-----	-----	-----	-----	------
Ohio	W	W	W	W	-----	-----	W	W	W	W
Oklahoma	W	W	W	W	-----	-----	W	W	W	W
Oregon	18	26	-----	-----	-----	-----	-----	-----	-----	------
Pennsylvania	W	W	-----	-----	-----	-----	W	W	W	W
Rhode Island	-----	-----	-----	-----	-----	-----	-----	-----	-----	------
South Carolina	W	W	W	W	-----	-----	W	W	W	W
South Dakota	-----	-----	-----	-----	-----	-----	-----	-----	-----	------
Tennessee	1	2	-----	-----	-----	-----	W	W	-----	------
Texas	10	14	W	W	W	W	W	W	106	453
Utah	7	18	-----	-----	-----	-----	W	W	-----	------
Vermont	-----	-----	-----	-----	-----	-----	-----	-----	-----	------
Virginia	W	W	W	W	-----	-----	W	W	W	W
Washington	-----	-----	-----	-----	-----	-----	W	W	W	W
West Virginia	W	W	W	W	-----	-----	W	W	W	W
Wisconsin	W	W	W	W	3	15	-----	-----	W	W
Wyoming	-----	-----	-----	-----	-----	-----	-----	-----	-----	------
Undistributed	760	1,631	182	379	238	1,619	1,313	4,286	1,336	9,267
Total	905	1,927	261	520	259	1,830	1,650	5,283	1,636	11,238
American Samoa	-----	-----	-----	-----	-----	-----	-----	-----	-----	------
Panama Canal Zone	-----	-----	-----	-----	-----	-----	-----	-----	-----	------
Puerto Rico	-----	-----	-----	-----	-----	-----	-----	-----	-----	------

W Withheld to avoid disclosing individual company confidential data; included with "Undistributed."

Table 4.—Sand and gravel sold or used by producers in the United States in 1965, by States, uses and classes of operations—Continued

(Thousand short tons and thousand dollars)

State	Gravel, construction							
	Building				Paving			
	Commercial		Government-and-contractor		Commercial		Government-and-contractor	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Alabama	2,098	$2,590	-------	-------	559	$669	-------	-------
Alaska	163	512	5	$16	262	510	1,078	$3,579
Arizona	1,553	2,056	-------	-------	3,409	3,945	5,924	5,827
Arkansas	1,928	2,823	-------	-------	3,444	3,985	2,006	2,744
California	24,859	29,958	99	117	28,461	33,093	12,680	11,281
Colorado	2,834	3,656	125	125	5,112	5,427	7,878	7,657
Connecticut	1,380	2,336	7	3	1,064	1,055	2,438	955
Delaware	87	166	-------	-------	815	622	-------	-------
Florida	W	W	-------	-------	W	W	-------	-------
Georgia	W	W	-------	-------	W	W	-------	-------
Hawaii	2	3	-------	-------	51	119	-------	-------
Idaho	324	453	-------	-------	1,862	1,974	8,064	8,696
Illinois	7,185	6,360	-------	-------	9,667	9,302	675	435
Indiana	3,793	4,409	3	1	6,615	6,623	647	380
Iowa	1,257	2,043	15	8	6,149	6,071	3,315	2,078
Kansas	494	487	18	16	1,353	1,131	966	371
Kentucky	715	805	30	18	1,015	1,148	368	275
Louisiana	5,313	6,640	168	19	3,409	4,121	105	78
Maine	195	202	-------	-------	667	695	9,199	3,639
Maryland	2,848	5,361	-------	-------	2,207	3,017	57	20
Massachusetts	2,741	3,646	-------	-------	2,247	2,364	2,224	1,080
Michigan	5,436	7,406	103	56	17,696	14,969	6,265	3,707
Minnesota	3,319	4,896	7	4	13,786	8,962	8,202	5,165
Mississippi	1,272	1,456	-------	-------	3,130	3,721	27	10
Missouri	2,749	3,094	-------	-------	1,001	828	760	689
Montana	520	730	-------	-------	2,048	1,574	7,670	9,124
Nebraska	1,265	1,519	12	13	5,079	5,923	1,077	1,028
Nevada	947	1,704	25	25	2,612	3,706	3,633	2,636
New Hampshire	733	926	-------	-------	709	908	3,974	1,392
New Jersey	2,868	5,090	-------	-------	1,416	1,533	-------	-------
New Mexico	1,106	1,397	-------	-------	2,963	3,246	5,282	4,924
New York	4,512	6,507	-------	-------	3,476	4,239	5,672	6,373
North Carolina	1,169	1,888	-------	-------	1,765	2,101	657	518
North Dakota	363	538	8	8	1,193	1,606	2,875	2,879
Ohio	6,219	7,502	-------	-------	13,312	16,117	102	59
Oklahoma	101	174	-------	-------	154	128	310	214
Oregon	2,434	3,023	141	219	5,301	6,680	10,068	17,826
Pennsylvania	3,522	4,987	-------	-------	3,418	5,241	32	66
Rhode Island	490	660	-------	-------	232	227	-------	-------
South Carolina	W	W	-------	-------	W	W	-------	-------
South Dakota	305	364	66	55	1,547	1,796	8,543	8,293
Tennessee	1,140	1,367	-------	-------	1,874	1,677	683	520
Texas	8,792	10,842	-------	-------	4,257	5,403	4,487	2,196
Utah	1,205	1,275	462	322	2,304	2,661	3,485	3,489
Vermont	215	297	3	1	532	720	379	128
Virginia	1,738	3,285	-------	-------	3,647	5,929	6	2
Washington	3,561	4,034	1	4	4,948	5,022	5,958	5,884
West Virginia	1,209	1,515	-------	-------	858	1,452	-------	-------
Wisconsin	3,507	2,986	-------	-------	11,824	8,588	8,678	5,069
Wyoming	413	496	2	2	2,131	2,483	2,662	2,514
Undistributed	1,492	2,556	-------	-------	659	1,240	-------	-------
Total	122,371	157,020	1,300	1,032	192,240	204,551	149,111	133,800
American Samoa	-------	-------	-------	-------	-------	-------	-------	-------
Panama Canal Zone	-------	-------	-------	-------	-------	-------	-------	-------
Puerto Rico	1,442	2,772	-------	-------	971	1,792	21	30

W Withheld to avoid disclosing individual company confidential data; included with "Undistributed."

Table 4.—Sand and gravel sold or used by producers in the United States in 1965, by States, uses and classes of operations

(Thousand short tons and thousand dollars)

State	Gravel, construction—Continued										Gravel miscellaneous (commercial)	
	Railroad ballast (commercial)		Fill				Other					
			Commercial		Government-and-contractor		Commercial		Government-and-contractor			
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Alabama	----	----	W	W	-----	------	97	$145	----	----	W	W
Alaska	18	$29	4,618	$4,045	23,825	$24,974	----	----	----	----	5	$11
Arizona	W	W	548	535	66	48	W	W	8	$4	47	63
Arkansas	W	W	108	54	-----	------	W	W	----	----	25	7
California	132	134	1,768	1,648	456	456	657	666	211	187	451	535
Colorado	1	1	158	101	567	481	1	5	60	60	70	67
Connecticut	----	----	622	306	49	30	40	41	----	----	151	210
Delaware	----	----	W	W	-----	------	----	----	----	----	W	W
Florida	----	----	-----	-----	-----	------	----	----	----	----	----	----
Georgia	----	----	-----	-----	-----	------	----	----	----	----	----	----
Hawaii	----	----	-----	-----	-----	------	----	----	----	----	----	----
Idaho	W	W	154	182	732	443	W	W	5	2	W	W
Illinois	52	39	1,257	773	-----	------	33	34	----	----	----	----
Indiana	45	35	1,956	1,041	44	16	203	99	----	----	----	----
Iowa	W	W	498	330	-----	------	W	W	----	----	----	----
Kansas	----	----	36	34	10	5	105	129	55	9	13	14
Kentucky	W	W	161	89	-----	------	----	----	----	----	6	11
Louisiana	----	----	W	W	-----	------	W	W	----	----	W	W
Maine	31	10	257	111	231	95	67	30	3	1	75	32
Maryland	W	W	1,649	900	90	37	W	W	----	----	364	392
Massachusetts	W	W	1,172	678	6,777	1,579	W	W	15	29	366	337
Michigan	240	264	378	199	190	63	347	397	88	27	----	----
Minnesota	357	165	1,951	951	298	60	39	24	20	7	----	----
Mississippi	36	13	63	30	187	479	W	W	----	----	260	243
Missouri	166	65	W	W	-----	------	W	W	----	----	305	269
Montana	W	W	186	151	285	172	57	87	379	492	W	W
Nebraska	W	W	W	W	-----	------	----	----	----	----	50	61
Nevada	W	W	419	376	185	193	W	W	----	----	129	245
New Hampshire	----	----	367	119	-----	------	W	W	----	----	W	W
New Jersey	----	----	485	325	-----	------	198	233	----	----	22	25
New Mexico	20	24	88	66	37	35	----	----	----	----	----	----
New York	W	W	1,920	1,175	4,390	2,816	W	W	36	18	378	337
North Carolina	24	21	12	11	-----	------	----	----	----	----	523	1,075
North Dakota	321	201	397	390	-----	------	2	1	----	----	----	----
Ohio	3	2	2,054	1,184	10	7	1,275	1,876	----	----	375	665
Oklahoma	W	W	-----	-----	14	31	W	W	----	----	W	W
Oregon	W	W	540	366	93	54	35	49	58	108	W	W
Pennsylvania	W	W	321	200	-----	------	W	W	----	----	53	83
Rhode Island	----	----	W	W	-----	------	W	W	----	----	----	----
South Carolina	W	W	-----	-----	-----	------	----	----	----	----	W	W
South Dakota	32	38	57	38	-----	------	8	8	----	----	2	1
Tennessee	60	60	114	134	115	108	----	----	----	----	21	29
Texas	W	W	160	89	-----	------	245	339	117	47	W	W
Utah	2	1	84	68	287	189	----	----	----	----	375	469
Vermont	----	----	75	27	3	(1)	W	W	5	2	W	W
Virginia	----	----	744	375	15	4	30	45	----	----	71	60
Washington	190	142	1,947	1,400	5,918	2,951	521	494	227	352	105	157
West Virginia	W	W	21	26	-----	------	W	W	----	----	----	----
Wisconsin	196	111	1,690	721	267	83	142	111	5	2	----	----
Wyoming	W	W	W	W	2	1	----	----	----	----	41	29
Undistributed	714	707	569	356	-----	------	2,603	3,420	----	----	628	883
Total	2,640	2,062	29,604	19,604	45,143	35,410	6,705	8,233	1,292	1,347	4,911	6,310
American Samoa	----	----	-----	-----	-----	------	----	----	----	----	----	----
Panama Canal Zone	----	----	-----	-----	-----	------	----	----	----	----	----	----
Puerto Rico	----	----	567	479	125	108	----	----	----	----	----	----

W Withheld to avoid disclosing individual company confidential data; included with "Undistributed."
[1] Less than ½ unit.

Table 5.—Sand and gravel sold or used by Government-and-contractor producers in the United States, by uses

(Thousand short tons and thousand dollars)

Year	Sand							
	Building		Paving		Fill		Other	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1961	2,321	$3,331	32,243	$21,621	7,991	$3,256	435	$242
1962	1,759	3,287	30,163	21,444	7,482	3,016	1,267	605
1963	728	882	33,285	23,840	7,076	3,124	1,433	668
1964	950	1,401	34,262	26,999	6,335	2,935	1,811	882
1965	318	330	37,460	29,695	14,824	7,112	2,722	2,038

Year	Gravel								Total Government-and-contractor sand and gravel	
	Building		Paving		Fill		Other			
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1961	6,480	$9,372	148,572	$109,155	13,510	$4,547	677	$493	212,229	$152,017
1962	8,626	11,870	145,602	113,094	14,125	5,535	698	454	209,722	159,305
1963	4,110	4,091	157,671	132,829	26,379	21,476	497	366	231,179	187,276
1964	3,515	3,946	163,872	139,297	35,870	18,030	772	551	247,387	194,041
1965	1,300	1,032	149,111	133,800	45,143	35,410	1,292	1,347	252,170	210,764

Table 6.—Sand and gravel sold or used by Government-and-contractor producers in the United States,[1] by types of producer

(Thousand short tons and thousand dollars)

Type of producer	Quantity	Value	Quantity	Value	Quantity	Value
	1956–60 (average)		1961		1962	
Construction and maintenance crews	49,768	$26,565	54,030	$33,194	55,547	$31,216
Contractors	129,766	90,524	158,199	118,823	154,175	128,089
Total	179,534	117,089	212,229	152,017	209,722	159,305
States	107,598	69,743	127,004	94,111	129,314	95,787
Counties	47,819	28,114	46,932	30,334	49,590	29,656
Municipalities	3,278	2,127	6,357	3,335	3,236	2,679
Federal agencies	20,839	17,105	31,936	24,237	27,582	31,183
Total	179,534	117,089	212,229	152,017	209,722	159,305
	1963		1964		1965	
Construction and maintenance crews	57,546	$35,945	64,820	$41,451	62,822	$39,611
Contractors	173,633	151,331	182,567	152,590	189,348	171,153
Total	231,179	187,276	247,387	194,041	252,170	210,764
States	146,053	124,138	157,136	130,651	159,763	144,293
Counties	57,493	39,728	60,764	41,151	59,730	40,987
Municipalities	3,928	3,436	3,363	2,500	3,278	2,343
Federal agencies	23,705	19,974	26,124	19,739	29,399	23,141
Total	231,179	187,276	247,387	194,041	252,170	210,764

[1] Includes possessions and other areas administered by the United States (1956 only).

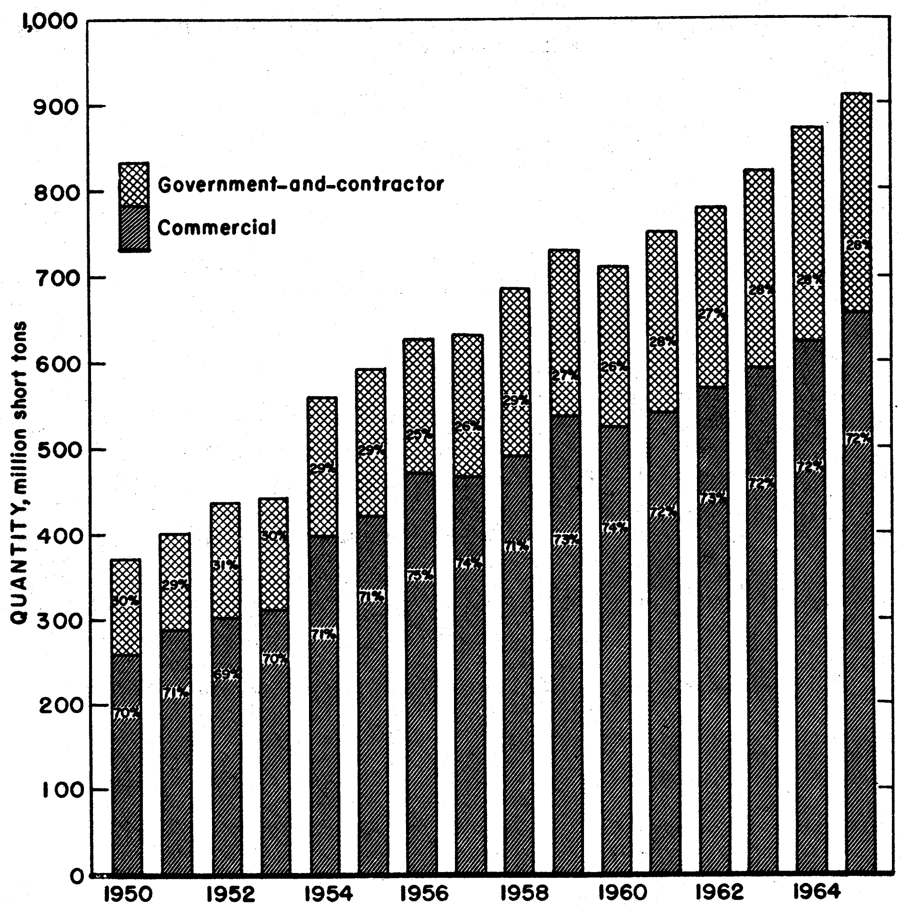

Figure 2.—Sand and gravel sold or used in the United States.

Table 7.—Sand and gravel sold or used by producers in the United States, by classes of operation and degrees of preparation

(Thousand short tons and thousand dollars)

	1964		1965	
	Quantity	Value	Quantity	Value
Commercial operations:				
Prepared	r 559,820	r $663,020	588,091	$704,802
Unprepared	61,001	36,314	67,793	41,856
Total	r 620,821	r 699,334	655,884	746,658
Government-and-contractor operations:				
Prepared	180,974	158,537	177,847	152,680
Unprepared	66,413	35,504	74,323	58,084
Total	247,387	194,041	252,170	210,764
Grand total	r 868,208	r 893,375	908,054	957,422

r Revised.

Table 8.—Number and production of domestic commercial sand and gravel plants, by size of operation

Annual production (short tons)	1964 Plant [1] Number	1964 Plant [1] Percent of total	1964 Production Thousand short tons	1964 Production Percent of total	1965 Plant [1] Number	1965 Plant [1] Percent of total	1965 Production Thousand short tons	1965 Production Percent of total
Less than 25.000	2,259	39.7	38,210	6.2	2,024	36.4	26,272	4.0
25,000 to 50.000	892	15.7	31,807	5.1	886	15.9	33,693	5.1
50,000 to 100 000	952	16.8	66,415	10.7	949	17.1	69,424	10.6
100.000 to 200.000	r 743	13.1	r 104,516	16.8	813	14.6	115,550	17.6
200.000 to 300.000	326	5.7	78,893	12.7	356	6.4	86,260	13.1
300.000 to 400.000	167	2.9	56,508	9.1	196	3.5	66,844	10.2
400.000 to 500.000	r 111	2.0	r 49,238	8.0	95	1.7	40,911	6.2
500.000 to 600.000	63	1.1	34,024	5.5	73	1.3	35,089	5.4
600.000 to 700.000	41	.7	26,469	4.3	32	.6	20,701	3.2
700.000 to 800.000	30	.5	22,501	3.6	26	.5	19,536	3.0
800.000 to 900.000	20	.4	15,018	2.4	26	.5	22,665	3.5
900.000 to 1.000.000	18	.3	16,898	2.7	15	.3	15,301	2.3
1,000,000 and over	61	1.1	80,324	12.9	69	1.2	103,638	15.8
Total	r 5,683	100.0	r 620,821	100.0	5,560	100.0	655,884	100.0

r Revised.
[1] Includes a few companies operating more than 1 plant but not submitting separate returns for individual plants.

Table 9.—Sand and gravel sold or used in the United States, by classes of operation and method of transportation

	1964 Thousand short tons	1964 Percent of total	1965 Thousand short tons	1965 Percent of total
Commercial:				
Truck	r 530,919	61	556,833	61
Rail	59,338	7	62,759	7
Waterway	28,198	3	33,573	4
Unspecified	2,366	(1)	2,719	(1)
Total commercial	r 620,821	71	655,884	72
Government-and-contractor: Truck: [2]	247,387	29	252,170	28
Grand total	r 868,208	100	908,054	100

r Revised.
[1] Less than 0.5 percent.
[2] Entire output of Government-and-contractor operations assumed to be moved by truck.

CONSUMPTION AND USES

Commercial production of building sand and gravel totaled 272 million tons valued at $315 million, compared with 260 million tons valued at $297 million in 1964. Use of sand and gravel for paving and fill increased and that for ballast decreased compared with 1964 figures. Unground industrial sand use increased in all categories except blast, grinding and polishing, and hydraulic fracturing. In ground sands, increases were reported in all user categories except abrasives and fillers. Total unground industrial sand sold or used increased 8 percent while the ground industrial sand total increased 3.8 percent compared with 1964 figures. Additional industrial silica raw material sold or used is reported in the Stone chapter of this yearbook under Crushed and Broken Sandstone, Quartz, and Quartzite.

Table 10.—Ground sand sold or used by producers in the United States,[1] by uses

(Thousand short tons and thousand dollars)

Use	1964		1965	
	Quantity	Value	Quantity	Value
Abrasives	218	$2,184	218	$2,072
Chemicals	18	164	34	198
Enamel	18	205	22	262
Filler	181	959	108	814
Foundry uses	172	1,414	293	2,077
Glass	152	775	182	943
Pottery, porcelain, and tile	230	2,467	243	2,549
Unspecified	197	1,994	536	2,323
Total	1,186	10,162	1,636	11,238

[1] Arkansas, California, Colorado (1964 only), Georgia, Illinois, Indiana, Louisiana, Michigan, Minnesota, Missouri, New Jersey, New York (1965 only), Ohio, Oklahoma, Pennsylvania, South Carolina, Texas, Virginia, Washington, West Virginia, and Wisconsin.

PRICES

The average value reported for commercially produced sand and gravel was $1.14 per ton compared with $1.13 per ton in 1964. Government-and-contractor producers reported an average value of $0.84 per ton compared with $0.78 per ton the previous year. Representative prices per ton for construction sand and gravel in various metropolitan centers are published each month in Engineering News-Record. In December, the following base prices were reported for typical cities:

	St. Louis	Denver	Atlanta	Philadelphia	Los Angeles
Gravel:					
1½-inch	$3.50	$2.05	$2.40	$1.65	$2.22
¾-inch	3.50	2.25	2.50	1.65	2.42
Sand	2.60	1.47	2.00	1.35	2.02

These sample cities clearly indicate the great diversity of prices from market to market depending on local demand, availability of supply, relation of available natural size fractions to demand for same, and abundance or suitability of competing aggregates.

In 1965 the average value per ton reported for unground industrial sands was $2.91 and for ground industrial sands $6.87. The actual selling prices range widely depending primarily upon physical and chemical specifications.

FOREIGN TRADE

As usual, the bulk of foreign trade in sand and gravel was with Canada. Exports to Canada were 1.5 million tons valued at $4.4 million; imports from Canada were 600,000 tons valued at $800,000. Imports of glass sand comprised of 10,687 tons valued at $35,974 from Viet-Nam, the balance being from Canada, Sweden, and Mexico.

Table 11.—U.S. imports for consumption of sand and gravel by classes

Year	Sand				Gravel		Total	
	Glass sand [1]		Sand, n.s.p.f., crude or manufactured					
	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value
1956–60 (average)	3,709	[2] $273,377	333,635	[2] $471,314	25,861	$25,574	363,205	[2] $770,265
1961	2	[2] 1,602	335,005	440,759	43,287	44,009	378,294	[2] 486,370
1962	31,416	63,950	307,637	414,703	29,198	31,948	368,251	510,601
1963	22,724	68,650	336,547	430,165	([3])	([3])	359,271	498,815
1964	40,308	127,639	443,213	558,178	([3])	([3])	483,521	685,817
1965	10,830	39,418	677,814	839,651	([3])	([3])	688,644	879,069

[1] Classification reads: "Sand containing 95 percent or more silica and not more than 0.6 percent oxide of iron, and suitable for manufacturing glass."
[2] Consists mainly of synthetically prepared silica from West Germany for specialized uses and is not comparable in value to ordinary glass sand.
[3] Sand, n.s.p.f. crude or manufactured and gravel no longer separately classified.

WORLD REVIEW

Australia.—A new plant at Gawler, South Australia, was described.[8] The installation produces washed sand and gravel at a rate of 65 tons per hour for use in concrete.

Canada.—Present trends in Canadian consumption of silica sands and availability of suitable resources were outlined.[9] Recently reported discoveries of silica sand resources included a deposit 40 miles northeast of Hearst in the Sault Sainte Marie mining division in Ontario and another a short distance north of Montreal in Quebec. Because most glass sand is imported from the United States, such newly discovered prospects are greeted with much interest. A new British Columbia gravel plant was described which featured improved processing systems that stressed flexibility to meet customer specifications.[10]

Malaysia.—Japanese teams have been surveying highgrade deposits of silica sand at Tulong and Muara in Brunei. The Brunei deposits were considered to represent an alternate source to the 200,000 tons of glass sand presently imported to Japan from South Viet-Nam.

United Kingdom.—Two leading British glass manufacturers (Pilkington Brothers Ltd. and United Glass Ltd.) have joined with a sand and gravel firm (United Gravel Co.) to form Sands Developments Ltd. which will search for and explore deposits of high-grade silica sand within the United Kingdom and elsewhere in western Europe. A new sand and gravel plant near Ludlow was described.[11] It produces washed, crushed, and graded gravel and concreting sand. Care in planning excavation was required due to proximity of the archaeological remains of an ancient Roman camp. The company will assist Birmingham University archaeologists in their site investigations. In addition, planning authorities stipulated that only a maximum of 6 acres of land could be out of use for agricultural purposes at any one time. Therefore, work is carried out in 3-acre blocks so that restoration to farm use on one block is completed before a third block is entered by mining operations.

An ultra-modern fluidized bed sand drying plant at Buckland was described.[12] The 40-ton per hour plant dries sand from a moisture content of 5 percent, splits it into three size gradings, and cools the product. Fully automated, only part-time attention from one operator is required.

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[8] Mining and Minerals Engineering (London). Australian Sand and Gravel Plant. V. 1, No. 15, November 1965, pp. 577–578.
[9] Collings, R. K. Silica Sand-Canadian Sources of Interest to the Domestic Glass Industry. Canada Dept. of Mines and Technical Surveys, Mines Branch, Tech. Bull. 69, April 1965, 9 p.
[10] Herod, B. C. British Columbia Gravel Plant Reflects Attention to Markets. Pit and Quarry, v. 58, No. 2, August 1965, pp. 82–85, 90.
[11] Mining and Minerals Engineering (London). Bromfield Sand and Gravel. V. 11, No. 14, October 1965, pp. 539–540.
[12] Mining and Minerals Engineering (London). Fluidized Bed Sand Drying at Buckland. V. 1, No. 11, July 1965, pp. 418–420.

TECHNOLOGY

The National Sand and Gravel Association received a merit award from the Soil Conservation Society of America for promoting the art and science of land rehabilitation. The Association sponsors a study program on how to restore depleted sand and gravel pits to beneficial use.

Numerous articles on mining and processing of sand and gravel were published. A new 800-ton-per-hour aggregate producing facility featured a centralized electronic control center.[13] All processing is done in a single, eight-story-high steel and concrete structure serviced by freight and passenger elevators and topped by a revolving crane with a 70-foot boom for maintenance services. Pit-to-plant and in-plant-material transport is either by belt conveyor or by gravity where possible in the 120-foot-high tower. A Florida operation can produce 240 tons per hour of bulk and bagged sands for such specialty purposes as blast sand, fillers, soil conditioner, and water filter media.[14] The sand is obtained from two pits featuring electric dredges with 8-inch rubber-lined pumps. The product is dried in a 4- by 20-foot, natural gas-fired rotary dryer. A new hydropneumatic method for deep dredging of unconsolidated mineral deposits was described.[15] The system was claimed to be effective at depths up to 300 feet and to be relatively free of blockages. The dredge requires ony one operator per shift.

Two methods of beneficiating contaminated sands or gravels were described. A modern version of the ancient art of jigging is used to oscillate shale out of gravel aggregates in Minnesota and for similar purposes elsewhere.[16] Shale content of the product is reduced to 0.2 percent or less. Jig tailings, representing about 3 percent of the original jig feed, average 2.5 to 3.0 percent shale. In the United Kingdom several companies have found the spiral concentrator to be an economical means of freeing sand from deleterious materials such as carbonaceous or calcareous impurities.[17] Such contaminants often resisted separation by more conventional means, such as vibrating screens or classifiers. The spiral also has advantages over a concentrating table in that it occupies a much smaller floor area per ton/hour capacity, has no moving parts, and requires no power except possibly for pumping. The effect of additions of bivalent lead upon sulfonate flotation of quartz and the mechanisms by which it is achieved was also reviewed.[18] Although clean quartz could not be floated by use of a high molecular weight sulfonate alone, good flotation was achieved from pH6 to 12 after the lead activator was added. Design and operation of scalping-classifying tanks were also described.[19] Such equipment performs three primary functions: (1) Removal of excess water from sand slurry; (2) elimination of unwanted size fractions; and (3) production of two or more gradations from the same feed. Many scalper classifiers have been fitted with automatic electronic devices which greatly increase quality control over products. A new European crest wave classifier offered high precision separation regardless of load or other variations.[20] The system uses the force of a stream of rising water to vertically separate finer and coarser grains.

The Bureau of Mines evaluated the performance of four types of sand flotation cones for washing coal.[21] In the sand flotation process, coal is floated in a fluid mixture of sand and water while slate and other impurities sink. The mixture is maintained in a fluid state by mechanical agitation and low-velocity upward currents of water. A new automatic steam autoclave process for making sand-lime brick was de-

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[13] Utley, H. F. Durbin-Crown Jewel of Conrock Plant Complex. Pit and Quarry, v. 58, No. 1, July 1965, pp. 80–88.

[14] Trauffer, W. E. Florida Sand Producer Makes Wide Variety of Products. Pit and Quarry, v. 58, No. 2, August 1965, pp. 86–87, 90.

[15] Cement, Lime and Gravel (London). High-Output Deep Dredging by Hydropneumatic Methods. V. 40, No. 7, July 1965, pp. 237–240.

[16] Levine, Sidney. Jigs Remove Shale at Northwestern Gravel. Rock Products, v. 68, No. 6, June 1965, pp. 72–75.

Macknight, D. E. Jiggins Aggregates. Rock Products, v. 68, No. 12, December 1965, pp. 53–55.

[17] Lissender, A. W. J. Decontamination of Sand. Cement, Lime and Gravel (London), v. 40, No. 7, July 1965, pp. 245–247.

[18] Fuerstenau, M. C., and S. Atak. Lead Activation in Sulfonate Flotation of Quartz. Trans. AIME, v. 232 (Min. Eng.), 1965, pp. 24–28.

[19] Bergstrom, J. H. What You Should Know About the Scalping-Classifying Tank. Rock Products, v. 68, No. 12, December 1965, pp. 47–51.

[20] Ironman, Ralph. European Sand Classifier Guarantees Tighter Grading. Rock Products, v. 68, No. 12, December 1965, p. 59.

[21] Duerbrouck, Albert W., and John Hudy. Performance Characteristics of Coal-Washing Equipment: Sand Cones. BuMines Rept. of Inv. 6606, 1965, 26 pp.

scribed.[22] The capital expenditure required was reported to be only 40 percent of that needed for a clay brick factory and only 1.3 man-hours of labor was needed to make 1,000 bricks notable for their high degree of product uniformity.

A two-part review was published on aggregates for use in concrete.[23] The articles featured sections on physical characteristics of aggregates, grading, impurities, beneficiation, alkali-aggregate reaction, and sampling and testing.

As aggregate specifications become steadily more rigorous, sampling and testing techniques are of increasing importance. A firm in Ohio uses a mobile laboratory to provide sampling services for sand and gravel operations at eight separate locations.[24] Random sampling to assure compliance with quality and grading requirements was discussed.[25] The paper described a statistically reliable sample method with an acceptable standard deviation. Several papers described methods of testing specific properties.[26]

Foundry sand practice, at one time essentially empirical, continued its recent history of rapid technological advance resulting from applied science and engineering. The influence of sand grain size and distribution on the properties of molding sands were discussed. The packing patterns which result from the grain characteristics primarily determine green strengths and rammed densities.[27] New no-bake binders and specialty resins continued to increase their share of an estimated $30 million a year United States binder market.[28] Ferrosilicone additives were also mentioned as an effective but relatively expensive way of obtaining an intense exothermic reaction to effect a self-cure in sodium silicate-sand mixtures. Lynchburg Foundry Company's installation of automatic equipment for resin coating of shell molding sand was described.[29] The foundry reported 40 percent resin savings by using the precoated sands over dry, powdered resin-sand mixes. Shorter cycle times on molding and coremaking machines were an ancillary benefit. Ford Motor Co.'s Specialty Foundry reduced new sand requirements 75 percent and concomitantly reduced old sand disposal problems the same amount by installing a new fluid bed shell sand reclamation system.[30] The system also eliminated the need for separate new sand drying equipment, lowered resin requirements, and increased salvage of backup shot. The key three-compartment reactor (calciner-cooler) was supplied by Dorr-Oliver, Inc. A summary of various types of reclamation systems was also published as a result of their many economically attractive features.[31] Both wet and dry systems were discussed as means of removing accumulated burned clay, carbonaceous materials, silica flour, and other impurities.

Two modern glass sand operations were described.[32] A plant at Ione, Calif., works a 70-foot thick sand deposit to supply a separation flowsheet featuring flotation cells and cyclones. A Newport, N.J., operation features a modern 12-inch hydraulic dredge capable of operating to 40-foot depths in quartz sand and pumping dredged material through a maximum pipeline length of 4,000 feet. Operation of both electric and recuperative-fired glass-batch melting furnaces were reviewed.[33] In addition, many interesting patents were issued on new apparatus or methods for

[22] Cement, Lime and Gravel (London). Automation in the Manufacture of Sand-Lime Bricks. V. 40, No. 6, June 1965, pp. 203–206.

[23] Timms, A. G. Aggregates for Concrete. Modern Concrete, v. 29, pt. 1, No. 7, November 1965, pp. 31–32; v. 29, pt. 2, No. 8, December 1965, pp. 29–33.

[24] Rock Products. Put Your Lab on Wheels. V. 68, No. 2, February 1965, pp. 62–63.

[25] Gray, J. E. Aggregate Sampling: Does It Work For Or Against You? Rock Products, v. 68, No. 2, February 1965, pp. 56–58.

[26] Hardin, B. O. Dynamic Versus Static Shear Modulus for Dry Sand. Materials Res. and Standards, v. 5, No. 5, May 1965, pp. 232–235.
Selig, E. T. Impact Test of Constrained Sand Specimens. Materials Res. and Standards, v. 5, No. 3, March 1965, pp. 111–118.

[27] Yearley, B. C., The Sand Grain and Molding Sand. Foundry, v. 93, No. 7, July 1965, pp. 60–64.

[28] Chemical Week. Binders-Changing the Cast. V. 96, No. 13, Mar. 27, 1965, pp. 35–37.

[29] Hermann, R. H. Lynchburg Installs Equipment for Sand Coating and Heat Treating. Foundry, v. 93, No. 1, January 1965, pp. 50–53.

[30] Hermann, R. H. Savings Are Achieved by Reclaiming Shell Molding Sand. Foundry, v. 93, No. 9, September 1965, pp. 80–83.

[31] Zimnawoda, H. W. Sand Reclamation Can Save You Money. Foundry, v. 93, No. 6, June 1965, pp. 62–66.

[32] Mining and Minerals Engineering (London). California Glass Sand Plant. V. 1, No. 6, February 1965, pp. 210–212.
The Glass Industry. Dredge Improves Sand-Mining Operation. V. 46, No. 2, February 1965, pp. 80–81.

[33] Olson, C. R., Sr. An Electrical Engineer Explores Glass Melting. Ceramic Industry, v. 84, No. 5, May 1965, pp. 56–59.
Tretheway, W. C. Controlling a Recuperative-Fired Glass Furnace. Ceramic Age, v. 81, No. 6, June 1965, pp. 26–32.

melting, refining, or processing glass.[34] Glass beads were used in place of sand to clean building exteriors in Boston.[35] The new abrasive does not pollute the air, disrupt traffic, or disturb the buildings staff. A vacuum machine blasts the microspheres against the building, sucks them back, and separates them from collected stone dust and dirt for reuse.

The range and quantity of works published on special silica powders and gels and the number and variety of new products reflected industrial and academic interest in the subject. These products are widely used for industrial purposes such as fillers, catelyst supports, absorbents, and chromatographic agents. A paper was presented that discussed the surface properties of these products, a knowledge of which is basic to optimum use of these special silicas.[36] A large number of patents were issued on methods of preparing various silicas for special use.[37]

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[34] Atkeson, F. V. (assigned to Pittsburgh Plate Glass Co., Pittsburgh, Pa.). Method and Apparatus for Drawing Glass Sheets. U.S. Pat. 3,206,293, Sept. 14, 1965.

Frazier, J. E., and N. L. Murphy (assigned to Frazier-P. Simplex, Inc., Washington, Pa.). Glass Melting Furnace. U.S. Pat. 3,201,219, Aug. 17, 1965.

Games, S., R. W. Soltis, and A. E. Hall (assigned to Owens-Corning Fiberglas Corp., Toledo, Ohio). Glass Foam. U.S. Pat. 3,207,588, Sept. 21, 1965.

Long, Bernard (assigned to G. B. D. Societe Anonyme Holding, Luxembourg, Luxembourg). Process and Apparatus for Making Sheet Glass. U.S. Pat. 3,183,072, May 11, 1965.

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Pilkington, L. A. B., and K. Bickerstaff (assigned to Pilkington Brothers Ltd., Liverpool, England). Method and Apparatus for the Manufacture of Flat Glass. U.S. Pat. 3,206,292, Sept. 14, 1965.

[35] Engineering News-Record. Glass Beads Clean Office Tower. V. 175, No. 14, Sept. 30, 1965, p. 46.

[36] Hockey, J. A. The Surface Properties of Silica Powders. Chemistry and Industry (London), No. 2, Jan. 9, 1965, pp. 57–63.

[37] Baker, C. L., and J. F. Austin (assigned to Philadelphia Quartz Co., Philadelphia, Pa.). Finely Divided Silica Product and Its Method of Preparation. U.S. Pat. 3,208,823, Sept. 28, 1965.

Burke, O. W., Jr., and C. B. Jackson (assigned to O. W. Burke, Jr.). Cyclic Process for Producing Silica Pigment, U.S. Pat. 3,172,-727, Mar. 9, 1965.

———. Silica Fillers Reacted With Sea Water and Uses Thereof. U.S. Pat. 3,178,388, Apr. 13, 1965.

———. Addition of Sea Water During Precipitation of Silica Pigment. U.S. Pat. 3,202,525, Aug. 24, 1965.

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Silicon

By John W. Thatcher [1]

The production and shipments of high-purity silicon increased sharply in 1965, as the growing popularity of this material in the expanding semiconductor market outweighed continued miniaturization and simplification of electronic devices.

Metallurgical-grade silicon metal and silicon alloy production increased 7 percent, and shipments for 1965 increased 4 percent.

[1] Commodity specialist, Division of Minerals.

Table 1.—Production, shipments, and stocks of silvery pig iron, ferrosilicon, and silicon metal in 1965 [1]
(Short tons)

Alloy: Type	Alloy: Silicon content (percent)	Producers stocks as of Dec. 31, 1964	Production	Shipments	Producers stocks as of Dec. 31, 1965
Silvery pig iron	5–13	23,006	52,589	55,492	20,103
Do	14–20	18,268	165,902	170,643	13,527
Ferrosilicon	21–55	[r] 35,132	368,976	364,663	39,445
Do	56–70	3,293	48,271	46,257	5,307
Do	71–80	6,195	72,926	71,152	7,969
Do	81–89	1,532	25,206	24,897	1,841
Do	90–95	353	368	524	197
Silicon metal	96–99	3,831	78,075	77,178	4,728
Ferrosilicon briquets	40–50	3,300	75,372	76,242	2,430
Miscellaneous silicon alloys	------	2,055	14,013	13,498	2,570

[r] Revised.
[1] Excludes ferrosilicon used to make other silicon alloys.

DOMESTIC PRODUCTION

Producers of either polycrystal or monocrystal high-purity silicon, or both, and their plant locations included the following:

Company	*Location*
Allegheny Electronics Chemical Co., a subsidiary of Metal Hydrides, Inc.	Lewis Run, Pa.
Dow Corning Corp.	Hemlock, Mich.
Elmat Corporation	Mountain View, Calif.
Fairchild Semiconductor	Mountain View, Calif.
General Diode Corp.	Framingham, Mass.
Mallinckrodt Chemical Works	St. Louis, Mo.
Monosilicon, Inc.	Gardena, Calif.
Monsanto Co.	St. Louis, Mo.
Motorola Inc.	Franklin Park, Ill.
Pittsburgh Materials & Chemicals Corp.	Murrysville, Pa.
Semimetals, Inc.	Westbury, N.Y.
Texas Instruments, Inc.	Dallas, Tex.

Early in the year Dow Corning Corp. completed a multimillion dollar expansion program at its semiconductor materials plant near Hemlock, Mich. This expansion doubled the plant's production capacity of high-purity silicon. About 6 months later the accelerated growth of the semiconductor silicon market led the company to begin another $3 million expansion at the same plant. The latest expansion will increase the production capacity for both polycrystal and single crystal silicon and add 25,000 square feet of new research and development laboratory space.

General Diode Corp. announced the addition of a new plant in Framingham, Mass., to increase their production capacity for float-zone refined single crystals, cast-silicon rods, and research facilities in general.

A new company, Pittsburgh Materials & Chemicals Corp., began supplying silicon crystals, slices, and epitaxial wafers to the national market. The new plant is located in Murrysville, Pa.

Silicon metal was produced in seven plants of six companies, as follows:

Company	*Location*
Interlake Steel Corp.	Beverly, Ohio
Keokuk Electro-Metals Co., division of Vanadium Corporation of America.	Wenatchee, Wash.
National Metallurgical Corp., subsidiary of Apex Smelting Co.	Springfield, Oreg.
Ohio Ferro-Alloys Corp.	Powhatan Point, Ohio
Do	Tacoma, Wash.
Reynolds Metals Co.	Sheffield, Ala.
Union Carbide Corp., Mining & Metals Division	Alloy, W. Va.

Calumet & Hecla, Inc., announced that the Alabama Metallurgical Corp. was dissolved and the plant will now be operated as the Alamet Division of the company. Also announced, was the installation of a ferrosilicon facility scheduled to be in production by the end of 1965. Alamet produces magnesium by reduction of dolomite with ferrosilicon.

Table 2.—Consumption by major end uses, and stocks, of silicon alloys and metal in the United States in 1965

(Short tons)

Material: Type	Silicon content (percent)	Stainless steels	Other alloy steels [1]	Carbon steels	Tool steels	Steel mill rolls	Gray and malleable castings
Silvery pig iron	5–13	------	214	484	------	710	96,819
Do	14–20	------	8,684	22,976	------	250	97,242
Ferrosilicon	[3] 21–55	8,602	78,509	96,747	1,095	1,403	109,276
Do	56–70	797	6,319	20,158	------	------	2,148
Do	71–80	11,579	16,803	6,794	332	194	12,307
Do	81–89	224	653	2,298	------	164	6,657
Do	90–95	20	1,053	231	------	69	381
Silicon metal	96–99	61	2,686	73	20	------	70
Ferrosilicon briquets	40–50	------	126	576	------	8	43,490
Miscellaneous silicon alloys [6]		347	3,734	5,337	58	137	24,014

Material: Type	Silicon content (percent)	Aluminum base alloys	High temperature alloys	Other alloys	Miscellaneous uses	Total consumption	Stocks Dec. 31, 1965
Silvery pig iron	5–13	------	------	1	2,028	100,256	6,434
Do	14–20	------	------	113	[2] 4,001	133,266	12,845
Ferrosilicon	[3] 21–55	58	282	3,153	[4] 21,376	320,501	25,577
Do	56–70	------	------	------	[4] 4,586	34,008	1,974
Do	71–80	------	9	35	15,142	63,195	5,735
Do	81–89	------	------	31	29	10,056	1,505
Do	90–95	3,287	------	56	------	5,097	551
Silicon metal	96–99	55,176	830	861	[5] 10,824	70,601	4,494
Ferrosilicon briquets	40–50	------	------	------	------	44,200	4,417
Miscellaneous silicon alloys [6]	------	119	68	52	4,347	38,213	3,144

[1] Includes quantities of carbon steels because some firms failed to specify individual uses.
[2] Used mainly in high-silicon iron, and to beneficiate ores.
[3] Mainly from 40 to 55 percent silicon.
[4] Used mainly in producing ferronickel.
[5] Used mainly in silicones and other chemical compounds.
[6] Includes calcium-silicon, calcium-manganese-silicon, silicon-manganese-zirconium, silicon carbide, Ferrocarbo (including briquets). Alsifer, and other miscellaneous silicon alloys.

CONSUMPTION AND USES

The quantity and value of shipments of both polycrystal and single crystal high-purity silicon increased appreciably in 1965 owing primarily to a sharp increase in the fabrication of silicon transistors, rectifiers, diodes, thyristors, and integrated circuits by the electronics industries. Improvements in silicon planar devices and metal-oxide-silicon (MOS) transistors, and the increased use of hybrid and monolithic integrated circuits in the computer and aerospace industries has contributed to an accelerated consumption of silicon at the expense of other semiconductor materials.

Silicon retained the dominant position in the manufacture of solar cells because of its efficiency, low cost, and past performances. The new physical form of silicon, the dendritic grown "web" crystal, has been used primarily for solar cell fabrication. Its long, thin configuration and a well ordered, low dislocation density (1,000 per square centimeter) give it unique advantages for making large-area devices. Silicon solar cells have been used in the development of a long lasting, highly reliable atomic battery. Two cells are activated by a radioactive source sandwiched between them to produce a power unit with an output of 10 microwatts. The theoretical lifetime may be several years, depending on the half life of the radioisotope.

A breakthrough was made in mass producing silicon carbide whiskers which has moved it, in a year's time, from an expensive laboratory curiosity to a commercially available commodity. Initial applications are seen in the aerospace industry where stronger, lightweight materials are needed.

Silicon carbide is a high-temperature resistant material; it maintains its strength in air up to 3,180° F and in inert atmosphere to at least 3,600° F. It has many other interesting properties which greatly extend possible applications. Because of its infrared opacity, silicon carbide fiber has high potential as an insulating material at both extremes of temperature — from —450° F to +3,600° F.

A bonded coating of silicon carbide which is abrasion resistant and completely gas impermeable constitutes a growing use for this material.

STOCKS

Overall producers' stocks of silicon metal and alloys increased 2 percent while consumers' stocks dropped 13 percent, or 9,559 tons.

PRICES

The average value of polycrystal high-purity silicon shipped in 1965, $107 per kilogram, remained at about the 1964 level. The average value of monocrystal high-purity silicon shipped in 1965, including epitaxial wafers, decreased 9 percent to $1,090 per kilogram.

Metallurgical-grade silicon, 98 percent minimum silicon, 0.35 percent maximum iron, opened the year at 19 cents per pound contained silicon, carload lots, bulk, delivered, and was changed in the first quarter to 18.25 cents per pound contained silicon, producer's plant.

On February 1 the base price for 50 percent ferrosilicon carload lots, bulk, delivered was changed to 12.7 cents per pound contained silicon and remained at this level throughout the year.

FOREIGN TRADE

High-purity silicon imports for consumption in 1965 totaled 11,946 kilograms—more than a fourfold increase over that of 1964. Value increased by a factor of three to $1,067,941, while the average value of imports decreased to $89.4 per kilogram. West Germany supplied 86 percent of the imports. The remainder came from France, Japan, Belgium-Luxembourg, and the United Kingdom.

Imports for consumption of ferrosilicon in 1965 were up 25 percent over the previous year; exports were down 21 percent, but value increased 42 percent. The major recipients for exports, in order of decreasing tonnage, were Canada, West Germany, and Belgium-Luxembourg.

Table 3.—U.S. exports of ferrosilicon

Year	Short tons	Value
1956–60 (average)	4,600	$644,968
1961	34,764	6,104,913
1962	4,101	1,348,661
1963	3,130	947,773
1964	5,785	1,232,450
1965	4,585	1,755,292

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Table 4.—U.S. imports for consumption of ferrosilicon and silicon metal, by grades and countries

	1963			1964			1965		
	Short tons		Value	Short tons		Value	Short tons		Value
	Gross weight	Silicon content		Gross weight	Silicon content		Gross weight	Silicon content	
Ferrosilicon:									
8 percent and less than 60 percent silicon:									
Canada	12,781	1,962	$667,616	10,978	1,672	$569,696	12,281	2,022	$743,636
France	-------	-------	-------	-------	-------	-------	11	6	3,091
Germany, West	38	5	4,850	358	53	59,714	523	78	86,873
Japan	-------	-------	-------	97	45	30,498	1,203	556	396,949
Outer Mongolia	-------	-------	-------	9	1	538	-------	-------	-------
Total	12,819	1,967	672,466	11,442	1,771	660,446	14,018	2,662	1,230,549
60 percent and less than 80 percent silicon:									
Canada	-------	-------	-------	504	343	84,307	-------	-------	-------
France	132	101	17,326	40	31	5,629	1,379	1,054	220,512
India	-------	-------	-------	1	1	284	-------	-------	-------
Italy	22	17	2,959	-------	-------	-------	-------	-------	-------
Norway	r 384	r 291	r 51,014	1,125	857	145,898	916	697	124,514
South Africa, Republic of	-------	-------	-------	-------	-------	-------	112	87	15,210
Total	r 538	r 409	r 71,299	1,670	1,232	236,118	2,407	1,838	360,236
80 percent and less than 90 percent silicon:									
Italy	-------	-------	-------	49	42	11,823	68	58	15,542
Grand total	r 13,357	r 2,376	r 743,765	13,161	3,045	908,387	16,493	4,558	1,606,327
Silicon metal: Germany, West	-------	-------	-------	-------	-------	-------	[1]	[1]	196

r Revised. [1] Less than ½ unit.

WORLD REVIEW

Canada.—A new enterprise, Les Silicuims de Chicoutimi, has been formed to construct a plant in Quebec to produce metallurgical-grade silicon metal for aluminum alloying. The venture is sponsored jointly by Aluminum Company of Canada, Ltd. (Alcan), Royal Securities Corp., Montreal Engineering Co., and Metal Mines Ltd. The $3 million plant is scheduled to begin operation early in 1967 with a capacity of 7,000 tons of silicon per year.

France.—An Italian affiliate of Fairchild Semiconductors won approval from the French Government to build a semiconductor plant in the Rennes region of Brittany. Societa Generale Semiconduttori-Fairchild plans to use the plant to manufacture planar transistors and integrated circuits. Production is estimated at 10,000 transistors daily by February 1966.

Italy.—Societa Generale Semiconduttori SpA of Milan has signed an export contract worth more than $1 million to ship high-purity silicon semiconductor materials and finished transistors to Norway. Export contracts have also been signed by the company with West Germany and the Netherlands.

Norway.—Electroschmelzwerk Kempten G.m.b.H., the silicon subsidiary of Wacher Chemie G.m.b.H., is to set up a new plant at Verdal near Trondheim in Norway. It will have a 10,000-ton-per-year capacity and will work in technical cooperation with A/S Hafslund-Karbidfabrikken.[2]

An electric furnace plant for the production of silicon carbide has been constructed at Lillesand, Norway, by the U.S. firm, Norton Co. The silicon carbide will be shipped to Norton's subsidiaries in Europe for further processing.[3]

The ferrosilicon producer, A/S Hafslund, completed modernization of its plant near Sarpsborg this year. The two ferrosilicon furnaces now have a capacity of 22,000 tons per year.

It was reported that Elektrokemish A/S will construct a new ferrosilicon smelter at Fauske in northern Norway. The new plant, to be known at Salten Verk, will be initially a one-furnace operation and will require 150 million kilowatt hours annually. When operation commences early in 1967, power will be supplied by the State-owned Rana Kraftwerk; however, the plant will eventually have its own hydroelectric power station capable of producing 420 million kilowatt hours per year.

United Kingdom.—Imperial Chemical Industries Ltd. has authorized an $8.4 million expansion of its silicones plant at Adeer in Scotland which, the company claims, will make it one of the largest silicones producers in Europe. All stages of production will be expanded, giving an additional capacity of 5,000 tons per year.

Yugoslavia.—A new 8,500-kilovolt-ampere electric furnace for the production of silicon metal was put into operation at the Elektrobosna ferroalloy plant at Jajce.[4]

TECHNOLOGY

Refinements in existing techniques and equipment highlighted the technological achievements within the silicon industry during 1965. Although no entirely new production concepts were introduced, many phases of processing were improved and/or made less costly.

Producers and consumers of high-purity silicon welcomed the improvements in process control. These made available high-quality crystals having consistent electronic and crystallographic properties. Since silicon materials used to produce electronic devices are moderately to highly doped, crystals of a higher purity than the purest ones commercially available were not in demand except for special devices such as radiation detectors and Reed Diodes. The trend was to standardize on the highest purity materials currently available to achieve production economies and to obtain maximum yields.[5] This standardization allowed researchers to progress more toward developing the physical forms of crystals and new products.

Approximately 75 percent of the single crystal silicon used was produced by the Czochralski (vertical-pull) process. Nearly 25 percent was produced by the float

[2] European Chemical News (London). V. 7, No. 178, May 7, 1965, p. 8.
[3] Metal Bulletin (London). No. 5029, Sept. 10, 1965, p. 21.
[4] Metal Bulletin (London). No. 5018, July 30, 1965, p. 13.
[5] Kern, E. L., and E. Earleywine. New Developments in Semiconductor Materials. Semiconductor Products and Solid State Technol., v. 8, No. 10, October 1965, pp. 28–43.

zone refining technique.[6] National Research Corp., a subsidiary of the Norton Co., advanced the art of crystal growing through the development of an improved furnace. The new unit, a resistance-heated furnace, uses the Czochralski crystal-growing method. With a crucible capacity of about 550 cubic centimeters, it is capable of handling a 1,050-gram silicon charge. This is double the production capacity of a previous mode. The new furnace operates under vacuum or in an inert gas with temperatures ranging from 600° to 1,600° C. Silicon crystals up to 2 inches in diameter can be pulled.[7] Much of the experimental research within the high-purity silicon industry was devoted to studying and developing dendritic and epitaxial growth processes. Westinghouse Electric Corp. developed the growth of silicon webs to the point where widths exceeding 1.9 centimeters can be expected.[8] Silicon web is a single crystal of hyperpure silicon grown as a long thin ribbon between two supporting dendrites. The web is the solidified membrane formed by natural surface tension on a liquid film between two growing dendrites. Progress in the silicon web technique has become possible through control of supercooling used to start crystal growth, thermal control of growth rate, and control of the pulling rate. Presently, silicon webs can be pulled to a length of about 15 feet.[9] The long lengths available make it suitable for process automation.

The web crystal has a natural thinness comparable to or less than the thinnest silicon slices. A new form, thin enough that a strong light will shine through it, has been developed by Dow Corning Corp. Called Micron Web crystal, the product is grown in thicknesses from 25 to 40 microns, in lengths of more than 1 meter, and in widths of several millimeters.[10] One of the greatest advantages offered by silicon web is that it has a nearly perfect natural finish which requires little or no grinding or lapping. Such surfaces are highly desirable in most diffusion and epitaxial growth processes. Silicon ribbon can be expected to find use in microelectric circuits, radiation detectors, large solar cells, and other semiconductor products.

Epitaxial growth, a vapor deposition process, and diffusion play an important role in microelectronics. Silicon microcircuits offer increased reliability by eliminating conventional interconnections. Their small size permits multiple fabrication of many complex elements in a space where formerly only one existed.[11] In the near future integrated-circuit technology can be expected to advance to the point where it will be possible to produce arrays of 100 to 1,000 logic circuits within a single slice of silicon.[12] Lower costs result by fabricating microcircuits on or in small wafers of inexpensively processed materials.

The effect of substrate orientation on the quality of silicon epitaxial layers was studied in terms of deposition rate and surface topography. Pyramidal defects were not observed for low-deposition rates and when the substrate was misoriented from the (111) direction.[13]

Experiments have shown that it is possible to grow silicon epitaxically at low temperatures by evaporation onto a thin alloy layer. Using silver, copper, tin, gold, and indium alloys, silicon has been epitaxically grown on silicon substrates at temperatures of 850°, 800°, 500°, 400° and 300° C, respectively.[14]

Significant progress has been achieved toward depositing single-crystal silicon films on amorphous substrates. If a thin layer of gold (1,000 to 3,000 angstroms) is evaporated on a fused quartz surface before the silicon is deposited, polycrystalline layers are obtained with grain size as large as 300 microns. If silicon is deposited directly on fused quartz, grain size is only about 5 microns.[15]

The use of focused ion beams to implant simple diode arrays in some circuits and passive components in integrated circuits has been investigated by Electro-Optical Systems, Inc. (EOS). An ion beam of 5

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[6] Work cited in footnote 5.

[7] Pellegrin, Oscar. Advances in Crystal Growing Technology. Semiconductor Products and Solid State Technol., v. 8, No. 8, August 1965, pp. 41–45.

[8] Electronic News. V. 10, No. 507, Sept. 13, 1965, p. 5.

[9] Work cited in footnote 8.

[10] Electronic News. V. 10, No. 513, Oct. 25, 1965, p. 43.

[11] Thornton, C. G. Microelectronics—1. Chem. Eng., v. 72, No. 10, May 10, 1965, pp. 175–182.

[12] Missiles and Rockets. V. 17, No. 12, Sept. 20, 1965, p. 24.

[13] Journal of the Electrochemical Society. The Effects of Substrate Orientation on Epitaxial Growth. V. 112, No. 4, April 1965, pp. 436–438.

[14] Journal of the Electrochemical Society. Low-Temperature Epitaxy of Silicon by Sublimation Onto Thin Alloy Layers. V. 112, No. 5, May 1965, pp. 535–536.

[15] Journal of the Electrochemical Society. Progress toward Single Crystal Films on Amorphous Substrates. V. 112, No. 9, September 1965, pp. 957–958.

mils in diameter is used to implant 6-mil-diameter diodes in silicon with no difficulty. The system is being modified to produce beams of less than 1 mil in diameter. Large-area ion implantation systems have been used by EOS to make ten 1-inch-diameter solar cells simultaneously with no variation in function depth or sheet resistance. Ion beam implantation is less complicated than the photoresist technique; however, the developers do not foresee ion beams replacing the photoresist method except for implantation of circuit components or passive elements which are impossible or very difficult to do by standard techniques.

Ion Physics Corp. has developed a method to change passivated silicon substrates to transistors, detector diodes, and solar cells by bombarding a substrate with a phosphorus ion beam. Advantages claimed are higher frequency response components, higher production yields (90 percent and over), and the ability to implant through the oxide layer, thus easing the surface contamination problem. This technique halves the number of processing steps which are inherent in the planar process. The developers claim that the process is highly adapted to integrate circuits and can turn out 1,600 units measuring 10 by 10 mils in 1 second.[16]

The effect of radiation on silicon oxide layers in semiconductors has received attention from researchers. X-rays, gamma-rays, and ultraviolet light have been used. MOS devices may have applications, therefore, in X-ray dosimetry. Exposure rates as low as 0.01 roentgen per minute have been observed with the MOS devices. The effects depend on the way the oxide films have been prepared and on the presence of electrical fields.[17]

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[16] Electronic News. V. 10, No. 495, June 28, 1965, pp. 4–5.

[17] Philips Research Reports (Eindhoven, The Netherlands). V. 20, No. 3, June 1965, pp. 304–314.

Philips Research Reports (Eindhoven, The Netherlands). V. 20, No. 5, October 1965, pp. 595–619.

Silver

By J. Patrick Ryan [1]

The salient event of the year in silver was the enactment of the new U.S. coinage law which completely changed the composition of subsidiary coins. Substantial increases in domestic mine production and in industrial and coinage consumption of silver also highlighted the year.

Domestic mine production rose to its highest level since 1950; industrial consumption was the greatest since World War II; and coinage consumption reached an alltime high. The U.S. Treasury's silver stock continued its sharp decline. The U.S. silver trade returned to a more normal net import pattern. The worldwide imbalance between new production and consumption continued to increase and prompted increased trading on the Commodity Exchange, although the price range was about the same as in 1964. The New York market price for prompt delivery remained unchanged for the second consecutive year.

Outside the United States the overall production of silver increased slightly. Consumption in the arts and industries was about 15 percent higher, but consumption for coinage dropped 11 percent.

Legislation and Government Programs.—The Treasury Department completed a 2-year study of silver supply and demand and coinage problems as a basis for developing policies to insure the adequacy of United States coinage.[2] New coinage recommendations contained in legislative proposals sent to Congress were based on the fundamental conclusion that the U.S. silver supply and production situation, and outlook did not warrant continued large-scale use of silver in the U.S. coinage. Cupronickel, modified for accommodation by vending machines, was judged the best material for subsidiary coins.

Following extensive hearings in the House and Senate, The Coinage Act of 1965 was passed and became law on July 23, 1965. The principal provisions of the Act are as follows:

1. It provides for a new half-dollar composed of an outer layer containing 80-percent silver and 20-percent copper clad on a core containing approximately 21.5-percent silver and 78.5-percent copper. The coin as a whole contains 40-percent silver compared with 90-percent silver in old type half dollars.
2. It provides for new silverless quarters and dimes, composed of an alloy of 75-percent copper and 25-percent nickel clad on a core of pure copper. Formerly these coins, like the half-dollar, contained 90-percent silver.
3. The silver dollar will remain unchanged, but none shall be minted for 5 years from the date of the Act.
4. The Treasury shall buy newly mined domestic silver, if offered, at $1.25 an ounce.
5. The Secretary of the Treasury is authorized at his discretion to prohibit the export or melting of any coin of the United States.
6. The President is authorized to establish a Joint Commission on the Coinage to study the progress made in introducing the new coins and to review and make recommendations on all aspects of the coinage system.
7. The Secretary of the Treasury is authorized to sell silver not needed to back silver certificates at not less than the monetary value of $1.29+ an ounce.

In June the Office of Emergency Planning established a stockpile objective of 165 million ounces of silver earmarked

[1] Commodity specialist, Division of Minerals.
[2] U.S. Treasury Department. Treasury Staff Study of Silver and Coinage. 1965, 91 pp.

Table 1.—Salient silver statistics

	1956-60 (average)	1961	1962	1963	1964	1965
United States:						
Mine production thousand troy ounces	34,592	34,794	36,798	35,243	36,334	39,806
Value thousands	$31,307	$32,166	$39,929	$45,076	$46,980	$51,469
Ore (dry and siliceous) produced:						
Gold ore thousand short tons	2,316	2,060	2,159	2,460	2,631	3,113
Gold-silver ore do	190	248	353	223	224	205
Silver ore do	655	565	557	587	644	902
Percentage derived from:						
Dry and siliceous ores	36	39	33	33	32	35
Base-metal ores	64	61	67	67	68	65
Refinery production thousand troy ounces	34,812	34,900	36,345	35,000	37,000	39,000
Imports general [1] do	132,932	50,256	76,359	59,062	51,674	54,709
Exports [1] do	10,861	39,828	13,057	31,485	109,395	39,665
Stocks Dec. 31: Treasury million troy ounces	2,031	1,862	1,767	1,583	1,218	804
Consumption–industry and the arts thousand troy ounces	96,780	105,500	110,400	110,000	123,000	137,000
Coinage do	41,800	55,900	77,368	111,493	203,000	320,321
Price per troy ounce	[2] $0.905+	[3] $0.924+	[3] $1.085+	[3] $1.279+	[3] $1.293	[3] $1.293
World:						
Production thousand troy ounces	231,860	236,900	244,700	250,300	246,400	251,000
Consumption [4]—industry and the arts thousand troy ounces	211,700	239,500	247,800	257,200	290,900	333,600
Coinage do	82,120	137,100	127,600	167,000	264,500	374,721

[1] Excludes coinage.
[2] Treasury buying price for newly mined silver.
[3] Average New York price.
[4] Free world only.

from the Treasury stock.

Nine contracts totaling $535.120 were executed during the year under the Government program of financial assistance administered by the Office of Minerals Exploration (OME). The Government share of the exploration cost was 75 percent. The following exploration contracts for silver or silver-gold were active or in force during the year:

Operator	*Location*	*Total cost*
Lombardi, Clemens A., and Arthur	Lemhi County, Idaho	$86,670
Oregon King Consolidated Mines, Inc	Jefferson County, Oreg	55,150
B.L.M.W. Mining Co	Madison County, Mont	20,550
Resource Americas Corp. and Associates	San Bernardino County, Calif	32,088
Wayne Erickson	Beaverhead County, Mont	61,560
Spokane National Mines, Inc	do	33,880
P. W. Beckley	Culberson County, Tex	16,800
Betty O'Neal Silver, Inc	Lander County, Nev	90,240
Cortez Joint Venture	Eureka and Lander Counties, Nev	174,860
J. Howard Sims	Lemhi County, Idaho	59,230
Mountain Copper Co	Eureka County, Nev	86,860
Cardiff Industries, Inc	Salt Lake County, Utah	10,500
Mascot Mines, Inc	Jefferson County, Mont	28,200
Escalante Silver Mines, Inc	Iron County, Utah	49,780
Claude Lovestedt	Alpine County, Calif	44,000
Total		850,368

The Bureau of Mines initiated, in the latter part of the year, a survey of refinery production, use, and flow of silver in the arts and industries of the United States. The Bureau also began a silver production and marketing survey of the Nation's silver resources to evaluate the potential output of silver under changing economic and technologic conditions.

DOMESTIC PRODUCTION

Output of recoverable silver from mines in the United States increased 3.5 million ounces over that of 1964. Production gains in Arizona, Idaho, Utah, and Nevada more than offset losses in Colorado and Montana. A 12-percent gain brought Idaho's silver output to the highest level since 1938; it reflected uninterrupted operations and increased production at the Sunshine mine. Similarly, a 24-percent increase in Utah's output of silver was attributed principally to the uninterrupted production of silver-bearing copper ore by the Utah Copper Division of Kennecott Copper Corp. Shutdowns owing to labor strikes had reduced output from these mines in 1964. A 2-percent falloff in silver production in Montana resulted from reduced output of byproduct silver from Butte copper mines and from operations in Phillips and Beaverhead Counties.

Idaho, the leading silver-producing State, contributed 46 percent of the total domestic silver output.

Continuing the pattern of recent years, approximately two-thirds of the total domestic silver output was recovered as a byproduct or coproduct of ores mined chiefly for copper, lead, zinc, and gold. Virtually all of the remainder came from ores in which silver was the principal product. Of the 25 leading silver-producing mines, only 4 in Idaho depended chiefly on the value of silver in the ore. Nine mines produced over 1 million ounces each, and supplied 61 percent of the total domestic output; the 25 leading mines supplied 84 percent. Domestic mines contributed 29 percent of the silver used in the Nation's arts and industries.

Exploration and development intensified, especially in Idaho, Nevada, Colorado, and Utah. In the Coeur d'Alene region, The Bunker Hill Co. reported significant ore intersections of the 3,300-foot level of the Crescent mine. Hecla Mining Co. reported new ore exposures on the 3,600-foot level of the Silver Summit mine. American Smelting and Refining Company began sinking to explore deep ore bodies on the Rainbow and Coeur d'Alene mines' properties. Hecla Mining Co. also reported significant new ore development on the 2,200-foot level of the Mayflower mine in the Park City District, Utah.

The Sunshine mine, the Nation's leading silver producer, substantially increased production in 1965. Recovery increased from 4.63 million ounces in 1964 to 6.44 million ounces in 1965. The quantity of ore milled increased 22 percent over 1964, and average-grade of ore increased from 36 to 38.7 ounces per ton. According to a company letter of June 9, 1966, discovery of new ore and extensions of productive ore shoots on deep levels increased ore reserves to 745,330 tons at the end of 1965 as compared with 424,900 tons at the end of 1964.

At the Lucky Friday mine of the Hecla Mining Co. 181,100 tons of ore was treated averaging 17.8 ounces of silver per ton, 11.3 percent lead, and 1.0 percent zinc. The ore reserve at yearend was 607,000 tons compared with 671,000 tons at the end of 1964.[3]

Table 2.—Mine production of silver in the United States, by months

(Thousand troy ounces)

Month	1964	1965
January	2,651	3,235
February	2,465	3,079
March	2,892	3,476
April	3,257	3,531
May	3,303	3,266
June	3,376	3,290
July	2,928	3,156
August	2,897	3,250
September	3,032	3,235
October	3,234	3,373
November	3,076	3,375
December	3,223	3,540
Total	36,334	39,806

Although complete data on sources were not available, a substantial quantity of secondary silver was recovered by refiners from scrap and returned to industrial use. Most of the recovered silver came from photographic and electroplating wastes, and discarded silverware and jewelry.

[3] Hecla Mining Co. Sixty-Eighth Annual Report. 1965, p. 7.

Table 3.—Twenty-five leading silver-producing mines in the United States in 1965, in order of output

Rank	Mine	State	County	Operator	Source of silver
1	Sunshine	Idaho	Shoshone	Sunshine Mining Co	Silver ore.
2	Galena	do	do	American Smelting and Refining Company	Do.
3	Lucky Friday	do	do	Hecla Mining Co	Lead ore.
4	Utah Copper	Utah	Salt Lake	Kennecott Copper Corp	Copper, gold ores.
5	Butte Hill Copper Mines	Montana	Silver Bow	The Anaconda Company	Do.
6	Bunker Hill	Idaho	Shoshone	The Bunker Hill Co	Lead-zinc ore, silver tailings.
7	Butte Hill Zinc Mines	Montana	Silver Bow	The Anaconda Company	Zinc ore.
8	Berkley Pit	do	do	do	Copper ore.
9	Mission	Arizona	Pima	American Smelting and Refining Company	Do.
10	Copper Queen-Lavender Pit	do	Cochise	Phelps Dodge Corp	Copper, silver ores.
11	U.S. and Lark	Utah	Salt Lake	United States Smelting, Refining and Mining Co.	Lead-zinc, lead ores.
12	Crescent	Idaho	Shoshone	The Bunker Hill Co	Silver ore.
13	Silver Summit	do	do	Hecla Mining Co	Do.
14	Star-Morning Unit	do	do	do	Lead-zinc ore.
15	Iron King	Arizona	Yavapai	Shattuck Denn Mining Corp	Do.
16	Eagle	Colorado	Eagle	The New Jersey Zinc Co	Copper, zinc ores.
17	Mineral Park	Arizona	Mohave	Duval Corp	Copper ore.
18	Morenci	do	Greenlee	Phelps Dodge Corp	Copper, gold-silver ores.
19	New Cornelia	do	Pima	do	Do.
20	Idarado	Colorado	Ouray and San Miguel	Idarado Mining Co	Copper-lead-zinc ore.
21	White Pine	Michigan	Ontonagon	White Pine Copper Co	Copper ore.
22	Mayflower	Utah	Wasatch	Hecla Mining Co	Lead-zinc ore.
23	Magma	Arizona	Pinal	Magma Copper Co	Copper, gold-silver ores.
24	Keystone	Colorado	Gunnison	McFarland & Hullinger	Lead-zinc ore.
25	United Park City	Utah	Summit and Wasatch	United Park City Mines Co	Do.

Table 4.—Production of silver in 1963–65 in the United States, by States and by source, 1965

(Troy ounces)

State	1963	1964	1965 by type of mine production: Placers	Dry ore	Copper ore	Lead and zinc ores	Complex base metal ores	Other sources [1]	Total	Refinery [2] production
Alaska	14,010	7,336	3,867	1,851	1,102	849	----------	4	7,673	6,700
Arizona	5,373,058	[3] 5,810,510	[4] 38	40,952	5,352,850	11,640	646,409	20,148	[3] 6,095,285	6,100,000
California	156,528	[5] 171,621	3,285	22,482	80	86,253	4,891	7	[5] 196,787	176,500
Colorado	2,307,305	2,626,431	168	63,430	299,078	270,096	1,415,991	2,342	2,051,105	2,002,500
Idaho	16,710,725	16,483,495	5	12,635,252	9,986	3,277,041	2,378,160	156,365	18,456,809	18,100,000
Kentucky	1,515	[6] 1,673	----------	----------	----------	----------	----------	----------	[6] 1,931	1,700
Michigan	338,997	349,195	----------	----------	457,851	----------	----------	----------	457,851	[7] 843,650
Missouri	131,664	----------	----------	----------	----------	299,522	----------	----------	299,522	80,000
Montana	4,241,620	5,289,959	10	236,656	3,318,664	1,577,559	6,029	68,113	5,207,031	5,100,000
Nevada	214,976	172,447	187	150,574	130,104	10,935	214,130	1,183	507,113	350,000
New Mexico	256,475	242,405	(4)	27,867	92,602	88,759	76,041	2,203	287,472	282,500
New York	19,544	13,306	----------	----------	----------	----------	11,441	----------	11,441	52,000
North Carolina	26,754	----------	----------	----------	----------	----------	----------	----------	----------	280
Oklahoma	----------	----------	----------	(8)	(8)	(8)	(8)	----------	(8)	----------
Oregon	58,234	14,372	30	8,751	20	----------	----------	----------	8,801	3,700
Pennsylvania	(8)	(8)	----------	(8)	(8)	(8)	(8)	----------	(8)	10
South Dakota	117,301	132,981	----------	128,971	----------	----------	----------	----------	128,971	130,900
Tennessee	107,913	90,539	----------	----------	----------	----------	94,142	----------	94,142	138,100
Utah	4,790,511	[3] 4,551,960	----------	225,460	3,043,630	209,393	2,149,801	6,658	[3] 5,635,570	5,240,740
Washington	[8] 374,373	[8 9] 375,603	----------	[8] 312,762	[8] 1,504	[8] 10,240	[8] 23,689	----------	[8 9] 358,477	355,150
Wyoming	----------	28	----------	27	25	----------	----------	----------	52	75
Total	35,241,503	36,333,861	7,590	13,855,035	12,707,496	5,842,287	7,020,724	257,023	39,806,033	[10] 39,000,000
Percent [9]	----------	----------	(10)	35	32	15	18	(10)	100	----------

[1] Silver recovered from mill and smelter cleanup, slags, and tailings.
[2] U.S. Bureau of the Mint.
[3] Includes byproduct silver from uranium ore.
[4] Arizona and New Mexico combined to avoid disclosing individual company confidential data.
[5] Includes byproduct silver from tungsten ore.
[6] Calcium fluorite.
[7] Includes an accumulation of silver recovered in 1965 from "Lake Copper"; the actual years of mine production of the copper are unknown.
[8] Pennsylvania and Washington combined in 1963–64, and Oklahoma, Pennsylvania, and Washington combined in 1965 to avoid disclosing individual company confidential data.
[9] Includes silver from magnetite-pyrite ore in Pennsylvania.
[10] Includes refinery production from: Illinois, 20,000; Texas, 3,420; Virginia, 75; and Wisconsin, 12,000.
[11] Percentage based on total, excluding 115,878 ounces from other ores.
[12] Less than 0.5 percent.

Table 5.—Mine production of recoverable silver in the United States, 1956–65, with production of maximum year, and cumulative production from earliest record to end of 1965, by States, in troy ounces

State	Maximum production [1]		Production by years				
	Year	Quantity	1956	1957	1958	1959	1960
Western States:							
Alaska	1916	1,379,171	28,360	28,862	23,507	21,358	25,934
Arizona	1937	9,422,552	5,179,185	5,279,323	4,684,580	3,898,336	4,774,992
California	1921	3,629,223	938,139	522,288	188,260	172,810	179,780
Colorado	1893	25,838,600	2,284,701	2,787,892	2,055,517	1,340,732	1,659,037
Idaho	1937	19,587,766	13,471,916	15,067,420	15,952,796	16,636,486	13,646,508
Montana	1892	19,038,800	7,385,908	5,558,228	3,630,530	3,420,376	3,606,991
Nevada	1913	16,090,083	993,716	958,477	932,728	611,135	707,291
New Mexico	1885	2,343,800	392,967	309,385	158,758	158,925	303,903
Oregon	1941	276,158	13,542	15,924	2,728	242	284
South Dakota	1900	536,200	136,118	134,737	152,995	124,425	108,119
Texas	1938	1,433,008	---------	---------	---------	---------	---------
Utah	1925	21,276,689	6,572,041	6,198,464	5,277,693	3,734,297	4,782,960
Washington	1902	721,450	448,442	[2] 521,133	[2] 666,278	[2] 606,537	[2] 628,678
Wyoming	1901	21,400	154	126	30	---------	4
Total	----	---------	37,845,189	37,382,259	33,726,400	30,725,659	30,424,481
West Central States:							
Missouri	1952	517,432	295,111	183,427	250,917	339,760	15,594
States east of the Mississippi:							
Alabama	1936	869	---------	---------	---------	---------	---------
Georgia	1904	1,500	---------	---------	---------	---------	---------
Illinois	1924	8,891	1,580	---------	---------	---------	---------
Kentucky	1961	2,065	31	56	99	75	---------
Maryland	1917	1,092	---------	---------	---------	---------	---------
Michigan	1916	716,640	379,990	430,000	---------	---------	---------
New York	1956	84,158	84,158	63,880	66,738	51,588	49,324
North Carolina	1960	212,368	753	12,347	15,157	16,319	212,368
Oklahoma	----	---------	---------	---------	---------	---------	---------
Pennsylvania	1942	15,501	(2)	(2)	(2)	(2)	(2)
South Carolina	1940	8,047	---------	---------	---------	---------	---------
Tennessee	1962	112,251	64,878	54,407	44,592	59,739	64,560
Vermont	1955	50,447	[2] 47,800	36,794	5,101	---------	---------
Virginia	1944	18,993	1,874	1,745	2,023	866	---------
Total			581,064	599,229	133,710	128,587	326,252
Grand total	----	---------	38,721,364	38,164,915	34,111,027	31,194,006	30,766,327

See footnotes at end of table.

Table 5.—Mine production of recoverable silver in the United States, 1956–65, with production of maximum year, and cumulative production from earliest record to end of 1965, by States, in troy ounces—Continued

State	Production by years—Continued					Total production from earliest record to end of 1965
	1961	1962	1963	1964	1965	
Western States:						
Alaska	18,485	22,199	14,010	7,336	7,673	20,378,840
Arizona	5,120,007	5,453,585	5,373,058	5,810,510	6,095,248	387,165,973
California	93,351	132,505	156,528	171,621	196,787	119,675,172
Colorado	1,965,021	2,087,813	2,307,305	2,626,431	2,051,105	777,539,047
Idaho	17,576,322	17,772,435	16,710,725	16,483,495	18,456,809	804,214,054
Montana	3,490,350	4,560,714	4,241,620	5,289,959	5,207,031	852,196,049
Nevada	388,426	245,164	214,976	172,447	507,113	605,865,739
New Mexico	282,755	301,549	256,475	242,405	287,509	73,710,403
Oregon	2,022	6,047	58,234	14,372	8,801	5,462,907
South Dakota	127,427	113,052	117,301	132,981	128,971	12,137,793
Texas	---------	---------	---------	---------	---------	33,303,399
Utah	4,797,583	4,628,446	4,790,511	4,551,960	5,635,570	833,436,482
Washington	[2] 625,176	[2] 350,185	[2] 374,373	[2] 375,603	[2] 358,477	[3] 20,897,709
Wyoming	7	---------	---------	28	52	75,327
Total	34,486,932	35,673,694	34,615,116	35,879,148	38,941,146	4,546,058,894
West Central States:						
Missouri	11,793	490,896	131,664	---------	299,522	8,431,382
States east of the Mississippi:						
Alabama	---------	---------	---------	---------	---------	5,239
Georgia	---------	---------	---------	---------	---------	10,963
Illinois	---------	---------	---------	---------	---------	163,707
Kentucky	2,065	1,410	1,515	1,673	1,931	8,855
Maryland	---------	---------	---------	---------	---------	2,595
Michigan	---------	401,491	338,997	349,195	457,851	13,091,636
New York	40,507	19,451	19,544	13,306	11,441	1,123,861
North Carolina	169,742	100,439	26,754	---------	---------	911,721
Oklahoma	---------	---------	---------	---------	([2])	([2])
Pennsylvania	([2])	([2])	([2])	([2])	([2])	[3] 275,126
South Carolina	---------	---------	---------	---------	---------	35,325
Tennessee	83,417	112,251	107,913	90,539	94,142	4,294,260
Vermont	---------	---------	---------	---------	---------	[4] 524,585
Virginia	---------	---------	---------	---------	---------	90,689
Total	295,731	635,042	494,723	454,713	565,365	20,538,562
Grand total	34,794,456	36,799,632	35,241,503	36,333,861	39,806,033	4,575,028,838

[1] Figures for States east of the Mississippi are peak since 1896, except New York and Pennsylvania, which are peak since 1905. The Illinois figure is the peak since 1907. Alaska, California, Nevada, and Oregon are peaks since 1880.
[2] Pennsylvania included with Vermont in 1956, Pennsylvania included with Washington 1957–65.
[3] Total production from earliest record to end of 1955; included with Washington 1957-65.
[4] Includes a small amount from New Hampshire.

Table 6.—Ore, old tailings, etc., yielding silver produced in the United States, and average recoverable content, in troy ounces of silver per ton in 1965

State	Gold		Gold-silver		Silver		Copper	
	Short tons	Average ounces of silver per ton	Short tons	Average ounces of silver per ton	Short tons	Average ounces of silver per ton	Short tons	Average ounces of silver per ton
Alaska	3,194	0.581	------	------	------	------	58	19.000
Arizona	115	.757	142,648	0.159	25,807	1.296	91,632,221	.058
California	7,048	.118	(1)	(1)	[1] 2,982	[1] 7.262	50	1.600
Colorado	3,681	.039	223	1.861	5,483	11.467	17,269	17.336
Idaho	869	.235	(2)	------	596,231	21.413	84,734	.132
Kentucky	---------	------	------	------	------	------	----------	------
Michigan	---------	------	------	------	------	------	6,261,568	.073
Missouri	---------	------	------	------	------	------	----------	------
Montana	2,087	19.825	15,080	3.372	36,701	5.079	14,460,366	.230
Nevada	892,742	.010	------	------	53,990	2.647	10,355,163	.013
New Mexico	---------	------	31,709	.701	502	11.498	8,129,639	.011
New York	---------	------	------	------	------	------	----------	------
Oklahoma	(3)	(3)	------	------	------	------	(3)	(3)
Oregon	29	.448	(1)	(1)	[1] 1,187	[1] 7.361	13	1.538
Pennsylvania	(3)	(3)	------	------	------	------	(3)	(3)
South Dakota	2,031,500	.063	------	------	------	------	----------	------
Tennessee	---------	------	------	------	------	------	----------	------
Utah	1,279	.150	15,231	.375	178,583	1.229	32,167,851	.095
Washington	[3] 170,142	[3] 1.838	------	------	------	------	[3] 26,880	[3] .056
Wyoming	---------	------	------	------	210	.129	28	.893
Total	3,112,686	.159	204,891	.531	901,676	14.902	163,135,840	.078

State	Lead		Zinc		Lead-zinc, copper-zinc, and copper-lead-zinc		Total material	
	Short tons	Average ounces of silver per ton	Short tons	Average ounces of silver per ton	Short tons	Average ounces of silver per ton	Short tons	Average ounces of silver per ton
Alaska	39	21.769	--------	-----	----------	---	3,291	1.156
Arizona	12,603	.298	2,798	3.334	421,766	1.538	92,237,958	[6] .066
California	8,881	9.712	--------	-----	523	9.352	19,484	[4] 9.931
Colorado	5,534	5.570	260,860	.917	727,309	1.950	1,020,359	2.010
Idaho	221,502	14.643	139,720	.377	740,353	3.217	1,783,409	10.349
Kentucky	---------	-----	--------	-----	--------	-----	[5] 153,898	.013
Michigan	---------	-----	--------	-----	--------	-----	6,261,568	.073
Missouri	5,279,420	.057	--------	-----	--------	-----	5,279,420	.057
Montana	20,465	3.788	1,097,634	1.390	1,204	5.163	15,633,537	.333
Nevada	1,427	6.463	1,489	1.150	166,721	1.284	11,471,532	.044
New Mexico	1,210	3.231	402,641	.211	59,603	1.311	8,625,304	.033
New York	---------	-----	--------	-----	629,168	.018	629,168	.018
Oklahoma	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)
Oregon	---------	-----	--------	-----	--------	-----	1,229	7.137
Pennsylvania	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)
South Dakota	---------	-----	--------	-----	--------	-----	2,031,500	.063
Tennessee	---------	-----	--------	-----	1,520,755	.062	1,520,755	.062
Utah	11,280	18.560	23,642	.202	488,298	4.407	32,886,164	[6] .171
Washington	[3] 1,322	[3] .524	[3] 382,352	[3] .025	[3] 640,604	[3] .037	[3] [7] 1,858,016	.193
Wyoming	---------	-----	--------	-----	--------	-----	238	.218
Total	5,563,683	.713	2,311,136	.834	5,396,304	1.303	181,416,830	.219

[1] Gold-silver material combined with silver material to avoid disclosing individual company confidential data.
[2] Less than ½ unit.
[3] Oklahoma, Pennsylvania, and Washington combined to avoid disclosing individual company confidential data.
[4] Includes byproduct silver recovered from tungsten ore.
[5] Calcium fluorite ore.
[6] Includes byproduct silver recovered from uranium ore.
[7] Includes magnetite-pyrite ore from Pennsylvania.

Table 7.—Silver produced in the United States from ore and old tailings in 1965, by States and methods of recovery, in terms of recoverable metal

State	Total ore, old tailings, etc., treated (thousand short tons)[1]	Ore and old tailings to mills: Thousand short tons	Recoverable in bullion: Amalgamation (troy ounces)	Recoverable in bullion: Cyanidation (troy ounces)	Concentrates smelted and recoverable metal: Concentrates (short tons)	Concentrates smelted and recoverable metal: Troy ounces	Crude ore to smelters: Thousand short tons	Crude ore to smelters: Troy ounces
Alaska	3	3	831	-------	25	310	(2)	2,665
Arizona	92,366	91,731	3	-------	2,750,506	5,622,805	635	472,439
California	20	13	459	-------	4,880	104,276	7	88,767
Colorado	1,021	1,006	3,378	-------	156,303	1,695,970	15	351,589
Idaho	1,783	1,732	160	-------	216,543	18,394,363	51	62,281
Kentucky	196	196	-------	-------	11,748	1,931	-----	---------
Michigan	8,979	8,979	-------	-------	224,366	457,851	-----	---------
Missouri	5,279	5,279	-------	-------	195,160	299,522	-----	---------
Montana	15,634	15,488	3	-------	440,187	4,883,899	146	323,119
Nevada	13,392	13,295	657	7,797	319,834	452,519	97	45,953
New Mexico	8,625	8,536	-------	-------	374,441	253,289	89	34,183
New York	789	789	-------	-------	132,517	11,441	-----	---------
Oklahoma	(3)	(3)	(3)	-------	(3)	(3)	(3)	(3)
Oregon	1	1	5	-------	48	6,849	(2)	1,917
Pennsylvania	(3)	(3)	(3)	-------	(3)	(3)	(3)	(3)
South Dakota	2,032	2,032	88,136	40,835	---------	----------	-----	---------
Tennessee	5,528	5,528	-------	-------	304,888	94,142	-----	---------
Utah	32,887	32,653	-------	-------	914,727	5,131,978	234	503,592
Washington	[3] 3,002	[3] 3,000	[3] 73,699	-------	[3] 149,815	[3] 284,134	[3] 2	[3] 644
Wyoming	(2)	-------	-------	-------	---------	----------	(2)	52
Total	191,537	190,261	167,331	48,632	6,195,988	37,695,279	1,276	1,887,201

[1] Includes some nonsilver-bearing ores not separable.
[2] Less than ½ unit.
[3] Oklahoma, Pennsylvania, and Washington combined to avoid disclosing individual company confidential data.

Table 8.—Silver produced at amalgamation and cyanidation mills in the United States and percentage of silver recoverable from all sources

Year	Bullion and precipitates recoverable (troy ounces): Amalgamation	Bullion and precipitates recoverable (troy ounces): Cyanidation	Silver from all sources (percent): Amalgamation	Silver from all sources (percent): Cyanidation	Silver from all sources (percent): Smelting [1]	Silver from all sources (percent): Placers
1956–60 (average)	90,582	394,883	0.3	1.1	98.5	0.1
1961	90,527	214,956	.3	.6	99.0	.1
1962	89,203	101,887	.2	.3	99.4	.1
1963	89,777	99,289	.2	.3	99.4	.1
1964	91,401	120,894	.3	.3	99.3	.1
1965	167,331	48,632	.4	.1	99.5	(2)

[1] Crude ore and concentrate.
[2] Less than 0.5 percent.

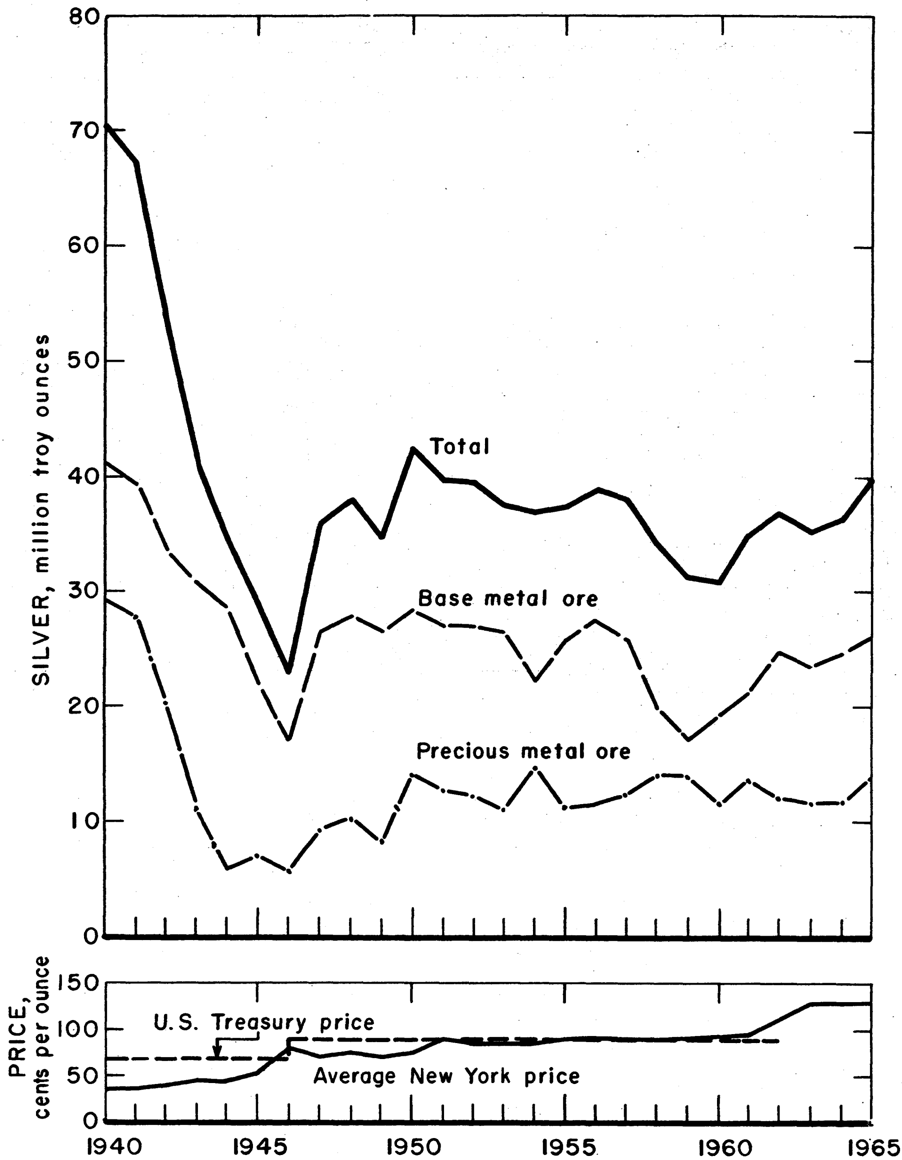

Figure 1.—Silver production in the United States and price per ounce.

CONSUMPTION AND USES

Net consumption of silver (see table 9) in the arts and industries was 137 million ounces, 11 percent more than in 1964, according to data compiled by the Bureau of the Mint. This was the highest consumption since the end of World War II. Imports and mine production furnished about two-thirds of domestic industrial requirements; the Treasury silver stock supplied most of the remainder.

Industrial silver consumption continued to increase, especially for sterling silverware and electrical and electronic products. Detailed data on end-use consumption were incomplete, but it was estimated that the manufacture of photographic materials and electrical and electronic products accounted for over one-half of the total silver used. The silverware industry consumed about one-quarter, and a large part of the remainder was used in fabricating brazing alloys and jewelry.

The quantity of sliver used in minting U.S. subsidiary silver coin increased 117.3 million ounces to 320.3 million ounces, an alltime high. U.S. coinage requirements constituted 85 percent of the total silver used in free world coinage. The 1965 gain was the seventh consecutive annual increase and, as in 1964, was due essentially to growth in the use of coin-operated vending and metering machines and to withdrawals of coins from circulation by collectors and speculators.

A silver-magnesium-nickel alloy improved the conductivity and insured the proper spring motion of light contactor blades. Contact buttons of silver-cadmium oxide are brazed to the blades without impairing their spring properties.

Silver-zinc batteries were chosen to meet the rigid power requirements for the *Voyager* space vehicle. Design studies indicated that an energy density of 30 watt-hours per pound, an 18-month activated life capability, and a capability of 30 charge-discharge cycles was necessary. Although the newer silver-cadmium and silver-zinc batteries have been successfully used in space vehicles, they have not yet been used to any appreciable extent in commercial products.

A silver-filled, polymer-in-solvent paint, Dynaloy 2510, was developed for high-temperature applications requiring electrical conductance. The paint, after air drying, is heated to 500° F to obtain maximum adhesion and conductivity. Coverage is 600 square feet per gallon and the operating temperature range is —60° to 1,500° F. Tests show the volume resistivity of the paint to be 0.02 ohm-centimeter for a film air-dried at 70° F and 0.003 ohm-centimeter for a film baked at 500° F.

Epoxy Products, Inc., developed a silver-filled conductive caulking compound, E-Kote No. 3202, for caulking seams in shielded rooms or filling imperfections in castings that are to be electroplated.

Ultrathin layers of silver were used to join aluminum thermal conditioning panels for the *Saturn* program. The components are bonded by eutectic diffusion under heat and pressure.

Silver-bearing catalysts were used by Shell Oil Co. in its hydrocracking processes for petroleum refining. The silver may be associated with tungsten or with a palladium group metal, ruthenium or rhodium. The hydrogenation and cracking parts of the catalyst are merged by a manufacturing process involving a hydrogel of the metal-salt solution.

A silver-rhenium alloy, developed by General Dynamics Corp. as a conductive lubricant, was particularly well-suited for sliding electrical contacts and can be used in a temperature range of —80° to 1,400° F.

Table 9.—Silver consumption in industry and the arts in the United States

(Thousand troy ounces)

Year	Issued for industrial use	Returned from industrial use [1]	Net industrial consumption
1956–60 (average)	135,847	39,067	96,780
1961	155,812	50,312	105,500
1962	180,812	70,412	110,400
1963	204,490	94,490	110,000
1964	196,600	76,100	[r] 123,000
1965	198,000	61,000	137,000

[r] Revised.

[1] Includes secondary materials (scrap) received by U.S. Mints and Assay Offices and by private refiners and dealers.

Source: U.S. Bureau of the Mint.

STOCKS

Heavy withdrawals of silver for monetary and commercial use continued during the year and Treasury stocks of bullion and coin were reduced approximately 414.4 million ounces to 803.6 million ounces by yearend. The withdrawals essentially comprised 320.3 million ounces for minting subsidiary coins; 77.4 million ounces issued to commercial consumers in exchange for silver certificates, and sales of 3.1 million ounces to other Government agencies for defense purposes. Silver received by the Treasury, including purchases at market value and coins withdrawn for re-

Table 10.—U.S. monetary silver
(Million troy ounces)

	1961	1962	1963	1964	1965
In the Treasury:					
Silver bullion	1,759.0	1,691.5	1,557.7	1,208.2	801.3
Silver dollars	100.7	72.7	22.1	2.3	2.3
Subsidiary coin	2.6	2.4	2.7	7.5	(1)
Total	1,862.3	1,766.6	1,582.5	1,218.0	[2] 803.6
Outside the Treasury:					
Silver dollars	276.4	303.6	352.9	372.6	372.6
Subsidiary coin	1,194.0	1,270.3	1,365.2	r 1,563.8	[3] 1,883.8
Total	1,470.4	1,573.9	1,718.1	r 1,936.4	2,256.4
Grand total	3,332.7	3,340.5	3,300.6	r 3,154.4	3,060.0

r Revised.
1 No breakdown is available between silver and nonsilver coins.
2 Excludes silver in subsidiary coin.
3 Estimated–Treasury data do not separate silver and nonsilver coins.

coinage, totaled 0.7 million ounces.

Part of the 77.4 million ounces withdrawn for commercial use went into industry stocks, but complete data on the magnitude of these stocks were not available. Silver held in Commodity Exchange warehouses at yearend totaled 2.1 million ounces compared with 2.5 million ounces at the end of 1964.

The ratio of the value of silver to the total value of gold and silver in the U.S. monetary stocks at yearend was 23 percent compared with 21 percent at the end of 1964.

PRICES

The price of silver in the New York market for prompt delivery, as quoted by Handy & Harman, remained unchanged at 129.3 cents per troy ounce throughout 1965, the second full year of price stability since 1960. The continued availability of Treasury silver through the redemption of silver certificates again provided an effective price ceiling at the monetary price.

Quotations on the Commodity Exchange for future deliveries continued to be substantially higher than the New York price for prompt delivery. About 155.4 million ounces was traded during 1965 at prices ranging from a low of 128 cents per ounce in June for nearby delivery of small amounts to a high in January of over 138 cents per ounce for a 12-month forward delivery. At yearend, open contracts for 12.8 million ounces were outstanding, compared with 30 million ounces at the same date in 1964.

The monetary price ratio of gold to silver remained unchanged at 27 to 1.

In the London market, the spot price of silver ranged from a low of 109.75d in June to a high of 112.125d in January, equivalent to 128.0 cents and 130.8 cents, respectively. Prices were depressed by some liquidation of accumulated stocks in the early part of the year. In the latter part of the year weakness in the pound sterling prompted hedging operations and a stronger market price. The average price for the year was 111.578d, equivalent to about 130.174 cents an ounce.

Prices for a 2-month delivery ranged from 109.750d (125.708 cents) to 113.500d (132.400 cents).

A shipment of 4.8 million ounces of silver to London from the U.S.S.R. in October was the first such shipment from that source since 1955.[4]

FOREIGN TRADE

U.S. trade in silver returned to a more normal pattern with imports exceeding exports. In 1964 the normal situation had been reversed with exports exceeding imports. Canada, Peru, and Mexico supplied nearly 70 percent of the total imports. Over 80 percent of total silver exported went to Canada and the United Kingdom.

4 Samuel Montagu & Co., Ltd. Annual Bullion Review, 1965.

Table 11.—U.S. exports of silver in 1965, by countries

Destination	Ore and base bullion		Refined bullion		U.S. coin value	Foreign coin value
	Troy ounces	Value	Troy ounces	Value		
North America:						
Bahamas	-------	-------	----------	----------	$66,000	---------
Bermuda	-------	-------	----------	----------	2,300	---------
Canada	5,660	$7,226	11,503,096	$14,868,493	150	$674,021
Mexico	-------	-------	----------	----------	5,900	---------
Netherlands Antilles	-------	-------	----------	----------	10,000	---------
Total	5,660	7,226	11,503,096	14,868,493	84,350	674,021
South America:						
Argentina	-------	-------	505	652	800	---------
Colombia	-------	-------	51,895	67,167	-------	---------
Total	-------	-------	52,400	67,819	800	---------
Europe:						
Austria	-------	-------	489,505	632,896	1,000	---------
Belgium-Luxembourg	274,800	357,240	----------	----------	2,100	---------
France	-------	-------	1,793,344	2,317,936	-------	---------
Germany, West	49,174	63,385	532,046	686,339	20,500	---------
Ireland	-------	-------	----------	----------	18,500	---------
Italy	-------	-------	40,771	53,000	-------	1,696,298
Netherlands	-------	-------	475,372	614,623	500	---------
Sweden	14,750	18,328	43,871	56,594	-------	1,400
Switzerland	-------	-------	642,128	830,227	69,253	---------
United Kingdom	138,599	180,181	21,010,568	27,308,951	500	---------
Total	477,323	619,134	25,027,605	32,500,566	112,353	1,697,698
Asia:						
Japan	54,497	70,301	2,544,734	3,290,167	66,992	---------
Nansei and Nanpo Islands	-------	-------	----------	----------	1,000	---------
Total	54,497	70,301	2,544,734	3,290,167	67,992	---------
Grand total	537,480	696,661	39,127,835	50,727,045	265,495	2,371,719

Table 12.—U.S. imports of silver in 1965, by countries

Country	Ore and base bullion		Refined bullion		U.S. coin value	Foreign coin value
	Troy ounces	Value	Troy ounces	Value		
North America:						
Bermuda					$1,050	$16,255
Canada	20,188,402	$25,574,077				377,909
Canal Zone	6,474	7,569	1,732	$2,078		
El Salvador	12,084	14,748				
Honduras	3,582,547	3,870,238				
Mexico	1,292,997	1,558,976	6,214,600	5,988,791	3,130	1,355,830
Netherlands Antilles	2,688	2,688			375	
Nicaragua	146,847	177,499				
Panama						12,520
Total	25,232,039	31,205,795	6,216,332	5,990,869	4,555	1,762,514
South America:						
Bolivia	2,095,231	2,263,692				
Brazil	4,827	5,691				
Chile	2,029,803	1,945,390				
Colombia	41,125	45,279				
Ecuador	38,974	48,486				
Peru	10,532,459	11,995,925	600,201	770,977		15,301
Venezuela	7,098	9,275				
Total	14,749,517	16,313,738	600,201	770,977		15,301
Europe:						
Austria					1,748	345
Bulgaria						364
France	202	261				13,340
Germany, West			804	1,037	1,070	876
Italy						3,370
Malta and Gozo					3,475	
Netherlands						560
Norway	7,043	9,095				287
Switzerland	322	418			2,626	4,370
U.S.S.R.						461
United Kingdom	72,166	64,615			6,119	5,977
Total	79,733	74,389	804	1,037	15,038	29,950
Africa:						
Kenya	428	554				
South Africa, Republic of	5,249,722	5,722,116				1,000
Tunisia						358
Uganda	222	273				
Zambia, Southern Rhodesia, and Malawi						490
Total	5,250,372	5,722,943				1,848
Asia:						
Aden						1,603
India	325,637	231,564				
Israel	3,470	3,738				739
Japan	3,027	3,677	50,179	63,299		28,143
Philippines	356,657	453,866	10,590	12,076		5,400
Turkey	33,923	43,134				
Total	722,714	735,979	60,769	75,375		35,885
Oceania:						
Australia	1,796,489	2,012,142				
New Zealand						529
Total	1,796,489	2,012,142				529
Grand total	47,830,864	56,064,986	6,878,106	6,838,258	19,593	1,846,027

Table 13.—Value of silver imported into and exported from the United States
(Thousand dollars)

Year	Imports	Exports	Year	Imports	Exports
1956-60 (average)	$106,181	$9,987	1963	67,281	40,022
1961	45,005	36,958	1964	64,394	141,397
1962	72,721	13,375	1965	62,903	51,424

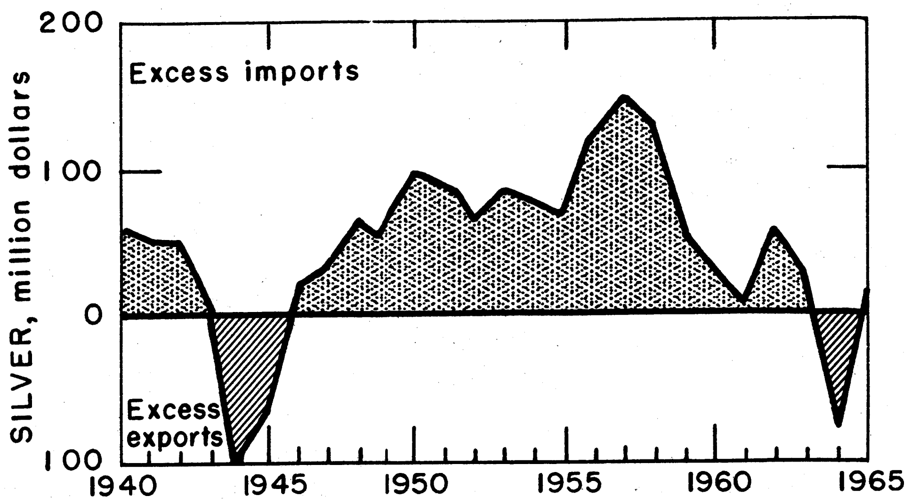

Figure 2.—Net imports or exports of silver.

WORLD REVIEW

World silver output was estimated at 251.0 million ounces, about 4.6 million ounces more than in 1964. Production gains in the United States, Canada, Japan, and Sweden more than offset declines in silver production in Mexico, Peru, and Australia. Western Hemisphere countries, Mexico, Peru, United States, and Canada contributed about 59 percent of the world output.

Consumption of silver in the arts and industries and in the coinage of the free world was estimated at 708.3 million ounces. Industrial uses consumed 333.6 million ounces, 42.7 million ounces more than in 1964, but coinage requirements aggregated 374.7 million ounces, 110.2 million ounces more than in 1964.[5] As in 1964, the gain in coinage consumption was due principally to an accelerated demand for subsidiary coins in the United States. The demand for silver coins also increased sharply in Canada and Italy but declined in France and Japan.

Free world net consumption exceeded new production by approximately 493 million ounces. Excluding U.S. coinage requirements the production deficit was about 173 million ounces, which was balanced by withdrawals from world stocks, chiefly the U.S. Treasury stock. Foreign government stocks contributed 17.0 million ounces, demonetized coin supplied 30.0 million ounces, liquidation of speculation holdings contributed 35.0 million ounces, and salvage and miscellaneous sources accounted for the remaining 7.1 million ounces.[6]

[5] Handy & Harman. The Silver Market in 1965. P. 22.
[6] Page 23 of work cited in footnote 5.

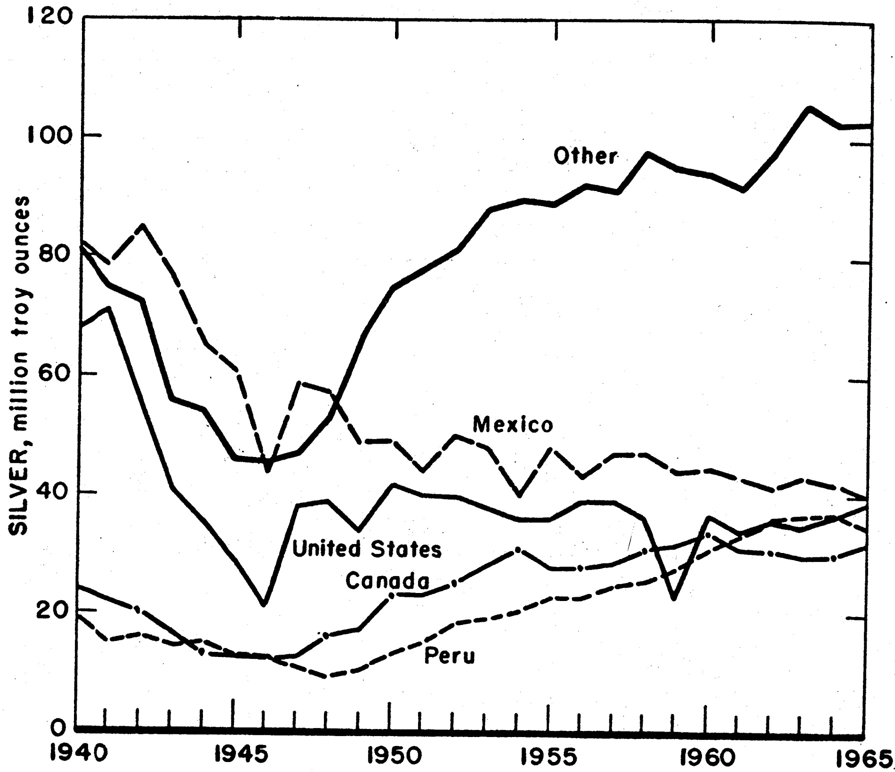

Figure 3.—World production of silver.

Table 14.—World production of silver, by countries [1] [2]

(Troy ounces)

Country	1961	1962	1963	1964	1965 [p] [3]
North America:					
Canada	31,381,977	30,669,028	29,839,756	[r] 29,902,611	31,917,243
Central America and West Indies:					
Guatemala	[4] 515,905	[r] 370,595	[r] 64,173	[5] 9,445	NA
Haiti	61,424	94,761	107,022	[r] 92,057	[e] 92,000
Honduras	3,544,702	3,179,653	[r] [e] 3,164,000	3,220,371	3,670,659
Nicaragua	417,253	500,050	405,252	332,370	380,377
Mexico	40,349,181	41,249,402	42,760,487	[r] 41,716,263	40,332,077
United States [6]	34,794,456	36,799,632	35,241,503	36,333,861	39,806,033
Total	[r] 111,064,900	[r] 112,863,100	[r] 111,582,200	[r] 111,607,000	116,198,400
South America:					
Argentina	1,430,675	2,086,101	[r] 1,928,530	[r] 1,945,795	2,256,500
Bolivia (exports)	3,901,203	3,759,193	[r] 4,869,037	4,822,611	4,115,295
Brazil	231,936	250,004	[r] 281,448	[r] 305,368	[e] 300,000
Chile	2,156,768	2,275,887	2,768,340	[r] 3,096,598	3,272,946
Colombia	127,943	131,599	106,279	130,353	115,866
Ecuador	101,190	127,739	121,784	117,126	69,966
Peru (recoverable)	34,161,707	32,930,783	36,800,350	37,043,217	35,255,411
Total	42,110,000	41,560,000	[r] 46,880,000	[r] 47,460,000	45,390,000
Europe:					
Austria	58,193	68,481	68,803	73,947	76,519
Czechoslovakia [7]	1,608,000	1,608,000	1,608,000	1,608,000	1,608,000
Finland	456,155	[r] 380,504	579,967	607,906	582,186
France	1,128,523	898,977	730,111	[r] 969,441	[e] 1,000,000
Germany:					
East [7]	4,800,000	4,800,000	4,800,000	4,800,000	4,800,000
West	1,879,436	1,925,701	[r] 2,067,068	[r] 2,062,599	1,992,189
Greece	113,396	[r] 138,730	157,539	[e] 157,000	144,678
Hungary [7]	64,300	64,300	64,300	64,300	64,300
Italy	973,139	[r] 918,933	[r] 996,673	[r] 1,073,770	1,093,125
Poland [7]	128,600	128,600	128,600	128,600	128,600
Portugal	48,258	52,920	48,419	[r] 48,773	47,100
Rumania [7]	643,000	643,000	643,000	643,000	643,000
Spain	4,526,599	5,684,123	4,955,201	[r] 2,314,853	[e] 2,320,000
Sweden	2,949,766	3,367,276	[r] 3,788,322	[r] 3,125,000	4,955,201
U.S.S.R. [e]	25,000,000	27,000,000	27,000,000	27,000,000	27,000,000
United Kingdom	4,744	514	----	----	----
Yugoslavia	3,454,083	3,750,931	3,791,923	4,036,879	4,148,057
Total [3]	47,800,000	51,400,000	[r] 51,400,000	[r] 48,700,000	50,600,000
Africa:					
Algeria [8]	300,000	275,000	[r] 255,000	[r] 295,000	295,000
Bechuanaland	39	33	21	1	----
Congo, Republic of the (Kinshasa, formerly Léopoldville)	3,457,877	1,595,513	1,097,176	1,480,252	1,538,413
Ghana (exports)	7,027	4,443	4,827	----	----
Kenya	40,731	50,160	52,422	47,702	21,247
Morocco	907,905	826,338	772,743	604,080	599,258
Rhodesia, Southern	106,801	83,540	83,742	88,463	[e] 95,470
South Africa, Republic of	2,288,279	2,549,206	2,736,868	2,916,660	3,131,580
South-West Africa (recoverable)	1,833,437	1,253,200	634,134	328,808	400,427
Sudan	----	----	----	40	----
Swaziland	103	132	120	130	130
Tanzania (exports)	64,144	23,959	22,669	25,329	22,865
Tunisia	69,767	[r] 24,627	[r] 9,581	12,635	33,758
Uganda (exports)	70	38	9	----	----
Zambia [9]	738,558	[r] 943,932	[r] 966,868	[r] 1,001,267	848,819
Total	9,810,000	[r] 7,630,000	[r] 6,640,000	[r] 6,800,000	6,990,000
Asia:					
Burma	1,743,302	1,940,037	[r] 2,075,282	1,355,000	[e] 1,700,000
China, mainland [7]	800,000	800,000	800,000	800,000	800,000
India	191,008	138,698	128,314	152,204	168,308
Indonesia	324,079	248,236	279,840	[e] 262,100	298,777
Japan	7,960,202	8,660,510	8,812,068	[r] 8,714,748	9,984,879
Korea:					
North [e]	640,000	640,000	640,000	640,000	640,000
South	460,341	412,912	444,002	404,456	434,003

See footnotes at end of table.

Table 14.—World production of silver, by countries [1] [2]—Continued

(Troy ounces)

Country	1961	1962	1963	1964	1965 p 3
Asia—Continued					
Philippines	812,793	675,570	r 838,304	r 907,504	932,944
Taiwan	r 77,300	r 80,136	61,440	60,633	87,315
Total e	13,000,000	13,600,000	r 14,100,000	r 13,300,000	15,000,000
Oceania:					
Australia	13,059,166	17,553,691	r 19,641,925	r 18,452,357	16,713,000
Fiji	37,712	38,935	46,870	60,564	60,470
New Guinea (including Papua)	r 30,246	r 24,510	23,696	r 23,206	19,664
New Zealand	805	416	286	141	55
Total	13,128,000	17,618,000	r 19,713,000	r 18,536,000	16,793,000
World total e	r 236,900,000	r 244,700,000	r 250,300,000	r 246,400,000	251,000,000

e Estimate. p Preliminary. r Revised. NA Not available.
[1] A negligible amount of silver is produced in Bulgaria, Mozambique, Panama, Thailand, and Turkey, no estimate has been included in the total.
[2] Data derived in part from the Yearbook of the American Bureau of Metal Statistics, the 52nd annual issue of Metal Statistics (Metallgesellschaft) Germany, and the 1964 annual issue of Minerais et Metaux (France).
[3] Compiled mostly from data available August 1966.
[4] Recoverable.
[5] U.S. imports.
[6] Revised to indicate mine production.
[7] Estimate, according to the 52nd annual issue of Metallgesellschaft (Germany) except 1965 which is an extension of the previous year's estimate.
[8] Estimated recoverable silver content of lead and zinc concentrates, according to the 1964 annual issue of Minerais et Metaux (France) except 1965.
[9] Partially recovered from refinery sludges and blister copper.

Australia.—A 9-percent decline in Australia's silver output was attributed partly to the effect of the prolonged labor strike against Mount Isa Mines Ltd. which ended on February 17. The quantity of silver-lead-zinc ore treated by Mount Isa dropped to 0.69 million from 0.94 million tons in the corresponding period of 1964. Silver recovered was 4.1 million ounces compared with 5.9 million ounces in 1964. The silver-lead-zinc ore reserve on June 30, 1965, was 27.1 million ounces averaging 5.6 ounces of silver per ton, 7.8 percent lead, and 5.9 percent zinc.[7]

The Zinc Corp. Ltd. treated 913,800 tons of lead-zinc-silver ore yielding 2.4 million ounces of silver in addition to lead and zinc, compared with 806,000 tons and 2.2 million ounces in 1964.

North Broken Hill Ltd. treated 499,500 tons of lead-zinc-silver ore averaging 7.9 ounces of silver per ton, 14.0 percent lead, and 11.6 percent zinc. Silver recovery was 94 percent. Ore reserves totaled 4.1 million tons. Broken Hill South Ltd. reported that it treated 278,700 tons of lead-zinc-silver ore averaging 6.8 ounces of silver per ton, 13 percent lead, and 11.5 percent zinc. Silver recovery was 92.4 percent. Ore reserves totaled 1.0 million tons.

Canada.—Silver production increased 2.0 million ounces and Canada continued to rank fourth among the world's silver-producing countries. About 80 percent of the production was a byproduct of base metal ores, 19 percent came from silver-cobalt and silver ores, and the remainder came from lode gold ores.

Exports of refined silver and silver in ores and concentrates aggregated 23.5 million ounces, compared with 20.1 million ounces in 1964.

Consumption of silver in the arts and industries in Canada was estimated at 5.3 million ounces, slightly more than in 1964. Approximately 23.9 million ounces was used in coinage, 10 million ounces more than in 1964.

United Keno Hill Mines Ltd. reported a sharp drop in production due largely to a critical shortage of skilled labor in the Yukon. Output from its group of mines in the Yukon Territory was 4.7 million ounces of silver from 146,900 tons of ore milled. The average grade of ore milled was 33.2 ounces of silver per ton, 7.1 percent lead, and 6.2 percent zinc. Exploration and development were curtailed and

[7] Mount Isa Mines Ltd. Annual Report 1965, pp. 5, 21.

were insufficient to maintain ore reserves which at yearend dropped to 386,000 tons averaging 32.2 ounces of silver per ton, 6.4 percent lead, and 6.5 percent zinc. This compares with a reserve of 459,000 tons averaging 34.1 ounces of silver per ton, 6.9 percent lead, and 6.2 percent zinc at the end of 1964.

The Consolidated Mining & Smelting Co. of Canada Ltd. reported production of 6.4 million ounces of silver of which 49 percent came from company mines. This was the lowest level of silver production in more than 10 years and represented an almost continuous decline in silver output since 1958. Ore production at both the Sullivan and Bluebell mines, which yield nearly all of the silver recovered from company mines, was curtailed during 1965.

Texas Gulf Sulphur Co. announced that it had removed three-fourths of the 6 million cubic yards of overburden at its Kidd Creek mine, destined to be one of the largest silver-producing mines in the world. Bulk pilot plant testing and construction of an ore concentrator and related facilities began in preparation for initial production of silver, copper, and zinc late in 1966. The company estimated that total investment in the development of the Kidd Creek project will be about $60 million. The company stated that silver will be recovered primarily in lead and copper concentrates. The zinc concentrate will contain some recoverable silver.

Table 15.—Canada: Geographical distribution of silver production

(Troy ounces)

Province or territory	1964	1965 p
Alberta	4	17
British Columbia	5,280,129	4,851,193
Manitoba	727,642	697,389
New Brunswick	1,469,192	2,914,600
Newfoundland	1,089,748	1,127,980
Northwest Territories	65,223	1,274,200
Nova Scotia	544,224	400,000
Ontario	9,929,858	11,203,506
Quebec	4,564,559	5,315,163
Saskatchewan	593,320	685,130
Yukon Territory	5,638,712	4,495,121
Total	r 29,902,611	32,964,299

p Preliminary. r Revised.

Source: Dominion Bureau of Statistics.

Honduras.—Production of silver was estimated at 3.7 million ounces. New York and Honduras Rosario Mining Co., which accounted for more than 90 percent of the total, reported that its production of silver at the El Mochito mine increased 11 percent to 3.4 million ounces. Tonnage of ore milled increased 26 percent over that of last year, but average grade of ore dropped 3.2 ounces to 21.6 ounces of silver per ton. Mill recovery of silver was up 0.6 percent to 91.2 percent as a result of finer grinding and by improved efficiency of ore pulps in the cyanide circuit. The company reported that ore reserves at yearend were 1.0 million tons averaging 18.6 ounces of silver and 0.02 ounce of gold per ton, and 7.6 percent lead, and 7.7 percent zinc.[8]

Japan.—Production of silver in Japan increased 15 percent compared with that of 1964. Industrial consumption of silver was about 25 million ounces, an increase of about 25 percent over that of 1964. Coinage consumption of silver dropped sharply from its abnormally high 1964 level to 0.5 million ounces in 1965. About 2.6 million ounces was imported from the United States. Government silver stocks at yearend were estimated at 26 million ounces compared with 23.5 million ounces in 1964.[9]

Mexico.—Silver output in Mexico, largely reflecting the decline in lead and zinc production with which most of the silver is associated, dropped nearly 3 percent to 40.3 million ounces. Exports also declined. One-half of the total silver exported went to West Germany and the United States. Exports included 3.4 million ounces of silver in demonetized Mexican coins.

Consumption of silver for industrial use increased 0.7 million ounces to 4.7 million ounces, and nearly 0.3 million ounces was used in minting 10-percent-silver 1-peso coins. At yearend government stocks were estimated at 18 million ounces, and it was estimated that 50 to 60 million ounces in old coins was still held by the public.[10]

San Francisco Mines of Mexico Ltd., reported production of 3.3 million ounces of silver in the fiscal year ending June 30, 1965, compared with 3.4 million ounces in the corresponding period of last year. About 917,000 tons was milled averaging 5.1 ounces of silver and 0.014 ounce of gold per ton, and 4.4 percent lead, 0.51 percent copper, and 6.9 percent zinc. De-

[8] New York and Honduras Rosario Mining Co. 85th Annual Report. 1965, pp. 14, 20.
[9] Page 18 of work cited in footnote 5.
[10] Pages 17–18 of work cited in footnote 5.

velopment at the San Francisco and Clarines mines totaled 21,626 feet. Drift footage was 12,578 of which 31 percent was in ore. Ore reserves dropped 2 percent to 6.4 million tons averaging 5.4 ounces of silver and 0.012 ounce of gold per ton, and 5.1 percent lead, 0.52 percent copper, and 7.4 percent zinc.[11]

The Fresnillo Co. reported that the Fresnillo and Naica mills treated 1.14 million tons of ore yielding 5.2 million ounces of silver in the fiscal year ending June 30, 1965. Ore reserves at the two major units were maintained and on June 30 were estimated at 4.6 million tons with a metal content of 0.01 ounce gold and 5.1 ounces silver per ton, and 4.9 percent lead, 4.7 percent zinc, and 0.3 percent copper. Operating costs averaged $8.52 per ton of ore treated, $0.16 less than in 1964 for the combined Fresnillo, Naica, and Zimapan Units.[12]

Peru.—Silver production was 1.8 million ounces less than in 1964 and Peru dropped from second to third rank among silver-producing countries. Exports of silver dropped 5.5 million ounces to 32.3 million ounces. Approximately 60 percent of the silver exports was in bars; the remainder was contained in ores and concentrates of lead, copper, and zinc.

Cerro de Pasco Corp. reported that production of silver from its operations dropped nearly 1 million ounces to 20.3 million ounces, 58 percent of Peru's total output. About 48 percent of the corporation's silver output came from its own or leased mines; the remainder was from purchased ores.

A 750-ton-per-day concentrator was being constructed at the Yauricocha mine to treat a mixed copper-zinc-lead-silver ore. The conversion from direct-shipping copper ore to production of a copper-lead and a zinc concentrate was expected to yield less copper and silver than in prior years, but will provide additional lead and zinc.

The corporation metallurgists developed a process for recovering silver from its oxidized near-surface silver-lead ores at the Cerro de Pasco mine. These potential reserves were being evaluated before construction of a pilot plant.

Progress on the twin-bore 7-mile Graton tunnel project, to permit mining below present working levels at the Casapalca mine was slowed by a continuous flow of hot water. As a result, completion will be delayed at least until mid-1968. The new 2,150-foot shaft at this mine advanced on schedule.[13]

United Kingdom.—Industrial consumption of silver in the United Kingdom increased about 2 million ounces over 1964 to 25 million ounces. Imports of silver aggregated 41.5 million ounces, 20 million of which came from the United States. About 9.4 million ounces came from the U.S.S.R., the first receipts from that source in 10 years. Australia supplied 0.2 million ounces. Approximately 2.7 million ounces was received from Peru and Mexico, and nearly all of the remaining 9.2 million ounces came from 16 other countries.[14]

Silver exports increased 16.8 million ounces to 38.1 million ounces. Italy, France, and West Germany were the largest buyers, taking 10.0 million, 9.2 million, and 8.1 million ounces, respectively. Approximately 4.5 million ounces was shipped to Belgium, 2.3 million ounces to the Netherlands, and the remaining 4.0 million ounces to 17 other countries.

Of an estimated 2.7 million ounces recovered from old coins, 1 million ounces was sold on the London market. Approximately 350,000 ounces was used in minting foreign coins.

TECHNOLOGY

An advanced theory on the formation of the photographic image, incorporating principles of solid-state physics as well as chemistry, was described.[15] The explanation of the silver-halide photographic process involves an understanding of holes and electrons, crystal dislocations, and charge transport, as well as reduction, solubility, and catalysis. The process is one of technology's earliest solid-state amplifiers, capable of a magnification factor of 10^9.

The Bureau of Mines began testing a method of recovering silver from spent photographic solution by passing the solu-

[11] San Francisco Mines of Mexico, Ltd. Report and Accounts for the year ended 31st December 1965, 1966, pp. 10–11.

[12] The Fresnillo Co. Annual Report for the year ended June 30, 1965, pp. 8–9.

[13] Cerro Corp. 1965 Annual Report. 1966, pp. 4–6.

[14] Work cited in footnote 4.

[15] James T. H., and John F. Hamilton. The Photographic Process. Internat. Sci. and Technol., No. 42, June 1965, pp. 38–44.

tion through columns containing steel wool and recovering the silver in metallic form on the steel wool by smelting.[16]

An atomic device, called the Silver Snooper, was developed by the Atomic Energy Commission and the Geological Survey for determining small quantities of silver and other chemical elements. The device, which is still being field tested, may be a useful tool for detecting silver and finding new silver resources. The device, based on the principle of neutron activation analysis, hurls neutrons at the ground some of which enter atoms of silver in the rock fragments making them radioactive. As the radioactive silver atoms disintegrate they are measured with a radiation detector.[17]

A rapid chemical method for determining trace amounts of silver in rocks and minerals was developed by scientists of the Geological Survey for use in geochemical exploration. The scientists report that silver in soils may be determined in quantities as low as 10 parts per billion by visual color-comparison techniques at the rapid rate of as many as 80 determinations per man-day.[18]

The development and production of an efficient and economic silver bimetal tape for use as a contact point material in the manufacture of the multicontact wire spring relay was described.[19] The new high-quality contact points were built up from a precious metal cap and a common metal base.

A silver-palladium alloy wire indicator, developed for measuring pellet-bed temperatures in a shaft furnace treating iron concentrates, overcomes the disadvantages of existing methods based on thermocouples. The silver-palladium wires, having specific melting points from 2,000° to 2,500° F, are enclosed in ceramic capsules and placed in Nichrome wire baskets filled with green pellets. The condition of the alloy wires after the firing cycle reveals the maximum temperature attained during induration of pellets.[20]

X-ray diffraction and electrochemical studies of the development and effects of oxides on silver electrodes were described.[21] These oxides comprise the positive active material of charged silver-zinc and silver-cadmium storage batteries. Surface area and crystal size, which depended on current density, were shown to be important in determining the charge-discharge characteristics of the silver electrode.

Researchers in the Bureau of Mines have demonstrated that the addition of a small quantity of copper to a refractory silver ore greatly improved the silver recovery attained by the segregation-froth flotation process. By addition of 1 percent copper as copper oxide to a manganese oxide-silver ore, silver volatilization loss was reduced from 25 to 4 percent and silver recovery increased from 50 to 81 percent. Segregation-flotation treatment of the copper-spiked ore, which assayed 14 ounces of silver per ton, enabled production of a concentrate that contained 182 ounces of silver per ton.

Scientists at the National Bureau of Standards found that silver alloys atomized into tiny droplets have improved properties for dental applications. When mixed with mercury, the resulting amalgams have high strength and adapt more readily to a tooth cavity than conventional amalgams, thus providing better results, particularly in areas difficult to reach.

The Southwest Research Institute developed a technique of low-level explosive forming, using a silver acetylide-silver nitrate in acetone-sprayed coating. The explosive material can be used for laboratory studies of armor plate as well as for forming small and intricate shapes. After drying on a work piece, the coating is detonated by a high-intensity light pulse. The technique was developed as part of a program for studying impulsive loading in nuclear blasts.

The Army's Institute of Exploration Research, working with the ion conductivity of silver-iodide pellets, discovered that tiny batteries could be made by depositing thin

[16] Bureau of Mines. Mines Bureau Sees Chance to Save Silver Now Being Wasted in Film Processing. News release, Nov. 25, 1965, 2 pp.

[17] Geological Survey. Atomic Silver-Detecting Device Being Field-Tested by Geological Survey. News Release, Aug. 21, 1965, 2 pp.

[18] Nakagawa, H. M., and H. W. Lakin. A Field Method for the Determination of Silver in Soils and Rocks. U.S. Geol. Survey Professional Paper 525-C, 1965, pp. C172-C175.

[19] Clark, Richard E. The Welding of Silver Bimetal Contact Tape. The West. Electric Eng., v. 9, No. 2, April 1965, pp. 30-35.

[20] Hitzrot, H. W., L. V. Fegan, and R. A. Limons. Silver-Palladium as an Indicator of Thermal Gradients in Pellet Induration. Trans., Soc. Min. Eng., v. 232, No. 2, June 1965, pp. 95-99.

[21] Wales, Charles P., and Jeanne Burbank. Oxides on the Silver Electrode. II. X-Ray Diffraction Studies of the Working Silver Electrode. J. Electrochem. Soc., v. 112, No. 1, January 1965, pp. 13-16.

films of silver and platinum or palladium on opposite sides of the iodide pellet. The solid-state battery had good chemical stabilty and resistance to temperature changes but had higher internal resistance than liquid electrolytes. The platinum cells produced a flash current of 100 microamperes per square centimeter of electrode area, approximately three times the current delivered by the best solid-electrolyte systems previously known. A flash-current value of 160 was obtained with the palladium cell.

Several patents were issued for processes of manufacturing photographic film and for techniques of preparing and applying silver halide emulsions and dyes on base materials. Other patents were issued for methods of electroplating, replacement plating, and cladding silver on other metals and nonmetals; and for preparing and applying silver catalysts in various processes.

Slag

Iron-Blast-Furnace

By William R. Barton [1]

Demand for iron-blast-furnace slag products in 1965 approximately equaled available slag supplies. Because slag products showed good prospects for a continued rapid increase in demand, open-hearth steel slag for supplemental slag aggregate use gained increasing interest.

Table 1.—Iron-blast-furnace slag processed in the United States, by types
(Thousand short tons and thousand dollars)

Year	Air-cooled				Granulated		Expanded		Total	
	Screened		Unscreened							
	Quantity	Value	Quantity	Value	Quantity	Value [1]	Quantity	Value	Quantity	Value
1956–60 (average)	23,042	$37,430	1,590	$1,173	3,643	$1,503	2,871	$8,276	31,146	$48,382
1961	19,250	33,906	1,493	985	2,663	1,367	2,275	6,806	25,681	43,064
1962	18,496	32,680	312	340	2,385	1,258	2,249	6,615	23,442	40,893
1963	18,290	32,408	689	624	2,461	1,663	2,251	6,703	23,691	41,398
1964	20,969	36,458	621	599	2,840	2,170	2,426	7,273	26,856	46,500
1965	22,531	39,624	1,402	1,270	3,550	2,674	2,596	7,879	30,079	51,447

[1] Excludes value of slag used for manufacturing hydraulic cement.
Source: National Slag Association.

DOMESTIC PRODUCTION

Production of 88.8 million tons of pig iron in 1965 yielded an estimated 31 million tons of iron-blast-furnace slag. Almost all of it was supplied to slag processors. Output of processed slag increased 12 percent in tonnage and 10 percent in value in 1965.

[1] Commodity specialist, Division of Minerals.

Table 2.—Iron-blast-furnace slag processed in the United States, by States
(Thousand short tons and thousand dollars)

Year and State	Screened air-cooled		All types	
	Quantity	Value	Quantity	Value
1964:				
Ohio	3,880	$7,274	4,973	$9,648
Pennsylvania	4,805	9,069	6,242	11,123
Illinois, Indiana, Michigan	5,611	8,809	7,361	11,642
Other States [1]	6,673	11,306	8,280	14,087
Total	20,969	36,458	26,856	46,500
1965:				
Ohio	5,062	9,271	6,598	12,460
Pennsylvania	5,442	10,343	7,633	14,384
Illinois, Indiana, Michigan	4,995	8,103	7,601	11,291
Other States [1]	7,032	11,907	8,247	13,312
Total	22,531	39,624	30,079	51,447

[1] Alabama, California, Colorado, Kentucky, Maryland, Minnesota, New York, Texas, Utah, and West Virginia.

Source: National Slag Association.

Thirty-six companies, compared with 38 in 1964, reported operation of 59 air-cooled, 18 expanded, and 17 granulated slag plants at which 30.1 million tons of slag was processed.

Slag-encrusted iron, reclaimed magnetically by slag processors for remelting amounted to 555,699 tons compared with 504,962 tons in 1964.

The industry's 1,611 plant and yard employees worked a total of 3,969,694 man-hours in 1965 without a disabling injury. Production per man-hour was 7.58 tons compared with 7.01 tons in 1964.

Table 3.—Shipments of iron-blast-furnace slag in the United States, by method of transportation

Method of transportation	1964		1965	
	Thousand short tons	Percent of total	Thousand short tons	Percent of total
Rail	5,720	22	6,930	23
Truck	19,920	74	22,508	75
Waterway	609	2	641	2
Total shipments	26,249	98	30,079	100
Interplant handling [1]	607	2	----	---
Total processed	26,856	100	30,079	100

[1] Confined mainly to granulated slag used in manufacturing cement.

Source: National Slag Association.

CONSUMPTION AND USES

Of all slag sold or used, more than 92 percent went to products used in construction or maintenance of roads, buildings, railroads, or airports, or into construction accessories such as mineral wool. The balance was put to other uses such as agricultural slag or sewage trickling filter medium.

Table 4.—Air-cooled iron-blast-furnace slag sold or used by processors in the United States, by uses

(Thousand short tons and thousand dollars)

Year and use	Screened			
	1964		1965	
	Quantity	Value	Quantity	Value
Aggregate in—				
Portland-cement concrete construction	3,254	$5,935	3,158	$5,835
Bituminous construction (all types)	3,451	6,326	4,459	8,008
Highway and airport construction [1]	[2] 8,348	[2] 14,604	[2] 8,683	[2] 15,425
Manufacture of concrete block	588	1,065	774	1,502
Railroad ballast	3,211	4,248	3,801	5,073
Mineral wool	479	865	423	766
Roofing slag—				
Cover material	361	1,112	397	1,164
Granules	43	253	45	259
Sewage trickling filter medium	83	146	11	19
Agricultural slag, liming	4	8	2	4
Other uses	[3] 1,147	[3] 1,896	[3] 778	[2] 1,569
Total	20,969	36,458	22,531	39,624

[1] Other than in portland-cement concrete and bituminous construction.
[2] In addition 592,000 tons of unscreened air-cooled slag valued at $579,000 in 1964; 987,000 tons valued at $845,000 in 1965.
[3] In addition 29,000 tons of unscreened air-cooled slag valued at $20,000 in 1964; 415,000 tons valued at $425,000 in 1965.

The use of slag as aggregate material in highway construction was reviewed in an authoritative article.[2] The intrinsic properties which make slag a superior aggregate material were reviewed. Among the major highway uses discussed were in water-bound slag macadam, earth-filled macadam, traf-

[2] Bauman, E. W. Blast Furnace Slag. American Road Builder, v. 42, No. 1, January 1965, pp. 10–11.

Table 5.—Granulated and expanded iron-blast-furnace slag sold or used by processors in the United States, by uses

(Thousand short tons and thousand dollars)

Use	1964				1965			
	Granulated		Expanded		Granulated		Expanded	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Highway construction (base and subgrade)	1,176	$1,426	----	----	1,394	$1,725	----	----
Fill (road, etc.)	322	217	----	----	365	355	----	----
Agricultural slag, liming	57	98	----	----	67	108	----	----
Manufacture of hydraulic cement	905	NA	----	----	953	NA	----	----
Aggregate for concrete-block manufacture	196	283	2,371	$7,083	243	255	2,519	$7,611
Other uses	184	146	55	190	528	231	77	268
Total	2,840	[1] 2,170	2,426	7,273	3,550	[1] 2,674	2,596	7,879

NA Not available.
[1] Excludes manufacture of hydraulic cement, value not available.
Source: National Slag Association.

fic-bound macadam, rumble strips, open-joint slag backfill drains, and as a non-skid slag bituminous surfacing. The question of using or blending open-hearth steel slags was also covered in the paper. Although iron-blast-furnace slag availability is increasing, demand for slag has been increasing even faster. Members of the National Slag Association are directing increased attention to open-hearth steel slag as a means of extending slag supplies. The association reported strong indications that properly processed and placed steel slag can be a useful and economical aggregate for uses such as roadway bases, highway shoulders, and as aggregate in bituminous mixtures. A case history of slag used for deslicking slippery pavement was published.[3] Limestone aggregate in an asphalt surface polished under heavy traffic created dangerous, slippery surfaces. Slag screenings in an asphalt slurry were an effective treatment. Sprayed on the slick highways, the slurry seal established improved skid resistance, good crack penetration, good contrast to paint markings, less tire noise, and good appearance at satisfactory cost.

PRICES

The average value reported for total slag produced was $1.71 per ton compared with $1.73 per ton in 1964. However, be-

[3] Ray, J. L. A County's Experience With Slurry Seal. Public Works, March 1965, pp. 84–85.

Table 6.—Average value of iron-blast-furnace slag sold or used by processors in the United States, by uses

(Per short ton)

Year and use	Air-cooled				Granulated		Expanded	
	Screened		Unscreened					
	1964	1965	1964	1965	1964	1965	1964	1965
Aggregate in—								
Portland-cement concrete construction	$1.82	$1.85	----	----	----	----	----	----
Bituminous construction (all types)	1.83	1.80	----	----	----	----	----	----
Highway and airport construction [1]	1.75	1.78	$.98	$.86	[2] $1.21	[2] $1.24	----	----
Manufacture of concrete block	1.81	1.94	----	----	1.44	1.05	$2.99	$3.02
Railroad ballast	1.32	1.33	----	----	----	----	----	----
Mineral wool	1.81	1.81	----	----	----	----	----	----
Roofing slag—								
Cover material	3.08	2.93	----	----	----	----	----	----
Granules	5.83	5.75	----	----	----	----	----	----
Sewage trickling filter medium	1.76	1.70	----	----	----	----	----	----
Agricultural slag, liming	1.80	1.70	----	----	1.70	1.61	----	----
Fill (road, etc.)	----	----	----	----	.67	.97	----	----
Other uses	1.65	2.02	.71	1.03	.79	.44	3.45	3.47

[1] Other than in portland-cement and bituminous construction.
[2] Base and subgrade material.

Source: National Slag Association.

cause slag with diverse characteristics is produced for a variety of uses, values ranged from $0.44 per ton for material which received little processing to $5.75 per ton for smaller quantities of slag which required a high degree of screening, sizing, and washing to meet rigid specifications.

Prices for crushed slag (air-cooled, screened) used as aggregate are published regularly for major U.S. market areas in Engineering News-Record. In December, 1½-inch slag sold for an average $2.38 per ton and ¾-inch slag sold for an average $2.39 per ton. Respective averages a year earlier were $2.37 and $2.38. Highest December 1965 prices were quoted for Atlanta, $3.90, and lowest for New Orleans, $1.95.

TECHNOLOGY

Several British slag developments were of interest to producers in this country.[4] Slag-ceram is a product made by heating a mix of iron-blast-furnace slag, sand, and a nucleating agent such as chromium, titanium, or iron. From this, bricks, tiles, and wallblocks can be made which can be given a polish or enameled finish in a variety of colors and textures. The material is strong, tough, and extremely resistant to abrasion. It can also be foamed to make a lightweight insulating material. A pilot plant for slag-ceram production was placed in operation in Middlesbrough, England. Other British developments included a road-surfacing mixture containing both crushed and granulated blast-furnace-slag, gypsum or lime, and bitumen or tar and also the use of granulated slag as a sandblasting grit.

Several patents were issued for either making expanded or foamed slag products or insulating materials containing expanded slag as an ingredient.[5] Cementitious formulas containing granulated blast-furnace-slag as an ingredient were also patented.[6] One patent was for a portland cement-based product using slag at a latent hydraulic binder, the other was for an autoclaved, inorganic fiber reinforced cement based on slag mixed with silica, gypsum, and calcium silicate.

The efficient handling system of a British slag firm was described.[7] Rubber-tired front-end loaders are used for slag loading and handling. Slag piles, some of which are 40 years old, are ripped by a bulldozer which offers savings over drilling and blasting as well as increasing production. A fleet of 200 trucks is used to transport finished material from the plant.

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[4] Convidon, A. An Improved Composition for Road Surfacing. British Pat. 981,503, Jan. 27, 1965, 3 pp.

South African Mining and Engineering Journal (Johannesburg). Building Material From Furnace Slag. V. 76 part II, No. 3785, Aug. 20, 1965, p. 1927.

[5] Gajardo, V. H., and J. S. Dennis (assigned to United Clay Mines Corp., Trenton, N. J.). Thermal Insulating Material, Composition and Process for Making the Same. U.S. Pat. 3,203,813, Aug. 31, 1965.

Rodis, Frany (assigned to Knapsack-Griesheim Aktiengesellschaft, Knapsack, West Germany). Process for Producing a Highly Porous Mass From Short Slag. U.S. Pat. 3,203,776, Aug. 31, 1965.

Tinker, C. D. Light Weight Aggregate and Process of Making It. U.S. Pat. 3,215,542, Nov. 2, 1965.

Wolf, E. (assigned to Schlosser & Co., G.m.b.H., Michelbach, West Germany). Mixing Device for Admixing Additives to a Melt. U.S. Pat. 3,223,508, Dec. 21, 1965.

[6] Frankert, O. P. (assigned to F. L. Smidth and Co., New York). Method of Making Cement. U.S. Pat. 3,183,106, May 11, 1965.

Yang, J. C. S., and E. F. Osborn (assigned to Johns-Manville Corp., New York). Cementitious Product. U.S. Pat. 3,202,522, Aug. 24, 1965.

[7] Steel Times (London). Slag Handling Economics. V. 191, No. 5072, Oct. 1, 1965, pp. 436–437.

Sodium and Sodium Compounds

By William H. Kerns [1]

Natural sources of sodium carbonate (soda ash) supplied a greater portion of the total national requirements of this basic manufactured and natural chemical than ever before. The Green River area of Wyoming was the center of the increased activity in expanding plants for processing and in new property development or acquisition. Major plant enlargements were completed and plans were announced for additional plant capacity expansions, and several major chemical companies conducted work on their holdings or acquired property in the Green River area. Primarily because of the increased natural soda ash output, total production (manufactured and natural soda ash) advanced to a record high.

Total output of sodium sulfate (salt cake) increased substantially to a new high. Of this total, more than half was recovered as a byproduct of chemical processes, and the remainder was produced from naturally occurring brines and semidry lake beds in California, Texas, and Wyoming.

DOMESTIC PRODUCTION

Total production of sodium carbonate, including manufactured and natural soda ash, was 6.4 million tons in 1965, 3.2 percent above the previous record of 1964.

Synthetic or manufactured soda ash, produced at 11 eastern and midwestern plants, supplied 77 percent of the total quantity of soda ash sold or used by producers. These plants, two each in Louisiana, Michigan, Ohio, and Texas, and one each in New Jersey, New York, and Virginia, were strategically situated both in regard to mineral raw materials supplies of salt and limestone and to chemical markets. Their estimated annual production capability of manufactured soda ash was 5.85 million tons.

Natural soda ash, produced by five plants from natural lake brines at three operations in California, and underground bedded trona (sodium sesquicarbonate) deposits at two operations in Wyoming, supplied the remaining 23 percent of the total sodium carbonate output. Production of natural soda ash again was the source of a greater portion of the total market and supplied a major part of the annual increase in total soda ash requirements, as it has each year during the last decade.

In California, American Potash & Chemical Corp. and Stauffer Chemical Co. recovered sodium carbonate and other minerals from natural brines of Searles Lake at the Trona and Westend plants, respectively. Pittsburgh Plate Glass Co. produced sodium carbonate from Owens Lake brine at its plant near Bartlett.

In Wyoming, FMC Corp., which in 1947 was the pioneer in mining and processing trona from the extensive underground deposits near Green River, was again the largest U.S. producer of natural soda ash. Soon after a program for increasing plant capacity by 85,000 tons to 835,000 tons of soda ash per year was completed, company officials announced in May that the company would begin immediately an expansion project on the Westvaco plant to enlarge its capacity to 900,000 tons per year. The latest plant expansion was to be completed by early 1966. Then, in December another announcement was made

[1] Commodity specialist, Division of Minerals.

Table 1.—Manufactured sodium carbonate produced and natural sodium carbonates sold or used by producers in the United States

(Thousand short tons and thousand dollars)

Year	Manufactured soda ash (ammonia-soda process) [1]	Natural sodium carbonates [2]	
	Quantity	Quantity	Value
1956–60 (average)	4,689	696	$18,433
1961	4,516	806	20,444
1962	4,607	978	24,330
1963	4,682	1,119	27,616
1964	r 4,948	1,275	30,451
1965	p 4,931	1,494	34,717

p Preliminary.
r Revised.
[1] Includes quantities used to manufacture caustic soda, sodium bicarbonate, and finished light and dense soda ash.
[2] Soda ash and trona (sesquicarbonate).

Table 2.—Sodium sulfate produced and sold or used by producers in the United States

(Thousand short tons and thousand dollars)

Year	Production (manufactured and natural)			Sold or used by producers (natural only)	
	Salt cake (crude)	Glauber salt (100 percent $Na_2SO_4 \cdot 10H_2O$	Anhydrous refined (100 percent Na_2SO_4)	Quantity	Value
1956–60 (average)	717	110	284	373	$7,218
1961	780	64	327	466	9,296
1962	[1] 826	([2])	368	458	9,092
1963	[1] 837	([2])	396	435	8,392
1964	r [1] 926	([2])	r 389	575	10,989
1965	p [1] 1,003	([2])	p 389	620	11,024

p Preliminary.
r Revised.
[1] Includes glauber salt converted to 100 percent Na_2SO_4.
[2] Included with salt cake (crude).

that the company would further expand the Westvaco production facilities to a capacity of 1.25 million tons per year. Scheduled for completion by the fourth quarter of 1966, the added capacity will make the plant the largest single soda ash producing facility in the world, and the company will become the second largest producer of soda ash in the United States.

Stauffer Chemical Co., which in 1962 opened the second mine and processing plant in the Green River area and in 1964 doubled its plant capacity to 400,000 tons of refined soda ash per year, announced plans in December 1965 to again double the production capacity at this operation, Big Island mine and plant, to 800,000 tons per year. Completion of the latest expansion program was scheduled for the fall of 1967.

Allied Chemical Corp., a major U.S. producer of synthetic soda ash and the third company to enter the natural soda ash-producing field of mining and refining trona from underground beds in the Green River area, completed its shaft to below 1,500 feet, started developing its trona deposit for mining, and began constructing a pilot plant scheduled for completion in the spring of 1966. Allied proposed a plant with a capacity of 300,000 tons per year of refined soda ash.

Other chemical companies, that were interested in trona production, acquired trona mining rights on lands, or conducted core drilling in the Green River area, included Texas Gulf Sulphur Co., Phillips Petroleum Co., Duval Corp., Diamond Alkali Co., American Potash & Chemical Corp., and Olin Mathieson Chemical Corp.

Total production of sodium sulfate (manufactured and natural salt cake) increased 6 percent to 1.4 million tons. More than half (55 percent compared with 56 percent in 1964) of this total salt cake output was recovered as byproducts of chemical processes that produced rayon, cellophane, hydrochloric acid, sodium bichromate, boric acid, phenols, and miscellaneous chemicals at 37 plants in 17 States. The remainder (45 percent compared with 44 percent in 1964) of the total salt cake output was produced from natural sources at four operations each in California and Texas and one in Wyoming.

In California, American Potash & Chemical Corp. and Stauffer Chemical Co. recovered sodium sulfate from Searles Lake brines at Trona and Westend, respectively, and United States Borax & Chemical Corp. and Stauffer Chemical Co. recovered sodium sulfate as coproducts at plants in Wilmington and San Francisco, respectively.

In Texas, Ozark-Mahoning Mining Co. recovered salt cake from subterranean brines at its Brownfield and Monahans operations throughout 1965 and at its Seagraves operation for the last 5 months of the year. In September, American Cyanamid Co. completed and placed in operation a unit to recover sodium sulfate from waste water from its Fort Worth plant that manufactures catalysts for the petroleum and chemical industries. The unit not only provided for the recovery of a valuable byproduct but upgraded the quality of the water discharge to the Trinity River. In Wyoming, William E. Pratt recovered a small quantity of sodium sulfate from semidry lake beds near Casper.

Sodium metal production increased 8 percent from 139,313 tons (revised) in 1964 to 149,946 tons in 1965. Three companies produced sodium and its coproduct, chlorine by electrolysis of molten salt at five plants: E. I. du Pont de Nemours & Co., Inc., with plants at Niagara Falls, N.Y., and Memphis, Tenn.; Ethyl Corp., with plants at Baton Rouge, La., and Houston, Tex.; and National Distillers & Chemical Corp. at Ashtabula, Ohio.

CONSUMPTION AND USES

Consumption and use of sodium carbonate, sodium sulfate, and sodium metal followed closely the patterns of the past 5 years. About 44 percent of the total output of sodium carbonate was used in producing glass, 26 percent in chemicals, 9 percent in pulp and paper, 5 percent in soap detergents, 4 percent in alumina and for water treatment, and 8 percent for miscellaneous purposes. Despite sizable inroads of plastics and other materials into the container markets, an increased production of nonreturnable glass beverage bottles maintained the quantity of sodium carbonate used in glassmaking. Use of caustic soda rather than soda ash in glassmaking was reported to have several advantages: (1) An immediate fluxing reaction due to intimate wetting of individual silica grains, (2) a lower melting temperature, and (3) lower fuel costs for same tank flow.[2] Substitution of caustic soda for soda ash in any large quantities for this use would have a major effect on the total soda ash demand because the use of soda ash in glassmaking is one of the principal uses of this commodity.

An estimated 70 percent of the sodium sulfate output was consumed in manufacturing kraft paper. Kraft paper production growth was sufficient to offset the decline in salt cake consumption per ton of paper produced, which resulted from increased efficiencies and the recovery and reuse of sodium sulfate in the process. Sodium sulfate also was used in manufacturing glass, ceramic glazers, detergents, stockfeeds, dyes, textiles, medicines, and miscellaneous chemicals.

Metallic sodium was used chiefly in producing tetraethyl lead (TEL) and tetramethyl lead (TML), two compounds added in small quantities to motor fuels to increase their antiknock characteristics. TEL was reported to have 85 to 90 percent of the antiknock market and TML to have the remaining 10 to 15 percent. Use rate of these antiknock compounds, now up to an average 2.3 grams per gallon in premium-grade gasoline, gained steadily as refiners increased their sales of more top-line fuels. Premiums made up 35 percent of the gasoline market of 4.5 million barrels per day, compared with 31 percent 2 years ago.[3] Other primary uses of metallic sodium include metal descaling, ore reduction, and manufacture of such sodium compounds as the peroxide, hydride, amide, cyanide, borohydride, and

[2] Ceramic Industry. How to Use Caustic Soda in Glass. V. 85, No. 5, November 1965, pp. 60–61.

[3] Chemical Week. $300-Million Market on Wheels. V. 96, No. 15, Apr. 10, 1965, pp. 71–72, 74, 76.

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other chemicals. Sodium is also used to cool nuclear reactors, atomic piles, and the valves in some internal combustion engines.

PRICES

Prices quoted for sodium carbonate, sodium sulfate, and metallic sodium by Oil, Paint and Drug Reporter in 1965 were unchanged from those quoted at the close of 1958. Dense soda ash (58 percent Na_2O) in carlots and at the works sold for $1.60 per 100 pounds in bulk and $1.90 in paper bags. On the same basis light soda ash was quoted at $1.55 and $1.85 respectively.

Domestic salt cake (100 percent Na_2SO_4) in bulk and at the works sold for $28 per ton. Sodium sulfate of technical detergent and rayon grade sold for $34 per ton in bulk at the works and for $38 per ton in bags and in carlots. Technical anhydrous sodium sulfate was priced at $56 per ton in bags and carlots.

Sodium metal in bulk, in tank cars, at works, was quoted at $0.17 per pound. Fused metallic sodium in lots of 18,000 pounds or more at the works was $0.195 per pound and in 5- or 12-pound bricks on the same basis was quoted at $0.21 per pound.

FOREIGN TRADE

Exports of sodium carbonate represented 4 percent of the U.S. total output of manufactured and natural sodium carbonate and were practically the same as in 1964. Of the total exports 39 percent went to Canada, 36 percent to Mexico, 7 percent to the Republic of Korea, 6 percent to Venezuela, 3 percent each to Argentina and New Zealand, 2 percent to South Viet-Nam, 1 percent to Colombia, and the remaining 3 percent to 47 other countries.

Imports of sodium carbonate were negligible.

Table 3.—U.S. exports of sodium carbonate and sodium sulfate
(Thousand short tons and thousand dollars)

Year	Sodium carbonate		Sodium sulfate	
	Quantity	Value	Quantity	Value
1956–60 (average)	166	$5,913	25	$885
1961	132	4,045	32	992
1962	152	4,693	51	1,486
1963	184	5,722	45	1,379
1964	r 276	r 8,535	44	1,320
1965	277	9,030	13	415

r Revised.

Table 4.—U.S. imports for consumption of sodium sulfate
(Thousand short tons and thousand dollars)

Year	Crude (salt cake)		Anhydrous		Total [1]	
	Quantity	Value	Quantity	Value	Quantity	Value
1956–60 (average)	110	$2,259	3	$82	113	$2,341
1961	193	4,089	3	64	196	4,153
1962	181	3,646	7	122	188	3,768
1963	159	3,084	1	27	160	3,111
1964	288	5,035	2	29	290	5,064
1965	261	4,521	12	242	273	4,763

[1] Includes glauber salt, as follows: 1958, 12 tons ($830); 1959, 227 tons ($4,839); 1960, 7 tons ($479); 1961–62 none; 1963, 3 tons ($285); 1964, 4 tons ($355); 1965, 1 ton ($262).

Sodium sulfate exports declined drastically so that they were less than a third of those in 1964 and accounted for less than 1 percent of the sodium sulfate produced (manufactured and natural) and sold and used in the United States during 1965. Exports to Canada dropped from over 20,000 tons in 1964 to nearly 12,000 tons in 1965 primarily because sodium sulfate production in Canada increased. Exports to Mexico dropped from over 21,000 tons in 1964 to about 100 tons in 1965. Exports to Canada accounted for 93 percent of total exports in 1965; Mexico, Venezuela, Philippines, and New Zealand each 1 percent, and 24 other countries the remaining 3 percent.

Imports of sodium sulfate declined 6 percent, compared to those of 1964, but represented one-fifth of the U.S. total output of manufactured and natural sodium sulfate. Nearly half of the imports came from Belgium-Luxembourg; 43 percent, from Canada; 7 percent, from West Germany; 1 percent, from the United Kingdom; and less than 0.5 percent each from Mexico and The Netherlands.

Tariff rates of sodium carbonate and sodium sulfate were the same as those reported in 1964.

WORLD REVIEW

Brazil.—Cía. Agro-Industrial Igarassu, the only caustic soda producer in northeastern Brazil, announced that it will expand its plant and diversify production to include caustic soda in flake as well as in liquid form, sodium hypochlorite, and hydrochloric acid.[4]

Canada.—An increased demand for sodium sulfate, used extensively in producing kraft paper and glass, which are exported in large quantities to the United States, resulted in the announcement of major expansions in the sodium sulfate industry in Saskatchewan, Canada. Construction was to begin soon on a $1.5 million sodium sulfate plant at Ingebright Lake, Saskatchewan. This plant was planned for an initial output of 150,000 tons per year and was to be operated by the Sodium Sulfate Division of the Province's crown-owned company, Saskatchewan Minerals. A second company, Sodium Sulphate Saskatchewan Ltd., announced that it would construct a $500,000 sodium plant near Alsask, Saskatchewan, about 160 miles west of Saskatoon. Saskatchewan is the only Canadian Province with reserves of naturally occurring sodium sulfate. These reserves are estimated at 200 million tons. The sodium sulfate is harvested from lake deposits.[5]

Chile.—Anglo-Lautaro Nitrate Corp. began trial production of sodium sulfate as a byproduct of its nitrate-producing operations. Plans called for an output of 50,000 tons annually for the local paper industry.[6]

India.—An announcement was made by the Indian Minister for Industries that new soda ash plants of at least 11,000-ton-per-year capacity were to be built in Madras, Maharashtra, and Orissa.[7]

Japan.—Asahi Glass Co., Ltd. bought the rights to use a new process developed by Britain's Imperial Chemical Industries Ltd., and Belgium's Solvay et Cie for producing chlorine without caustic soda as a coproduct. The company announced that next year it would build a 3,300-ton-per-month plant, using this process, at its Chiba Works near Tokyo. The process involves decomposition of ammonium chloride with a ferric oxide catalyst and can be run to produce chlorine from the chloride, hydrogen chloride from the chloride, or chlorine from the hydrogen chloride. Economics favor this process over electrolytic processes only when salt and power are relatively costly, and chlorine and caustic are not in balance.[8]

Malaysia.—Fourteen months after the site at Padang Jawa was cleared of rubber trees, the Imperial Chemical Industries Ltd., Mond Division completed construction of a chlorine plant for the Chemical Company of Malaysia Ltd. Initially the plant will produce liquid chlorine, and nearly all of its output will be used for water purification and for producing hydrochloric acid and sodium hypochlorite.[9]

Pakistan.—Toyo Engineering Co. and Gosho Ltd., of Japan, signed an agreement with Hirjina Salt & Chemicals (Pak.) Ltd., to supply machinery and equipment for a $15.75 million soda ash plant at

[4] Bureau of Mines. Mineral Trade Notes. V. 61, No. 5, November 1965, p. 49.

[5] European Chemical News (London). New Sodium Sulfate Producer in Canada. V. 8, No. 187, Aug. 13, 1965, p. 4.

[6] Bureau of Mines. Mineral Trade Notes. V. 61, No. 4, October 1965, p. 52.

[7] Chemical Age (London). New Soda Ash Capacity for India. V. 93, No. 2385, Mar. 27, 1965, p. 509.

[8] Chemical & Engineering News. A New Process for Producing Chlorine Without Caustic Soda as a Coproduct. V. 43, No. 24, June 14, 1965, p. 39.

[9] Chemical Age (London). Mond Division Completes Malaysian Chlorine Plant. V. 94, No. 2399, July 3, 1965, p. 9.

Karachi. This plant, scheduled for completion in 1967, will have an annual capacity of about 67,200 tons each of soda ash and ammonium chloride.[10]

South-West Africa.—South West Africa Co. Ltd., began producing trona from salt pans at Otjivalunda, northwest of Etosha Pan and began shipping it to the Johannesburg area. South-West Africa's supply of this material, used in glassmaking and papermaking, had been obtained from Kenya until late 1963 and subsequently from the United Kingdom.

U.S.S.R.—Demand for sodium sulfate in the Soviet Union increased with the growth in the kraft pulp, glass, and detergent industries. This material has been supplied from natural sodium sulfate deposits in the Aral and Caspian depressions, in the Kalunda steppe in Kazakhstan, in the Cancasus Mountains region, and throughout Soviet Central Asia. In addition, sodium sulfate has been supplied as a byproduct at manmade fiber plants at Ryazan and Kalinin. Surplus production from both natural and byproduct sources were exported to Finland, Hungary, Bulgaria, Yugoslavia, Sweden, Japan, and the United Kingdom.[11]

United Arab Republic (Egypt).—Rumania and the United Arab Republic entered into a technical and economic agreement whereby the Industrial-Export Company of Bucharest will supply the design, equipment, materials, and technical assistance for the erection of a soda ash plant at Elmex, Alexandria. The plant will use the traditional Solvay process with supplementary causticization to produce 32,500 tons per year of soda ash, 45,000 tons per year of caustic soda, and 5,000 tons per year of pharmaceutical quality sodium bicarbonate.[12]

TECHNOLOGY

The distribution of stress adjacent to each of 25 mine openings in the FMC Corp. Westvaco trona mine at Westvaco, Wyo., was determined by the borehole stress-relief method by the Brueau of Mines, and a report of the findings was published.[13] The purpose of the stress determinations was twofold: First, to study the effect on these distributions of various factors such as opening shape, stress level, and loading history; and second, to estimate the distribution of stresses adjacent to extensive high-extraction areas.

Laboratory studies, sponsored by the Bureau of Reclamation and the Missouri River Basin Field Committee and conducted by the Bureau of Mines, indicated that an inexpensive technique significantly reduced seepage in irrigation canals.[14] Laboratory tests simulating optimum field conditions determined that easily applied sodium carbonate solutions made test beds of canal-lining materials virtually impermeable for long periods.

Claims were made that a salable commodity, sodium sulfate suitable for kraft pulpmills, can be recovered from spent liquor at sulfite mills.[15] Sodium-based sulfite pulpers, who have long sought an economical chemical-recovery process to use in existing mills, may choose among three fluid-bed systems to oxidize their black liquor. Because sodium sulfate cannot be recycled to a sulfite mill, complete oxidation to sulfate is only partial relief for sulfite pulpers. Developers of the three systems were reported to be working on modifications that would produce sodium sulfite instead of sodium sulfate. However, even at the present stage, the process is attractive because the sulfate recovered can be sold at a profit, and it is a method by which sulfite chemical and semichemical pulpmills can meet antipollution pressures.

According to a General Electric Co. spokesman, a new light source that ranks in importance with the fluorescent lamp was developed by company employees.[16] The lamp has a ceramic arc tube that con-

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[10] Bureau of Mines. Mineral Trade Notes. V. 58, No. 6, June 1964, p. 30.

[11] European Chemical News (London). Surplus of Sodium Sulphate in USSR. V. 7, No. 156, Jan. 8, 1965, p. 6.

[12] European Chemical News (London). Rumania to Build Caustic Soda Plant for UAR. V. 8, No. 196, Oct. 15, 1965, p. 20.

[13] Morgan, Thomas A., William G. Fischer, and William J. Sturgis. Distribution of Stress in the Westvaco Trona Mine, Westvaco, Wyo. BuMines Rept. of Inv. 6675, 1965, 58 pp.

[14] Agey, W. W., and B. F. Andrew. Reduction of Seepage Losses From Canals by Chemical Sealants (In 2 parts). 1. Laboratory Research on Sodium Carbonate and Other Compounds. BuMines Rept. of Inv. 6584, 1965, 33 pp.

[15] Chemical Engineering. Finding Money in Sulfite-Pulp Spent Liquor. V. 72, No. 17, Aug. 16, 1965, pp. 74–76.

[16] Chemical Engineering. New Lamps for Old. V. 72, No. 26, Dec. 20, 1965, p. 62.

tains sodium vapor at higher pressure and temperatures than previous sodium lamps. The new unit has the high efficiency of the sodium lamp, but produces light of an acceptable golden color instead of the monochromatic yellow of the old lamp.

Patent applications were filed in the United States and overseas by Union Carbide Corp. for producing an electrical cable using a sodium metal core encased in polyethylene insulation. The company and three power utility companies conducted field trials on the cable. To produce and use the cable, Union Carbide filled polyethylene tubes with sodium metal at its pilot plant at Bound Brook, N.J., Simplex Wire & Cable Co. finished the filled tubes into various sizes and types of electrical cable, and Burndy Corp. furnished special terminals and splices for installing the cable. Production of the cable went entirely into field tests, and none was available to the commercial market.

Sodium metal was used in this radically new type of electrical cable because of three desirable physical properties, low specific gravity, high ductility, and good electrical conductivity. One pound of sodium metal costing approximately 17 cents was reported to conduct as much electrical current as 3.5 pounds of copper costing $1.26 or 1.75 pounds of aluminum costing 43 cents. Sodium cables were reported to weigh 50 percent less than conventional cables but were 45 percent larger in diameter than a conventional insulated copper conductor of equal current carrying capacity. Because sodium metal is flexible, it can be used in solid form as the cable core and does not have to be stranded as with other metals to achieve flexibility.

Sodium metal also has two objectionable physical properties; it is highly reactive, particularly with oxygen and water; and it is toxic to the skin. Use of sodium in the cable therefore posed safety problems that required more study in the field applications.

Scientists from Argonne National Laboratory, while discussing ways of converting heat directly into electricity, described the operation of the first engineering cell of the sodium-bismuth type.[17] This cell operates with molten sodium as the anode, molten bismuth as the cathode, and molten sodium salts as the electrolyte. In the power-generating step, sodium metal reacts with bismuth metal, generating power as it forms an intermetallic compound that dissolves in the liquid bismuth cathode.

Construction was started late in 1965 on the Southwest Experimental Fast Oxide Reactor. The 20-thermal-megawatt sodium-cooled reactor at Cove Creek, about 20 miles southwest of Fayetteville, Ark., was scheduled for completion in 1968. This international research and development program on the fast breeder reactor system using plutonium oxide-uranium oxide fuel and sodium coolant was sponsored by the U.S. Atomic Energy Commission, Atomic Energy Associates of Little Rock, Ark., Gesellschaft für Kernforschung of the Federal Republic of Germany, and the European Atomic Energy Community.

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[17] Chemical Engineering. Distillation, Power, and Fibers Are Highlights of Detroit ACS Meeting. V. 72, No. 9, Apr. 26, 1965, pp. 61, 63.

Stone

By William R. Barton [1]

Domestic production of stone in 1965 was 780 million tons valued at $1.2 billion, a record for the fourth consecutive year. Crushed and broken stone represented 92 percent of the total value. Stone imports declined 14 percent in value and exports increased 12 percent in value compared with 1964 figures.

Legislation and Government Programs.—A bill (S.2281) was introduced in the 89th Congress to provide that certain varieties of stone, sand, gravel, and similar mineral commodities be considered as valuable mineral deposits under United States mining law. The bill, not acted on during 1965, was primarily intended to increase availability of aggregates in the Western States.

Urbanization and land use conflicts continued to generate litigation over quarry operations. Administered by local jurisdictions, decisions went both ways with the balance during the year in favor of the quarry operator.

[1] Commodity specialist, Division of Minerals.

Table 1.—Salient stone statistics in the United States [1]

(Thousand short tons and thousand dollars)

	1956–60 (average)	1961	1963	1964	1962	1965
Sold or used by producers:						
Dimension stone	2,463	2,315	2,729	2,616	2,545	2,403
Value	$84,199	$88,093	$90,687	$96,318	$96,970	$92,235
Crushed stone	553,450	609,623	654,225	685,750	723,038	777,669
Value	$775,151	$859,266	$935,010	$971,790	$1,037,594	$1,111,383
Total stone	555,913	611,938	656,954	688,366	725,583	780,072
Value	$859,351	$947,359	$1,025,697	$1,068,108	$1,134,564	$1,203,618
Exports (value)	$6,366	$6,648	$6,009	$6,102	$6,796	$7,599
Imports for consumption (value)[2]	$9,474	$12,268	$17,204	$18,978	[3] $23,753	[3] $20,414

[1] Includes slate. 1956 includes territories of the United States, possessions, and other areas administered by the United States.
[2] Includes whiting.
[3] Data not comparable with other years.

Table 2.—Stone sold or used by producers in the United States, by States

(Thousand short tons and thousand dollars)

State	1964		1965	
	Quantity	Value	Quantity	Value
Alabama	[1] 15,852	[1] $24,976	[1] 17,987	[1] $30,810
Alaska	W	W	W	W
Arizona	3,759	6,283	2,474	4,171
Arkansas	20,241	26,172	21,241	26,778
California	45,805	63,566	42,575	59,668
Colorado	3,217	6,805	4,789	8,638
Connecticut	5,864	10,764	5,871	10,444
Delaware	180	450	180	450
Florida	33,157	38,362	35,730	41,148
Georgia	r 22,822	r 46,428	23,421	48,265
Hawaii	5,282	8,765	5,172	9,353
Idaho	1,144	2,773	1,831	3,440
Illinois	42,987	56,553	47,066	61,294
Indiana	22,318	39,978	24,574	42,124
Iowa	23,935	33,038	25,891	35,468
Kansas	14,138	18,912	15,270	20,538
Kentucky	[1] 21,868	[1] 29,594	26,029	34,533
Louisiana	[1] 5,459	[1] 7,228	[1] 7,452	[1] 10,905
Maine	1,414	4,506	1,100	3,409
Maryland	13,348	26,715	14,553	28,432
Massachusetts	6,519	16,663	6,168	16,980
Michigan	34,650	37,002	34,713	36,438
Minnesota	3,588	12,297	4,371	11,680
Mississippi	1,553	1,557	[1] 2,357	[1] 2,358
Missouri	31,487	47,984	36,247	53,574
Montana	7,345	8,477	5,512	5,971
Nebraska	3,779	6,417	4,198	6,637
Nevada	788	1,396	1,248	2,247
New Hampshire	202	2,138	153	1,932
New Jersey	12,326	28,461	12,232	27,247
New Mexico	2,760	4,244	1,911	3,020
New York	29,141	46,669	30,801	48,675
North Carolina	[1] 17,943	[1] 30,378	[1] 18,835	[1] 30,920
North Dakota	31	56	356	624
Ohio	37,715	61,814	42,263	66,969
Oklahoma	13,987	15,087	16,417	18,071
Oregon	16,120	19,296	21,212	27,301
Pennsylvania	52,829	91,075	56,806	99,627
Rhode Island	450	935	437	1,119
South Carolina	[1] 6,109	[1] 9,176	[1] 5,948	[1] 8,447
South Dakota	2,118	6,245	1,554	5,387
Tennessee	[1] 26,497	[1] 38,239	[1] 28,888	[1] 38,859
Texas	40,240	52,070	39,520	53,659
Utah	3,105	6,930	2,158	4,552
Vermont	2,070	20,652	2,591	21,564
Virginia	30,407	52,153	36,350	59,397
Washington	r 10,498	r 15,204	12,461	17,446
West Virginia	[1] 7,481	[1] 13,105	[1] 8,482	[1] 14,587
Wisconsin	13,901	20,232	15,344	21,924
Wyoming	2,154	3,671	1,594	2,791
Undistributed	5,000	13,073	5,739	13,747
Total	r 725,583	r 1,134,564	780,072	1,203,618
American Samoa	157	234	60	60
Guam	469	868	483	925
Panama Canal Zone	153	349	153	366
Puerto Rico	5,504	8,586	5,344	9,111
Virgin Islands	69	342	68	302
Wake Island	2	5	1	4

r Revised.

W Withheld to avoid disclosing individual company confidential data; included with "Undistributed."

[1] To avoid disclosing individual company confidential data, certain State totals are incomplete, the portion not included being combined with "Undistributed." The class of stone omitted from such State totals is noted in the State tables in the Statistical Summary chapter of this volume.

DIMENSION STONE

Unusual color or texture in building stone continued to be fashionable. Black and green granites, colored marbles, and travertine were used in many unusual and creative ways. Flame-finished granite was also used by architects to add interesting textures to structures. Classic, ever popular, stones such as gray or white marble and gray granite were also used in new and stimulating modes by architects such as Minoru Yamasaki and Associates (Northwestern National Life Insurance Building, Minneapolis, Minn.,) Bodin and Lamberson (Life of Georgia Tower, Atlanta, Ga.) and Welton Becket and Associates (Humble Oil Building, Houston, Tex.).

The results of the 1963 Census of Manufactures on cut stone and stone products were published by the Bureau of the Census as part of Industry Statistics Report MC 63 (2)-32D. The 32-page document is available from the U. S. Government Printing Office.

Granite.—The value of dimension granite shipments decreased 1.8 percent compared with 1964. Shipments of granite for building stone decreased 5.6 percent in tonnage and 7.1 percent in value. Monumental granite increased in tonnage and value. Appropriately enough, New England granite was chosen as the featured stone for the permanent gravesite of President John F. Kennedy at Arlington National Cemetery. Two thousand tons of Deer Isle Granite Corp. stone from Stonington, Maine, will be used in harmony with white marble to lend a simple dignity to the shrine.

Basalt and Related Rocks (Traprock).—Total shipments of dimension basaltic-type rocks were 26,000 tons valued at $787,000. Pennsylvania produced the greatest tonnage and value. Virginia, Washington, Oregon, and California also reported production. The higher value dimension basalt-type rocks are for precision instrument plates which must be ground to surface tolerances within 25 millionths of an inch of perfect level. Shaping and storage are done at 68° F so that distortion will not occur when installed in an air conditioned shop or office.

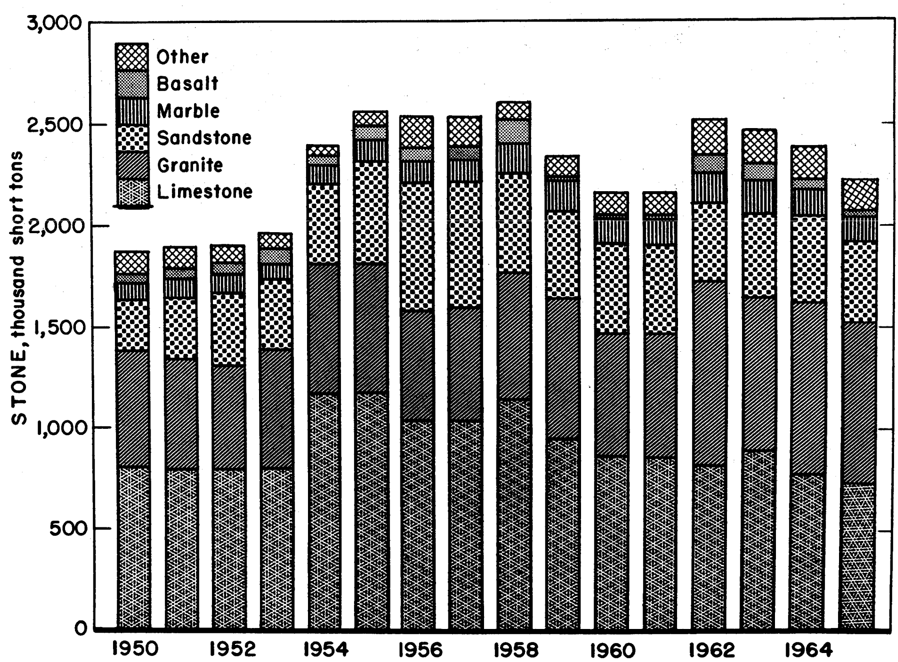

Figure 1.—Sales of dimension stone, except slate, in the United States, by kinds.

Table 3.—Stone sold or used by producers in the United States, by kinds

(Thousand short tons and thousand dollars)

Year	Granite		Basalt and related rocks (traprock)		Marble		Limestone and dolomite		Shell	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1956–60 (average)	36,711	$75,908	47,223	$74,708	1,463	$26,614	408,136	$561,801	19,396	$31,265
1961	44,058	93,870	62,776	95,576	1,592	30,960	438,253	608,139	18,004	30,375
1962	50,058	102,898	69,768	108,264	1,769	33,117	461,849	649,647	20,054	31,241
1963	48,793	103,633	72,958	111,538	1,902	34,567	489,243	680,060	19,019	29,420
1964	r 56,331	r 114,465	66,090	108,929	2,093	36,693	r 511,026	r 713,675	19,493	30,157
1965	60,028	121,147	75,529	121,278	2,172	38,662	554,766	765,714	21,560	34,314

Year	Calcareous marl		Sandstone		Slate		Other stone [1]		Total	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1956–60 (average)	[2] 1,761	[2] $1,686	18,656	$48,881	620	$10,935	21,947	$27,553	555,913	$859,351
1961	1,099	987	23,386	49,114	496	9,334	22,274	29,004	611,938	947,359
1962	1,182	1,011	26,077	51,119	544	10,100	25,653	38,300	656,954	1,025,697
1963	1,164	989	28,978	58,015	902	11,365	25,407	38,521	688,366	1,068,108
1964	1,043	899	28,169	62,087	1,303	13,695	40,035	53,964	r 725,583	r 1,134,564
1965	1,291	1,125	29,097	61,710	1,263	13,697	34,366	45,971	780,072	1,203,618

r Revised.
[1] Includes mica schist, conglomerate, argillite, various light-colored volcanic rocks, serpentine not used as marble, soapstone sold as dimension stone, etc.
[2] Average for 1957–60 only.

Table 4.—Dimension stone sold or used by producers in the United States, by uses

Use	1964			1965		
	Thousand short tons	Thousand cubic feet	Value (thousands)	Thousand short tons	Thousand cubic feet	Value (thousands)
Building:						
Rough:						
Construction	385	----	$2,800	374	----	$2,766
Architectural [1]	367	4,868	7,669	336	4,432	7,511
Dressed:						
Sawed [1]	521	6,807	21,462	435	5,696	17,910
Cut [2]	202	2,540	26,420	198	2,494	25,116
Rubble	391	----	2,041	355	----	1,859
Roofing (slate)	33	----	2,228	24	----	1,872
Millstock (slate)	28	----	3,951	28	----	3,871
Monumental (rough and dressed) [3]	241	2,940	20,464	266	3,221	20,902
Paving blocks	6	----	163	5	----	109
Curbing	168	2,038	4,682	157	1,915	4,708
Flagging [4]	203	2,455	5,090	225	2,699	5,611
Total	2,545	----	96,970	2,403	----	92,235

[1] Includes stone for refractory use to avoid disclosing individual company confidential data.
[2] Includes a small quantity of stone for precision surface plates and monumental work.
[3] Includes stone for precision surface plates.
[4] Includes a small quantity of slate for miscellaneous uses.

Table 5.—Granite (dimension stone) sold or used by producers in the United States, by uses

Use	1964 Thousand short tons	1964 Thousand cubic feet	1964 Value (thousands)	1965 Thousand short tons	1965 Thousand cubic feet	1965 Value (thousands)
Building:						
Rough:						
Construction	250	----	$1,195	223	----	$1,190
Architectural	43	515	1,599	26	320	1,183
Dressed:						
Construction	16	190	1,240	16	190	788
Architectural	51	622	7,984	42	506	8,070
Rubble	89	----	398	72	----	305
Monumental: [1]						
Rough	174	2,128	8,852	193	2,341	8,376
Dressed	49	596	7,777	55	665	8,509
Paving blocks	6	----	163	5	----	109
Curbing and flagging	165	1,994	4,544	154	1,879	4,605
Total	843	----	33,752	786	----	33,135

[1] Includes stone for precision plates.

Table 6.—Granite (dimension stone) sold or used by producers in the United States in 1965, by States

State	Active plants	Short tons	Value	State	Active plants	Short tons	Value
California	6	9,755	$972,192	New York	4	20,662	$318,402
Colorado	7	941	42,319	North Carolina	8	33,088	1,821,163
Connecticut	4	2,647	58,196	Oklahoma	7	5,963	502,898
Georgia	35	189,125	4,106,639	South Dakota	7	20,129	2,944,586
Maine	7	10,335	1,347,976	Wisconsin	12	19,534	1,883,151
Maryland	1	148	5,500	Other States [1]	25	321,906	10,542,941
Massachusetts	12	122,849	4,289,041				
Minnesota	21	25,748	4,053,844	Total	158	785,979	33,134,740
Missouri	1	3,124	233,892	Puerto Rico	---	8,300	26,700
New Mexico	1	25	12,000				

[1] Includes plants in New Hampshire 2; Pennsylvania 4; Rhode Island 2; South Carolina 3; Texas 4; Utah 1; and Vermont 9.

Marble.—The reported value of dimension marble decreased 10 percent in 1965 while volume of that sold or used declined 3 percent. The average value for monumental marble was $18.68 per cubic foot compared with $17.75 a year earlier. For dressed building marble, respective figures were $17.70 and $14.49. Minerals & Chemicals Philipp Corp. late in 1965 announced plans to acquire Georgia Marble Co. by an exchange of stock valued at about $25 million. Final agreement was in abeyance pending approval by boards and shareholders of both firms. Deposits of onyx marble and travertine being mined 20 miles west of Belen, N. Mex., were reported to be of excellent quality. The deposits, on the Laguna Indian Reservation, were leased by Ultra Marble, Inc.

Limestone.—Shipments of dimension limestone decreased 6 percent in tonnage and 9 percent in value. The Bedford-Bloomington, Ind., area continued to lead in production of this type of stone. Veneers and stone-faced precast panels continued to increase in popularity in preference to massive architectural blocks.

Sandstone.—Shipments of dimension sandstone decreased 8 percent in quantity and increased 2 percent in value compared with 1964. One hundred and ninety-seven plants reported shipments in 1965, compared with 207 plants a year earlier. Ohio was the leading producing State in terms of both tonnage and value.

Slate.—Slate sold or used by producers gained 11 percent in volume and 2 percent in value compared with 1964. On a tonnage basis flagstones continued to be the leading dimension slate product but the largest relative increase in tonnage over 1964 figures was 30 percent in the miscellaneous category. The most important slate products in order of total value in 1965 were electrical, structural, and sanitary slate products followed by miscellaneous slate and roofing slate.

Miscellaneous Stone.—Shipments of miscellaneous stone increased 1 percent in tonnage and decreased 19 percent in value compared with those of 1964. This category accounted for less than 7 percent of total dimension stone volume and consisted of stones not classified under the more popular categories. Examples of such stones include light-colored volcanics, tuffs and scoria, greenstones, gneisses, and schists.

Table 7.—Marble (dimension stone) sold or used by producers in the United States,[1] by uses

Use	1964			1965		
	Thousand short tons	Thousand cubic feet	Value (thousands)	Thousand short tons	Thousand cubic feet	Value (thousands)
Building: [2]						
Rough: Architectural	28	325	$1,031	54	640	$2,001
Dressed:						
Sawed	36	424	3,888	25	293	3,035
Cut	48	568	10,491	29	343	8,224
Monumental (rough and finished)	18	216	3,835	18	215	4,017
Total	130	----	19,245	126	----	17,277

[1] Produced by the following States in 1965 in order of value and with number of plants: Vermont 9; Georgia 1; Missouri 4; Alabama 2; Tennessee 12; North Carolina 1; Arkansas 2; New Mexico 3; Montana 2; Colorado 1; Washington 3; California 1; Maryland 1; and Arizona 2.

[2] Includes: 1964—882,000 cubic feet, $8,697,000 for exterior use, and 435,000 cubic feet, $6,713,000 for interior use; 1965—854,000 cubic feet, $8,087,000 for exterior use, and 422,000 cubic feet, $5,173,000 for interior use.

Table 8.—Limestone (dimension stone) sold or used by producers in the United States, by uses

Use	1964			1965		
	Thousand short tons	Thousand cubic feet	Value (thousands)	Thousand short tons	Thousand cubic feet	Value (thousands)
Building:						
Rough:						
Construction	23	----	$266	66	----	$422
Architectural	239	3,284	3,928	210	2,876	3,387
Dressed:						
Sawed [1]	273	3,669	8,070	222	2,974	6,639
Cut	65	860	5,826	75	981	5,951
Rubble	155	----	694	137	----	618
Curbing and flagging	24	312	160	22	279	155
Total	779	----	18,944	732	----	17,172

[1] Includes house stone veneer.

Table 9.—Limestone (dimension stone) sold or used by producers in the United States in 1965, by States

State	Active plants	Short tons	Value	State	Active plants	Short tons	Value
California	5	2,379	$26,726	Nebraska	4	9,335	$48,869
Colorado	1	466	3,728	Ohio	4	52,286	73,078
Florida	1	750	6,500	Oklahoma	5	2,735	31,280
Georgia	1	219	1,533	Pennsylvania	1	42	336
Illinois	3	4,180	123,145	South Dakota	1	6,000	9,000
Indiana	21	455,759	10,992,799	Wisconsin	30	88,317	1,724,096
Iowa	2	16,833	202,880	Other States [1]	13	42,582	1,344,886
Kansas	10	16,129	614,830				
Michigan	3	5,286	76,989				
Minnesota	5	23,656	1,847,138	Total	115	732,023	17,171,908
Missouri	5	5,069	44,095	Puerto Rico	---	74,430	180,150

[1] Includes plants in Alabama 2; New York 1; Rhode Island 1; Texas 5; Utah 2; Virginia 1; and Wyoming 1.

Table 10.—Limestone sold by producers in the Indiana oolitic limestone district, by classes

Year	Construction: Rough blocks: Thousand cubic feet	Rough blocks: Value (thousands)	Sawed and semi-finished [1]: Thousand cubic feet	Sawed and semi-finished [1]: Value (thousands)	Cut: Thousand cubic feet	Cut: Value (thousands)
1956–60 (average)	2,877	$2,987	3,065	$5,630	804	$4,750
1961	2,820	3,159	2,498	4,675	497	2,784
1962	2,467	2,695	2,427	4,674	560	3,251
1963	2,183	2,533	2,518	5,217	530	2,258
1964	3,035	3,535	[2] 2,752	[2] 5,770	400	2,624
1965	2,651	3,095	[2] 2,052	[2] 4,503	481	3,091

Year	Construction—Continued: Total: Thousand cubic feet	Total: Thousand short tons	Total: Value (thousands)	Other uses: Thousand short tons	Other uses: Value (thousands)	Total: Thousand short tons	Total: Value (thousands)
1956–60 (average)	6,746	489	$13,367	157	$427	646	$13,794
1961	5,815	422	10,618	161	515	583	11,133
1962	5,454	395	10,620	191	659	586	11,279
1963	5,231	379	10,008	197	640	576	10,648
1964	6,187	449	11,929	71	225	520	12,154
1965	5,184	376	10,689	70	224	446	10,913

[1] Includes house stone veneer.
[2] Includes small quantity produced outside the district.

Table 11.—Sandstone (dimension stone) sold or used by producers in the United States, by uses

Use	1964: Thousand short tons	1964: Thousand cubic feet	1964: Value (thousands)	1965: Thousand short tons	1965: Thousand cubic feet	1965: Value (thousands)
Building:						
Rough:						
Construction	95	----	$1,205	67	----	$995
Architectural [1]	57	744	1,111	46	596	940
Dressed:						
Sawed [1]	122	1,654	4,263	120	1,627	4,319
Cut	37	471	1,677	48	616	2,282
Rubble	46	----	325	45	----	333
Curbing	3	42	133	3	36	103
Flagging	71	872	1,901	67	820	1,815
Total	431	----	10,615	396	----	10,787

[1] Includes stone for refractory use to avoid disclosing individual company confidential data.

Table 12.—Sandstone (dimension stone) sold or used by producers in the United States in 1965, by States

State	Active plants	Short tons	Value	State	Active plants	Short tons	Value
Alabama	1	257	$2,570	New Mexico	3	88	$2,036
Arizona	20	10,635	137,567	New York	13	42,012	1,159,004
Arkansas	6	13,155	184,174	Ohio	12	119,259	4,811,703
California	6	2,420	53,286	Pennsylvania	37	78,362	1,407,080
Colorado	27	21,154	411,200	Tennessee	13	34,110	799,526
Connecticut	3	9,650	46,630	Utah	6	1,269	24,812
Georgia	1	498	15,304	Virginia	2	1,035	15,453
Kansas	1	514	10,349	Wisconsin	9	3,065	57,870
Kentucky	1	42	383	Wyoming	4	1,018	20,604
Massachusetts	2	6,145	618,884	Other States [1]	25	42,833	914,365
Michigan	4	6,396	42,760				
Missouri	1	2,258	51,934	Total	197	396,175	10,787,494

[1] Includes plants in Indiana 9; Maryland 3; Mississippi 1; Nevada 3; New Jersey 1; Texas 2; Washington 4; and West Virginia 2.

Table 13.—Slate (dimension stone) sold or used by producers in the United States,[1] by uses

Use	1964 Quantity: Thousand short tons	1964 Quantity: Thousand square feet (unless otherwise specified)	1964 Value (thousands)	1965 Quantity: Thousand short tons	1965 Quantity: Thousand square feet (unless otherwise specified)	1965 Value (thousands)
Roofing slate	33	[2] 88	$2,228	24	[2] 63	$1,872
Millstock:						
Electrical, structural, and sanitary slate	24	2,897	2,822	24	2,813	2,803
Blackboards and bulletin boards [3]	2	941	840	2	895	801
Billiard tabletops	2	274	289	2	236	267
Total	28	4,112	3,951	28	3,944	3,871
Flagstones [4]	60	11,132	1,481	74	12,442	1,631
Miscellaneous uses [5]	43	------	1,426	56	------	1,902
Grand total	164	------	9,086	182	------	9,276

[1] Produced by the following States in 1965 in order of value of output and with number of plants: Pennsylvania 10; Vermont 21; Virginia 2; New York 11; Maine 1; Utah 1; North Carolina 2; and California 2.
[2] Thousand squares.
[3] Includes a small quantity of school slates.
[4] Includes slate used for walkways and stepping stones.
[5] Includes slate for aquarium bottoms, buildings, fireplaces, flooring, headstones, shims, and unspecified uses.

Table 14.—Miscellaneous varieties of dimension stone sold or used by producers in the United States,[1] by uses

Use	1964			1965		
	Thousand cubic feet	Thousand short tons	Value (thousands)	Thousand short tons	Thousand cubic feet	Value (thousands)
Building:						
Sawed [2]	74	870	$4,001	52	612	$3,129
Rubble	74	----	572	97	----	564
Flagging	5	59	122	6	71	108
Total	153	----	4,695	155	----	3,801

[1] Produced by the following States in 1965 in order of value of output and with number of plants: Virginia 2; California 28; Maryland 1; Pennsylvania 4; New Jersey 1; Hawaii 4; New Mexico 1; Oregon 1; and Washington 2.
[2] Includes rough and cut stone and stone for refractory use to avoid disclosing individual company confidential data.

FOREIGN TRADE

Exports of marble and other dimension stones to Canada totaled $3.3 million. Lesser amounts were shipped to Latin America, Europe, and Asia.

Imports of decorative and specialty marbles (including travertine and onyx) in 1965 totaled $13 million and came principally from Italy, except for onyx which was imported principally from Mexico. Substantial amounts of marble were also imported from Portugal and other countries. Granite imports decreased 8 percent in value from 1964 figures, with principal quantities from Canada and Italy. Other substantial dimension stone imports included slate from Italy and Portugal.

WORLD REVIEW

Angola.—Plans for expanding marble production included entrance of Lobito Mining Co. into large scale operations.[2] Large unexploited deposits of marble were reported in the Mocamedes district in southern Angola.

Ireland.—Output of slab marble was expected to reach 35,000 tons by 1967. The enlarging of the harbor at Galway and a new factory containing almost $400,000 of modern Italian marble-finishing machinery were expected to increase exports.[3]

Italy.—A 200-ton slab of marble quarried near Carrara was claimed to be the largest in the world. The slab was freed from the quarry wall by wire-sawing.[4] The Italian Government presented a $1.2 million gift of marble to the United States for use in the Washington, D.C., John F. Kennedy Center for the Performing Arts. It constituted the largest contribuition to the center by any foreign country.

Norway.—Output of quartzite slate at Alta was estimated at 8 million square feet in 1965 compared with 6 million square feet in 1964. Most of the slate was used for flooring or building cladding with roofing a minor end use.

South Africa, Republic of.—The Marikana quarries in the Brits district have become the most important source of rough granite blocks in the Republic. In the first half of 1965 they accounted for 41 percent, or 2,100 tons of rough granite blocks exported from the country.[5]

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[2] Bureau of Mines. Mineral Trade Notes. V. 61, No. 5. November 1965, p. 31.
[3] Mining Journal (London). Eire's Marble Exports. V. 265, No. 6795, Nov. 12, 1965, p. 345.
[4] Mining and Minerals Engineering (London). Record Marble Slab. V. 1, No. 13, September 1965, p. 515.
[5] South African Digest (Pretoria, Republic of South Africa). Granite, v. 12, No. 29, July 23, 1965, p. 15.

TECHNOLOGY

The popularity of dimension stone faced panels continued to increase as architects developed new forms and combinations to free their creations from the aesthetics limitations of media such as concrete. Ground was broken for a particularly imaginative concept of stone use in a telephone company building on Manhattan's east side. The 24-story structure by architects Kahn and Jacobs will have two sides of bronze granite and bronze-tinted windows contrasted with the other two walls of uninterrupted white limestone.

The story of quarrying another stone of unusual aspect was reviewed.[6] Quarried in Connecticut, the stone consists of dark red garnets in a velvet-sheen muscovite mica schist. It is marketed as "Jewel building stone" and used mostly for decorative purposes and memorial structures.

The resurgence of slate for chalkboard use inspired another article.[7] The article stressed that composition chalkboards could not match the utility, endurance, and economy of slate. In addition, the neutral, achromatic color of slate harmonizes with any color scheme. A specialty use for dimension granite was patented.[8] Polished slabs of the stone are described for use in surfacing bowling lanes.

Description of dimension stone colors can be made more quantitative by a centroid-color chart issued in February 1965.[9] The chart contains samples of 251 colors and is intended to serve as a visual supplement for National Bureau of Standards Circular 553, The ISCC–NBS Method of Designation Colors and a Dictionary of Color Names.

CRUSHED AND BROKEN STONE

Production of crushed and broken stone in 1965 was 777.7 million tons valued at more than $1.1 billion a new record. By end use the largest consumer category was concrete and roadstone, but the largest rate of increase was for fill, which gained 359 percent in tonnage over 1964 figures. Concrete and roadstone gained 10 percent and stone for use as a flux 3 percent.

Building and road construction were the prime indicators for the highest volume crushed stone uses; concrete and roadstone, cement, and riprap. The U. S. Department of Commerce projected continued growth, by estimating construction value in 1966 to be 6 percent above that of 1965. Increased building of structures and roads is of course a function of our expanding population and burgeoning economy. A specific case has been the rate of increase in estimated car-miles driven by Americans. In 1922, Americans drove only 67 billion miles, but by 1972 they will drive more than a trillion miles annually. Road construction must proceed apace with the added drivers and cars to preclude massive traffic congestion.

Demand for stone sand continued to increase, partially because of depletion of some natural sand deposits. Interest in this alternate source of fine aggregate required the National Crushed Stone Association to reprint its bulletin on stone sand.[10]

Price.—Average prices for crushed and broken stone continued to be relatively stable. December 1965 prices quoted for 20 U. S. cities in Engineering News-Record averaged $2.57 per ton for 1½-inch stone and $2.67 per ton for ¾-inch stone. In December 1964, respective quotations were $2.60 and $2.69. These prices are much higher than the f.o.b. quarry values reported in Bureau of Mines tables, because of transportation and handling charges. A typical cost breakdown for delivered stone, as quoted by the National Limestone Institute, Inc., in a Technical Information Release was as follows: Aggregate f.o.b. quarry,

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[6] Hatsian, K. G. Garnets and Gumption. Stone Magazine, v. 85, No. 7, July 1965, pp. 10–11.
[7] Stone Magazine. Slate Chalkboards From Quarry To Classroom. V. 85, No. 12, December 1965, pp. 19–20.
[8] Stengel, J. L., and N. D. Lewis. Granite Bowling Lane. U.S. Pat. 3,223,415, Dec. 14, 1965.
[9] National Bureau of Standards. ISCC–NBS Color-Name Charts Illustrated With Centroid Colors. Supplement to NBS Circular 553, 1965, 22 pp.
[10] Gray, J. E., and J. E. Bell. Stone Sand. National Crushed Stone Association, Eng. Bull. 13, (2d printing), June 1965, 70 p.

$.70 per ton; freight to unloading point, $2.00 per ton; unloading cost, $.20 per ton hauling to job site, $.40 per ton; total cost, $3.30 per ton. In the example cited f.o.b. cost of material was only 21 percent of delivered cost.

Size of Plants.—A total of 3,235 plants reported production, but the 393 largest producers accounted for 55 percent of the commercial production. The total number of plants operated increased by 20 from those operated in 1964. The greatest increase in number of operations, 43, was in the 75,000 to 100,000 short-ton class.

Transportation.—Truck transportation increased 15 percent, and rail and waterway transportation increased respectively 5 percent and 4 percent. Truck transport, by far the most popular mode, carried 74 percent of total stone tonnage in 1965, 501 million tons of commercial production and 72 million tons of Government-and-contractor material.

Granite.—Production and value of crushed and broken granite increased 7 percent and 9 percent, respectively, compared with 1964. The average value reported in 1965 was $1.49 per ton, compared with $1.45 per ton the previous year. Production was reported from 29 States, but Georgia, North Carolina, Virginia, and South Carolina produced 75 percent of the total. A special quartz-feldspar product was marketed from crushed granite screenings in Georgia.[11] The byproduct, an earner of welcome additional income, was sold to a glass container manufacturer.

Basalt and Related Rocks (Traprock).—Tonnage of basalt type rocks produced in 1965 increased 14 percent, while value gained 11 percent from the previous year. The principal end use category, concrete and roadstone, accounted for 82 percent of production. A modernized and expanded crushed gabbro plant in Pennsylvania was described.[12]

[11] Trauffer, W. E. Georgia Crushed Granite Firm Makes Feldspar Quartz By-product. Pit and Quarry, v. 58, No. 2, August 1965, pp. 97–100.

[12] Herod, Buren C. General Crushed Stone Adds Capacity to Flexibility. Pit and Quarry, v. 58, No. 3, September 1965, pp. 78–81, 111.

Table 15.—Crushed and broken stone sold or used by producers in the United States, by uses

(Thousand short tons and thousand dollars)

Use	1964		1965	
	Quantity	Value	Quantity	Value
Agriculture	27,047	$46,485	28,531	$48,889
Cement	r 98,475	r 103,398	98,465	104,954
Concrete and roadstone	r 456,071	r 628,222	503,263	690,736
Fill	1,416	946	6,505	3,539
Filtration	183	394	83	281
Flux	31,979	46,633	33,025	48,728
Glass	1,635	5,219	2,088	6,559
Lime and dead-burned dolomite	r 24,996	r 43,022	26,689	44,290
Mineral food	684	4,077	747	3,941
Poultry grit	861	6,391	693	5,376
Railroad ballast	14,170	16,801	14,023	17,375
Refractory	600	5,237	868	6,780
Riprap	39,495	49,780	38,754	46,038
Roofing granules, aggregates, and chips	2,369	12,407	2,607	14,416
Stone sand	3,536	5,270	3,569	5,258
Terrazzo	421	5,547	367	5,183
Other uses [1] and unspecified	r 19,100	r 57,765	17,392	59,040
Total	r 723,038	r 1,037,594	777,669	1,111,383

r Revised.

[1] Includes some uses listed separately in the sections on limestone and sandstone.

Table 16.—Crushed stone sold or used by Government-and-contractor producers in the United States, by uses [1]

(Thousand short tons and thousand dollars)

Use	1964		1965	
	Quantity	Value	Quantity	Value
Concrete and roadstone	42,508	$50,045	44,438	$55,777
Riprap	23,220	26,774	20,101	20,859
Agricultural (limestone)	355	524	333	485
Other uses	521	677	6,866	5,828
Total	66,604	78,020	71,738	82,949

[1] Figures represent tonnages reported by States, counties, municipalities, and other Government agencies, produced either by themselves or by contractors expressly for their consumption, often with publicly owned equipment; they do not include purchases from commercial producers.

Table 17.—Crushed stone for concrete and roadstone sold or used by producers in the United States, by States

(Thousand short tons and thousand dollars)

State	1964		1965	
	Quantity	Value	Quantity	Value
Alabama	[1] 8,539	[1] $10,771	10,975	$12,662
Alaska	W	W	W	W
Arizona	676	926	363	732
Arkansas	9,007	14,784	12,558	16,753
California	15,510	19,321	16,274	21,378
Colorado	694	1,268	913	1,188
Connecticut	5,413	8,762	[1] 5,327	[1] 8,526
Delaware	W	W	W	W
Florida	[1] 27,270	[1] 30,590	[1] 30,258	[1] 33,405
Georgia	[r] [1] 17,239	[r] [1] 23,253	[1] 17,272	[1] 24,081
Hawaii	4,706	7,863	4,613	8,558
Idaho	771	1,156	1,205	1,860
Illinois	31,615	41,524	35,399	45,984
Indiana	15,789	20,305	18,170	23,718
Iowa	17,714	24,126	19,622	26,283
Kansas	9,671	12,908	[1] 10,121	[1] 13,772
Kentucky	17,210	23,762	19,970	27,346
Louisiana	[1] 3,931	[1] 5,292	[1] 5,572	[1] 8,181
Maine	663	1,450	348	700
Maryland	10,290	18,313	11,585	20,101
Massachusetts	5,180	8,620	4,901	8,223
Michigan	4,593	5,464	5,614	6,540
Minnesota	[1] 2,507	[1] 3,060	3,253	4,126
Mississippi	W	W	W	W
Missouri	[1] 18,032	[1] 24,814	[1] 20,681	[1] 28,155
Montana	5,458	5,454	4,094	3,487
Nebraska	1,842	3,247	1,747	2,962
Nevada	62	72	277	282
New Hampshire	W	W	W	W
New Jersey	10,379	22,004	10,744	21,880
New Mexico	[1] 766	[1] 1,221	1,182	1,786
New York	18,281	32,678	19,941	34,600
North Carolina	16,958	25,954	17,676	27,180
North Dakota	27	48	59	103
Ohio	[1] 18,993	[1] 24,941	[1] 22,465	[1] 29,747
Oklahoma	9,952	10,148	[1] 12,586	[1] 12,659
Oregon	[1] 11,819	[1] 14,046	13,293	19,886
Pennsylvania	28,983	42,279	31,389	46,597
Rhode Island	W	W	W	W
South Carolina	[1] 5,242	[1] 7,652	5,188	7,231
South Dakota	1,108	1,778	822	1,294
Tennessee	[1] 21,660	[1] 28,111	23,101	29,087
Texas	25,746	30,248	25,318	30,713
Utah	[1] 156	[1] 297	261	513
Vermont	1,582	2,161	1,106	1,881
Virginia	21,615	32,519	26,945	38,611
Washington	7,709	9,745	8,208	10,488
West Virginia	[1] 2,256	[1] 3,459	2,533	3,791
Wisconsin	10,905	10,726	12,469	12,183
Wyoming	835	1,295	282	458
Undistributed	6,717	9,807	6,583	11,045
Total	[r] 456,071	[r] 628,222	503,263	690,736

[r] Revised.

W Withheld to avoid disclosing individual company confidential data; included with "Undistributed."

[1] To avoid disclosing individual company confidential data, total is somewhat incomplete, the portion not included being combined as "Undistributed."

Table 18.—Number and production of commercial crushed-stone plants in the United States, by size of operation

Annual production (short tons)	1964 Number of plants	1964 Production Thousand short tons	1964 Production Percent of total	1964 Cumulative total, thousand short tons	1965 Number of plants	1965 Production Thousand short tons	1965 Production Percent of total	1965 Cumulative total, thousand short tons
Less than 25,000	987	8,121	1.2	8,121	987	8,661	1.2	8,661
25,000 to 50,000	345	12,408	1.9	20,529	325	11,585	1.6	20,246
50,000 to 75,000	259	16,019	2.4	36,548	212	12,997	1.9	33,243
75,000 to 100,000	193	16,753	2.6	53,301	236	21,066	3.0	54,309
100,000 to 200,000	r 498	r 71,418	10.9	r 124,719	477	68,441	9.7	122,750
200,000 to 300,000	r 268	r 65,211	9.9	r 189,930	274	66,544	9.4	189.294
300,000 to 400,000	176	60,942	9.3	r 250,872	206	71,483	10.1	260,777
400,000 to 500,000	129	r 57,613	8.8	r 308,485	125	56,211	8.0	316,988
500,000 to 600,000	103	55,448	8.5	r 363,933	103	56,234	8.0	373,222
600,000 to 700,000	69	44,283	6.7	r 408,216	79	51,362	7.3	424,584
700,000 to 800,000	36	26,635	4.1	r 434,851	37	27,625	3.9	452,209
800,000 to 900,000	41	34,978	5.3	r 469,829	33	27,585	3.9	479,794
900,000 tons and over	111	186,605	28.4	r 656,434	141	226,137	32.0	705,931
Total	r 3,215	r 656,434	100.0	r 656,434	3,235	705,931	100.0	705,931

r Revised.

Table 19.—Crushed stone sold or used in the United States, by methods of transportation

Method of transportation	1964 Thousand short tons	1964 Percent of total	1965 Thousand short tons	1965 Percent of total
Commercial:				
Truck	r 436,091	60	501,382	65
Rail	r 89,709	13	93,992	12
Waterway	60,268	8	62,535	8
Unspecified	r 70,366	10	48,022	6
Total commercial	r 656,434	91	705,931	91
Government-and-contractor:				
Truck [1]	66,604	9	71,738	9
Grand total	r 723,038	100	777,669	100

r Revised.
[1] Entire output of Government-and-contractor operations assumed to be moved by truck.

Table 20.—Granite (crushed and broken stone) sold or used by producers in the United States, by uses

(Thousand short tons and thousand dollars)

Use	1964 Quantity	1964 Value	1965 Quantity	1965 Value
Concrete and roadstone	r 46,999	r $68,060	48,727	$71,259
Railroad ballast	2,604	3,327	3,036	3,791
Riprap	3,339	5,581	3,812	7,070
Fill	345	223	462	212
Stone sand	1,292	1,134	1,049	930
Poultry grit	182	1,524	135	1,103
Other uses [1]	r 727	r 864	2,021	3,647
Total	r 55,488	r 80,713	59,242	88,012

r Revised.
[1] Includes stone used for agriculture, roofing granules, and unspecified uses.

Table 21.—Granite (crushed and broken stone) sold or used by producers in the United States in 1965, by States

State	Short tons	Value	State	Short tons	Value
Arizona	236,735	$362,186	South Carolina	5,947,764	$8,447,400
California	4,276,338	5,220,384	Vermont	137,312	179,686
Colorado	2,057,676	3,047,060	Virginia	8,951,588	14,432,764
Georgia	17,185,284	23,676,732	Washington	17,560	65,920
Minnesota	616,812	857,149	Wisconsin	700,861	143,002
Montana	126,952	267,178	Wyoming	722,873	1,030,285
New Jersey	952,925	1,867,402	Other States [1]	4,671,173	9,092,482
New Mexico	3,420	5,130			
North Carolina	12,630,822	19,309,223	Total	59,241,531	88,011,749
Oregon	5,436	7,766	Puerto Rico	115,600	284,800

[1] Includes Alaska, Connecticut, Delaware, Maine, Maryland, Massachusetts, Missouri, Nevada, New Hampshire, New York, Pennsylvania, Rhode Island, and Texas.

Table 22.—Basalt and related rocks (traprock) (crushed and broken stone) sold or used by producers in the United States, by uses

(Thousand short tons and thousand dollars)

Use	1964		1965	
	Quantity	Value	Quantity	Value
Concrete and roadstone	56,907	$92,618	61,582	$101,830
Railroad ballast	1,887	2,846	1,299	2,064
Riprap	5,051	7,243	6,260	8,617
Fill	72	52	5,045	2,657
Other uses [1]	2,128	5,537	1,317	5,323
Total	66,045	108,296	75,503	120,491

[1] Includes stone used for concrete products, dam construction, filler, filtration, poultry grit, road base (including stabilized), rock wool, roofing granules, and unspecified uses.

Table 23.—Basalt and related rocks (traprock) (crushed and broken stone) sold or used by producers in the United States in 1965, by States

States	Short tons	Value	States	Short tons	Value
California	2,479,058	$3,032,104	Oregon	20,500,460	$26,036,112
Connecticut	5,440,071	8,698,732	Pennsylvania	3,762,470	7,223,276
Hawaii	3,556,232	7,184,535	Utah	200	800
Idaho	1,464,990	2,046,596	Virginia	3,161,265	5,334,785
Maryland	4,019,641	7,703,048	Washington	10,807,307	13,420,926
Massachusetts	4,429,066	7,317,688	Wyoming	39,724	87,382
Minnesota	75,000	131,000	Other States [1]	2,716,815	6,367,506
New Jersey	10,576,359	22,028,692	Total	75,502,978	120,491,402
New Mexico	84,490	248,500	Panama Canal Zone	93,109	254,415
North Carolina	2,389,830	3,629,720	Virgin Islands	67,948	301,975

[1] Includes Alaska, Arizona, Colorado, Nevada, New York, Texas, and Wisconsin.

Table 24.—Marble (crushed and broken stone) sold or used by producers in the United States,[1] by uses

(Thousand short tons and thousand dollars)

Use	1964		1965	
	Quantity	Value	Quantity	Value
Terrazzo	406	$5,277	356	$5,059
Concrete and roadstone	W	W	568	1,962
Other uses [2]	1,557	12,171	1,122	14,364
Total	1,963	17,448	2,046	21,385

W Withheld to avoid disclosing individual company confidential data; included with "Other uses."

[1] Produced by the following States in 1965, in order of tonnage: Georgia, Alabama, Missouri, Texas, New York, Tennessee, California, Wisconsin, North Carolina, Washington, Virginia, Vermont, Wyoming, Arizona, New Jersey, Maryland, Montana, Colorado, Utah, and Nevada.

[2] Includes stone used for acid neutralization, agriculture, asphalt filler, cast stone, poultry grit, roofiing chips, stucco, whiteing (excluding marble whiting made by companies that purchase marble), and unspecified uses.

Table 25.—Limestone and dolomite (crushed and broken stone) sold or used by producers in the United States, by uses

(Thousand short tons and thousand dollars)

Use	1964		1965	
	Quantity	Value	Quantity	Value
Concrete and roadstone	302,311	$397,481	337,770	$440,905
Flux	31,454	44,511	32,530	46,851
Agriculture	26,791	46,147	28,289	48,586
Railroad ballast	5,536	7,032	6,150	7,596
Riprap	9,943	11,509	13,874	14,723
Alkali manufacture	3,254	3,617	2,671	2,929
Cement-portland and natural	r 92,387	r 96,335	92,110	96,179
Coal-mine dusting	525	2,279	614	2,578
Fill material	742	471	703	414
Filler (not whiting substitute):				
Asphalt	1,745	5,065	1,512	4,210
Fertilizer	430	1,127	515	1,816
Other	374	2,045	266	1,449
Filtration	71	139	54	136
Glass manufacture	1,420	4,437	1,694	5,262
Lime and dead-burned dolomite	r 23,951	r 41,643	26,460	44,250
Limestone sand	1,852	3,420	1,944	3,443
Limestone whiting [1]	775	8,903	818	9,818
Mineral food	684	4,077	746	3,935
Paper manufacture	363	1,100	325	973
Poultry grit	134	1,190	131	1,170
Refractory (dolomite)	162	744	235	951
Sugar refining	852	2,298	755	1,875
Other uses [2]	2,755	6,230	2,171	5,173
Use unspecified	1,736	2,931	1,697	3,320
Total	r 510,247	r 694,731	554,034	748,542

r Revised.

[1] Includes stone for filler for abrasives, calcimine, calking compounds, ceramics, chewing gum, fabrics, floor coverings, insecticides, leather goods, paint, paper, phonograph records, plastics, pottery, putty, roofing, rubber, wire coating, and unspecified uses. Excludes limestone whiting made by companies from purchased stone.

[2] Includes stone for acid neutralization, calcium carbide, cast stone, chemicals (unspecified), concrete products, disinfectant and animal sanitation, electrical products, magnesia, magnesium, mineral wool, oil-well drilling, patching plaster, roofing granules, stucco, terrazzo, and water treatment.

Marble.—Most crushed or broken marble is sold as concrete and roadstone, facing aggregate, terrazzo, or roofing granules. A crystalline onyx marble in Montana was described.[13] Sales were principally for terrazzo chips and rough or polished exposed aggregate for precast decorative paneling. Whiter varieties found a variety of uses, such as filler, poultry and livestock food supplements, and white sand for use in plaster, in marking sport fields, and in terrazzo matrix.

Limestone.—Limestone (including dolomite), because of its nearly universal availability and diversified uses, was the leading type of crushed stone, accounting for 71 percent of all crushed stone produced and 67 percent of total crushed stone value in 1965. The average value reported for crushed limestone was $1.35 per ton in 1965. Sixty-one percent was used in concrete and roadstone, and 17 percent in cement manufacture. Totals included some crystallized limestones (marble) sold for purposes identical with limestone in areas deficient in unrecrystallized limestones such as Massachusetts and Connecticut. A new limestone-type product appearing on the United States market is "oolitic aragonite" from the Bahamas. The material, marketed by Olefins Division, Union Carbide Corp., is a granular, natural chemical precipitate from seawater and contains 54.40 percent calcium oxide (97 percent calcium carbonate), calculated.

American Iron and Steel Institute figures indicate that 61 percent of limestone for flux was consumed by iron blast furnaces, 22 percent in making iron ore agglomerates, and the balance in steel making. An average of 0.279 tons of limestone per ton of pig iron was required in blast furnaces compared with 0.274 tons of limestone in 1964. Respective Canadian requirements reported were 0.198 tons for both years. The Institute also reported a 41-percent increase in the amount of lime used in the various basic oxygen processes for steelmaking. In 1965, 55 percent of lime used for steelmaking was for the basic oxygen process, 32 percent for open-hearth, and the balance for electric and bessemer.

Articles were published summarizing the use of limestone aggregates in paving.[14] Several limestone producing operations were described.[15]

Shell.—Output of shell increased 11 percent in volume and 14 percent in value over 1964 figures. Two shell producing operations were described.[16]

Calcareous Marl.—The average value of marl produced in 1965 was $0.87 per ton compared with $0.86 per ton in 1964. Marl produced for cement manufacture increased 32 percent and marl for agricultural purposes decreased 4 percent.

Sandstone, Quartz, and Quartzite.—Use in concrete and roadstone accounted for 65 percent of the production of these rock types. Additional tonnages of silica raw materials are covered in the chapter on sand and gravel under industrial sands and gravels and ground sand.

Crushed and Broken Slate.—Production of crushed slate decreased 5 percent in 1965. Average value reported was $4.09 per ton compared with $4.05 per ton in 1964.

Miscellaneous Stone.—The average value of miscellaneous crushed stone produced in 1965 was $1.23 per ton compared with $1.24 in 1964. Local use for concrete and roadstone accounted for 61 percent of total 1965 production compared with 53 percent in 1964. Production of crushed volcanic cinder for railroad ballast was described in a journal article.[17]

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[13] Trauffer, W. E. New Montana Plant Makes Variety of Pulverized, Crushed and Split Marble Products. V. 57, No. 12, June 1965, pp. 79–81, 112, 114.

[14] Limestone. Limestone-Nature's Best Paving Material. V. 2, No. 1, March 1965, pp. 18–21.
National Limestone Institute, Inc., ABC's of Flexible Limestone Pavement for Subdivision Roads and Parking Areas. Paving Pamphlet, January 1965, 4 p.

[15] Levine, Sidney. Country Music Helps Lee Crawford Peddle Aggregate and Aglime. Rock Products, v. 68, No. 10, October 1965, pp. 76–79.
Rock Products. Rock Dust Round the Clock. V. 68, No. 6, June 1965, pp. 88–89.
Taeler, D. H. Dolomite at Natividad. Minerals Processing, v. 6, No. 5, June 1965, pp. 16–20.

[16] Pit and Quarry. Southern Industries New Shell Dredge. V. 58, No. 3, September 1965, pp. 91–93.
Taeler, D. H. They Sell Clam Shells. Minerals Processing, v. 6, No. 10, October 1965, pp. 46, 48–49.

[17] Construction Methods and Equipment. Crushed Volcanic Cinders Used as Track Ballast. V. 47, No. 8, August 1965, p. 29.

Table 26.—Limestone and dolomite (crushed and broken stone) sold or used by producers in the United States in 1965, by States, and uses

State	Riprap		Concrete and roadstone		Fluxing stone	
	Short tons	Value	Short tons	Value	Short tons	Value
Alabama	77,383	$101,608	867,124	$1,394,739	10,185,299	$12,208,595
Arizona	W	W	W	W	59,938	105,602
Arkansas	W	W	W	W	2,687,865	3,779,716
California	W	W	W	W	W	W
Colorado	W	W	W	W	W	W
Connecticut	------	------	W	W	------	------
Florida	W	W	------	------	30,258,300	33,405,119
Georgia	W	W	W	W	2,139,537	2,929,238
Hawaii	460	2,300	1,600	4,000	445,592	734,433
Idaho	------	------	W	W	------	------
Illinois	724,320	1,071,079	390,909	556,093	35,399,232	45,984,029
Indiana	142,966	229,505	35,680	50,300	18,169,790	23,718,356
Iowa	450,144	575,473	W	W	19,622,403	26,283,456
Kansas	1,189,802	1,081,812	------	------	9,927,107	13,356,196
Kentucky	W	W	------	------	19,969,952	27,345,994
Maine	------	------	------	------	W	W
Maryland	W	W	W	W	7,134,734	11,989,742
Massachusetts	------	------	W	W	W	W
Michigan	99,952	150,915	12,550,357	14,447,480	5,613,846	6,540,406
Minnesota	159,263	99,671	W	W	3,043,307	3,712,858
Mississippi	1,163,956	1,163,956	------	------	------	------
Missouri	2,873,070	2,383,311	W	W	20,681,018	28,155,335
Montana	W	W	W	W	W	W
Nebraska	1,539,953	1,910,966	------	------	1,747,328	2,962,000
Nevada	------	------	W	W	W	W
New Jersey	------	------	W	W	W	W
New Mexico	11,867	17,800	W	W	866,079	1,313,956
New York	86,983	175,406	29,949	65,074	17,025,697	29,514,291
North Carolina	------	------	------	------	W	W
Ohio	217,947	314,013	5,811,483	8,875,833	22,465,032	29,746,533
Oklahoma	W	W	------	------	10,529,728	10,567,187
Oregon	W	W	W	W	2,000	4,000
Pennsylvania	W	W	6,289,387	11,197,022	24,041,261	34,862,283
Rhode Island	------	------	W	W	------	------
South Carolina	------	------	W	W	W	W
South Dakota	W	W	------	------	392,091	611,218
Tennessee	W	W	W	W	23,101,188	29,086,521
Texas	1,009,532	1,245,305	W	W	17,685,554	18,390,288
Utah	W	W	W	W	W	W
Vermont	W	W	------	------	W	W
Virginia	W	W	1,018,109	1,588,002	14,065,792	18,124,010
Washington	------	------	W	W	W	W
West Virginia	W	W	W	W	2,532,699	3,790,891
Wisconsin	67,269	62,414	10,634	12,794	11,622,954	11,798,014
Wyoming	31,033	54,517	W	W	180,257	264,297
Undistributed	4,027,878	4,082,611	5,524,678	8,659,292	6,174,775	9,620,602
Total	13,873,778	14,722,662	32,529,910	46,850,629	337,770,355	440,905,166
American Samoa	------	------	------	------	------	------
Guam	------	------	------	------	W	W
Puerto Rico	16,600	11,000	------	------	2,068,368	4,996,694
Wake Island	------	------	------	------	1,253	3,807

W Withheld to avoid disclosing individual company confidential data.

Table 26.—Limestone and dolomite (crushed and broken stone) sold or used by producers in the United States in 1965, by States and uses—Continued

State	Railroad ballast		Agriculture		Miscellaneous		Total	
	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value
Alabama	W	W	546,291	$892,282	W	W	17,486,167	$20,592,896
Arizona	------	------	------	------	1,255,911	$1,612,322	1,601,867	2,146,626
Arkansas	------	------	273,417	457,995	1,637,038	2,002,667	5,363,933	7,029,864
California	------	------	20,329	118,099	13,500,894	20,092,780	15,259,134	21,999,024
Colorado	------	------	------	------	1,465,815	2,840,545	2,203,140	4,063,198
Connecticut	------	------	W	W	W	W	259,404	1,043,790
Florida	508,700	$785,849	660,970	2,136,057	W	W	34,324,723	38,972,846
Georgia	W	W	189,155	331,457	W	W	3,343,652	4,777,956
Hawaii	------	------	W	W	W	W	947,175	1,314,022
Idaho	------	------	------	------	W	W	W	W
Illinois	557,793	527,615	4,754,899	7,053,200	5,233,220	5,970,160	47,060,373	61,162,176
Indiana	435,841	544,255	2,453,392	3,488,602	2,786,920	2,626,808	24,024,589	30,657,826
Iowa	143,991	127,953	1,847,839	2,860,839	W	W	25,873,741	35,265,515
Kansas	W	W	521,579	850,086	W	W	14,657,016	18,950,947
Kentucky	W	W	2,221,865	3,120,335	732,132	977,546	26,028,574	34,532,384
Maine	51,362	82,179	W	W	W	W	900,755	1,385,185
Maryland	W	W	W	W	2,366,251	5,390,040	9,692,378	17,756,183
Massachusetts	------	------	187,526	621,836	498,527	2,386,379	712,596	3,058,950
Michigan	W	W	609,298	1,068,557	W	W	34,569,947	36,228,183
Minnesota	W	W	292,625	465,842	W	W	3,559,643	4,630,965
Mississippi	------	------	W	W	W	W	1,495,808	1,493,358
Missouri	W	W	3,509,192	5,572,749	7,730,523	13,423,607	34,947,623	49,726,148
Montana	------	------	------	------	931,915	1,250,624	1,017,738	1,443,005
Nebraska	------	------	W	W	W	W	4,188,826	6,587,971
Nevada	------	------	------	------	W	W	W	W
New Jersey	------	------	W	W	W	W	W	W
New Mexico	------	------	------	------	W	W	1,452,401	2,084,281
New York	556,742	909,849	378,752	1,352,580	9,447,027	8,937,223	27,525,150	40,954,423
North Carolina	3,229	4,359	10,884	21,768	W	W	3,708,808	5,600,484
Ohio	1,103,486	1,358,624	2,030,844	3,626,179	9,904,349	15,995,991	41,533,141	59,917,173
Oklahoma	W	W	220,851	317,828	2,232,506	3,695,867	13,118,526	14,740,290
Oregon	------	------	W	W	618,173	908,689	625,518	927,151
Pennsylvania	W	W	1,236,490	3,731,886	15,751,062	21,990,745	47,914,046	72,552,031
Rhode Island	------	------	W	W	W	W	W	W
South Carolina	------	------	W	W	W	W	W	W
South Dakota	110,203	129,624	------	------	W	W	862,726	1,402,917
Tennessee	304,275	369,828	2,208,537	2,810,964	3,144,971	4,237,093	28,801,191	36,564,246
Texas	W	W	432,990	598,643	7,727,743	9,486,248	27,864,497	30,719,987
Utah	------	------	W	W	937,938	2,272,673	1,852,365	3,733,580
Vermont	W	W	W	W	W	W	1,318,282	4,237,150
Virginia	265,498	349,388	1,295,064	2,319,572	W	W	21,875,227	31,941,437
Washington	------	------	23,599	92,879	1,348,708	2,632,552	1,416,736	2,853,654
West Virginia	636,051	797,883	125,444	299,506	2,472,980	4,575,469	7,801,150	13,272,830
Wisconsin	W	W	1,116,031	1,484,917	W	W	12,941,828	13,666,511
Wyoming	W	W	------	------	484,997	1,046,327	764,191	1,465,714
Undistributed	1,472,528	1,608,447	1,120,994	2,891,779	43,211,698	55,529,168	3,139,312	7,089,393
Total	6,149,699	7,595,853	28,288,857	48,586,437	135,421,298	189,881,523	554,033,897	748,542,270
American Samoa	------	------	------	------	60,000	60,000	60,000	60,000
Guam	------	------	------	------	W	W	482,839	925,030
Puerto Rico	------	------	92,600	295,150	2,057,942	1,304,422	4,235,510	6,607,366
Wake Island	------	------	------	------		------	1,253	3,807

W Withheld to avoid disclosing individual company confidential data; included with "Undistributed."

Table 27.—Sales of fluxing limestone, by uses

(Thousand short tons and thousand dollars)

Year	Blast furnace		Open-hearth plants		Other smelters [1]		Other metallurgical [2]		Total	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1956–60 (average)	23,815	$33,663	7,026	$10,195	928	$1,185	713	$1,089	32,482	$46,132
1961	18,129	25,891	6,412	10,056	896	1,205	1,761	2,573	27,198	39,725
1962	16,996	23,062	6,411	9,835	646	952	2,028	2,972	26,081	36,821
1963	18,514	26,456	5,772	8,511	741	1,162	2,158	3,193	27,185	39,322
1964	22,364	31,437	5,625	8,082	1,075	1,278	2,390	3,714	31,454	44,511
1965	23,168	32,980	5,594	8,189	1,167	1,487	2,601	4,195	32,530	46,851

[1] Includes flux for copper, gold, lead, zinc, and unspecified smelters.
[2] Includes flux for foundries and for cupola and electric furnaces.

Table 28.—Shell sold or used by producers in the United States, by uses

(Thousand short tons and thousand dollars)

Use	1964		1965	
	Quantity	Value	Quantity	Value
Concrete and road material	12,738	$18,529	15,111	$22,047
Cement	5,042	5,921	4,938	7,271
Lime	1,045	1,379	329	371
Poultry grit	545	3,677	422	3,072
Other uses [1]	123	651	760	1,553
Total	19,493	30,157	21,560	34,314

[1] Includes, whiting, asphalt filler, other filler, mineral food, and unspecified uses.

Table 29.—Shell sold or used by producers in the United States in 1965, by States

State	Short tons	Value	State	Short tons	Value
Arkansas	2,165	$161,430	Texas	9,689,357	$15,355,914
Florida	1,404,380	2,168,639	Other States [1]	3,012,150	5,722,860
Louisiana	7,452,421	10,905,244	Total	21,560,473	34,314,087

[1] Includes Alabama, California, Maryland, Mississippi, New Jersey, Pennsylvania, and Virginia.

Table 30.—Calcareous marl sold or used by producers in the United States,[1] by uses

(Thousand short tons and thousand dollars)

Use	1964		1965	
	Quantity	Value	Quantity	Value
Agriculture [2]	228	$156	219	$150
Cement	815	743	1,072	975
Total	1,043	899	1,291	1,125

[1] Produced by the following States in 1965, in order of tonnage: Mississippi, Virginia, Michigan, Texas, Indiana, Minnesota, Wisconsin, and Nevada.
[2] Includes marl used in mineral food.

Table 31.—Sandstone, quartz, and quartzite (crushed and broken stone) [1] sold or used by producers in the United States, by uses

(Thousand short tons and thousand dollars)

Use	1964 Quantity	1964 Value	1965 Quantity	1965 Value
Concrete and roadstone	16,163	$25,393	18,757	$26,958
Railroad ballast	1,369	1,490	1,255	1,573
Riprap	6,961	9,231	5,024	5,539
Refractory stone (ganister)	438	4,493	533	5,501
Abrasives	56	287	81	409
Ferrosilicon	98	612	104	610
Filtration	110	195	22	60
Flux	522	2,122	495	1,877
Foundry	44	173	51	210
Glass	215	782	394	1,297
Other uses [2]	1,762	6,694	1,985	6,889
Total	27,738	51,472	28,701	50,923

[1] Includes ground sandstone, quartz, and quartzite. Friable sandstone is reported in the chapter on sand and gravel.

[2] Includes cement, fill, filler, porcelain, pottery, roofing granules, stone sand, terrazzo, tile, and unspecified uses.

Table 32.—Sandstone, quartz, and quartzite (crushed and broken stone) sold or used by producers in the United States in 1965, by States

State	Short tons	Value	State	Short tons	Value
Arizona	449,517	$1,096,221	Pennsylvania	2,991,463	$10,124,388
Arkansas	9,614,667	10,526,221	South Dakota	650,847	1,006,609
California	4,059,003	7,148,604	Texas	879,790	1,412,142
Colorado	168,175	421,423	Utah	200,872	474,552
Illinois	744	7,440	Virginia	899,408	1,297,872
Minnesota	62,886	154,045	Washington	100,040	483,855
Montana	306,420	626,425	West Virginia	680,535	1,314,442
New York	634,610	1,318,140	Wyoming	2,212	2,865
North Carolina	72,391	559,630	Other States [1]	4,233,220	8,378,355
Ohio	558,319	2,167,180			
Oklahoma	2,056,651	2,091,631			
Oregon	79,505	311,008	Total	28,701,275	50,923,048

[1] Includes Alabama, Connecticut, Georgia, Idaho, Indiana, Kansas, Maryland, Missouri, Nevada, New Hampshire, New Mexico, Tennessee, and Wisconsin.

Table 33.—Slate (crushed and broken stone) sold or used by producers in the United States,[1] by uses

(Thousand short tons and thousand dollars)

Use	1964 Quantity	1964 Value	1965 Quantity	1965 Value
Granules [2]	295	$1,848	247	$1,747
Flour	141	798	155	904
Lightweight aggregates	703	1,963	679	1,770
Total	1,139	4,609	1,081	4,421

[1] Produced by the following States in 1965 in order of tonnage: Virginia, Georgia, Pennsylvania, Arkansas, Vermont, California, and Illinois.

[2] Includes crushed slate used for roadstone and unspecified uses to avoid disclosing individual company confidential data.

Table 34.—Miscellaneous stone (crushed and broken stone) sold or used by producers in the United States, by use

(Thousand short tons and thousand dollars)

Use	1964		1965	
	Quantity	Value	Quantity	Value
Concrete and roadstone	20,953	$26,141	20,748	$25,775
Railroad ballast	2,774	2,106	2,283	2,351
Riprap	14,201	16,216	9,784	10,089
Fill	200	153	200	138
Other uses [1]	1,754	4,653	1,196	3,817
Total	39,882	49,269	34,211	42,170

[1] Includes stone used for agriculture, filtration, flux, roofing granules, stone sand, terrazzo, and unspecified uses.

Table 35.—Miscellaneous varieties of stone (crushed and broken stone) sold or used by producers in the United States in 1965, by States

State	Short tons	Value	State	Short tons	Value
Arizona	48,064	$102,495	South Dakota	14,068	24,117
Arkansas	6,158,567	7,960,389	Utah	100,366	$200,732
California	15,776,624	19,084,435	Wyoming	57,302	92,183
Hawaii	654,932	773,964	Other States [1]	3,842,191	6,382,749
Montana	4,053,626	3,509,781			
New Mexico	316,442	472,326			
North Dakota	355,618	624,319	Total	34,211,097	42,170,229
Oklahoma	1,232,776	705,036	Panama Canal Zone	60,309	111,683
Pennsylvania	1,600,521	2,237,703	Puerto Rico	839,500	1,805,900

[1] Includes Alaska, Colorado, Kansas, Louisiana, Maine, Maryland, Massachusetts, Missouri, Montant, Nevada, New Hampshire, New Jersey, New York, Rhode Island, Texas, Vermont, and Washington.

FOREIGN TRADE

The most important export items were $4.1 million worth of crushed stone to Canada and $100,000 worth of crushed limestone to Chile.

Crushed stone importes were mostly whiting from Europe and stone chips from Canada and Europe.

Table 36.—U. S. exports of stone

Year	Building and monumental stone		Crushed, ground, or broken: Limestone		Crushed, ground, or broken: Other		Other manufacturers of stone (value)
	Cubic feet	Value	Short tons	Value	Short tons	Value	
1956–60 (average)	393,187	$1,176,352	985,614	$1,635,550	157,856	$3,066,631	$487,232
1961	435,173	1,595,805	790,912	1,596,122	128,149	3,026,785	429,604
1962	534,919	1,795,048	621,177	1,546,663	114,744	2,166,167	501,389
1963	452,167	1,669,098	762,658	1,752,930	110,949	2,095,217	584,582
1964	441,312	2,027,016	1,369,728	2,079,240	105,504	2,013,078	676,766
1965	[1] 264,407	1,258,572	1,165,327	2,905,338	73,096	1,955,103	1,479,682

[1] Beginning Jan. 1, 1965, dolomite separately classified, 253,436 short tons, ($2,031,515).

Table 37.—U. S. exports of slate, by uses [1]

(Value)

Use	1956–60 (average)	1961	1962	1963	1964	1965
Roofing	$9,152	W	$15,096	W	W	W
Structural, flagging, flooring, granules (1956-59), and flour	140,392	$9,154	16,321	$20,081	$17,263	$19,711
Other uses [2]	107,941	73,918	84,639	56,228	43,312	56,297
Total	257,485	83,072	116,056	76,309	60,575	76,008

W Withheld to avoid disclosing individual company confidential data; included with "Other uses."
[1] Figures collected by the Bureau of Mines from shippers of products named.
[2] Includes electrical slate, school slate, blackboards, billiard tabletops, millstock (unspecified), and sculpings.

WORLD REVIEW

Canada.—Plans were announced to mine vein quartz at St. Urbain, Quebec, to supply the abrasive, glass, and silicon industries. Indicated reserves were reported to be 33 million tons, averaging 98.69 percent silica and 0.28 percent iron.[18] Another silica deposit was reported on the shore of Holberg Inlet on Quatsino Sound, British Columbia, and a limestone deposit was explored on the west coast of Princess Royal Island in the same province. Several Canadian crushed stone operations were described.[19]

Hungary.—The quarrying industry of Hungary was described.[20] Igneous rock was the leading crushed stone followed by crushed limestone. The average haulage distance was 65 miles due to uneven distribution of workable deposits.

Japan.—A 10-mile-long conveyor belt, the longest in the world, was being built to transport crushed limestone from a quarry to a seaport. The belt will travel through 14 tunnels, crossing numerous highways and a main railroad line.

[18] The Northern Miner (Toronto, Canada) Leeds Metals Moves Into High Gear On Silica Operation. No. 31, October 21, 1965, pp. 1, 7.
[19] Rock Products. Market Dictates High-Capacity Material Handling. V. 68, No. 9, September 1965, pp. 66–67.
Trauffer, W. E. New 900–T.p.h. Quebec Crushed Stone Plant Has Many Features. Pit and Quarry, v. 58, No. 5, November 1965, pp. 100–106.
[20] Fish, B. G. Quarrying in Hungary. Quarry Managers J. (London), v. 49, No. 11, November 1965, pp. 433–438.

Table 38.—U. S. imports for consumption of stone and whiting, by classes

Class	1964 Quantity	1964 Value	1965 Quantity	1965 Value
Granite:				
Monumental, paving and building stone:				
Rough ---cubic feet--	144,907	$656,170	166,192	$790,530
Dressed, manufactured ---do---	155,273	1,615,210	101,242	1,265,051
Not manufactured and not suitable for monumental, paving or building stone ---short tons--	237	3,452	236	3,373
Other, n.s.p.f. ---	------	32,940	------	63,436
Total ---	------	2,307,772	------	2,122,390
Marble, breccia, and onyx:				
In block rough or squared ---cubic feet--	104,137	813,561	68,300	563,795
Sawed or dressed over 2 inches thick ---do---	10,371	145,324	10,383	82,134
Slabs and paving tiles ---superficial feet--	7,475,465	6,531,942	7,173,148	6,449,896
All other manufactures ---	------	4,708,814	------	4,416,961
Total ---	------	12,199,641	------	11,512,786
Travertime stone:				
Rough, unmanufactured ---cubic feet--	112,019	391,386	62,214	202,208
Dressed, suitable for monumental, paving or building stone ---short tons--	32,750	1,238,279	30,926	1,149,171
Other, n.s.p.f. ---	------	258,710	------	157,693
Total ---	------	1,888,375	------	1,509,072
Limestone:				
Monumental, paving and building stone:				
Rough ---cubic feet--	1,076	1,963	900	2,700
Dressed, manufactured ---short tons--	2,788	111,748	1,560	32,447
Crude, not suitable for monumental, paving or building stone ---short tons--	675,443	1,014,545	624,983	729,263
Other, n.s.p.f. ---	------	51,039	------	34,078
Total ---	------	1,179,295	------	798,488
Slate:				
Roofing slate ---square feet--	------	------	5,167	731
Other, n.s.p.f. ---	------	1,400,619	------	1,319,121
Total ---	------	1,400,619	5,167	1,319,852
Quartzite ---short tons--	70,959	252,420	84,230	365,615
Stone and articles of stone, n.s.p.				
Statuary and sculptures ---	------	359,672	------	410,908
Stone, unmanufactured ---short tons--	353	14,146	13,099	20,939
Building stone, rough ---cubic feet--	505	1,480	4,574	5,659
Building stone, dressed ---short tons--	100,425	2,028,958	1,029	39,495
Other ---	------	134,106	------	126,597
Total ---	------	2,538,362	------	603,598
Stone, chips, spalls, crushed or ground:				
Marble, breccia and onyx chips ---short tons--	20,826	227,342	17,235	196,027
Limestone, chips and spalls, crushed or ground ---short tons--	325,223	388,974	477,028	777,459
Stone chips and spalls and stone crushed or ground, n.s.p.f. ---short tons--	1,254,888	935,292	898,389	896,557
Total ---	------	1,551,608	------	1,870,043
Whiting:				
Whiting, dry, ground, or bolted ---short tons--	3,283	264,516	2,250	164,424
Chalk whiting, precipitated ---do---	11,019	170,161	9,775	147,556
Chalk, whiting putty ---do---	------	------	1	147
Total ---	------	434,677	------	312,127
Grand total ---	------	r 23,752,769		20,413,971

r Revised.

Malaysia.—A Government-operated quarry at Lunchoo was described. The granite was quarried and crushed at a rate of 800 to 1,000 tons per day following a modernization program started in 1961.[21]

South Africa, Republic of.—A dolomite quarry at Lyttelton was described.[22] Quartzite was quarried for the first time in the Richtersveld Coloured Area in Namaqualand.

United Kingdom.—Operations at several crushed granite and limestone quarries were the subject of articles in periodicals.[23]

TECHNOLOGY

Urbanization, zoning, and the desire to enhance the beauty of the countryside placed increasing pressure on aggregate producers by restricting available sites and placing more stringent permissible limits upon operations.[24] As a result research continued on manufactured aggregates, utilizing wastes such as fly ash, slate quarry, and coal and other mine dumps, slags, and debris from old roads and buildings.[25] Also mining of crushed and broken stone underground has been of increasing interest. New machinery and mining methods have lessened the cost gap between surface and underground techniques in some instances. Because of the large magnitude of crushed stone demand, nuclear explosives have attracted special attention for possible economical underground mining of aggregate materials. The results of research to date on breaking rock with nuclear explosives for use as aggregate were summarized by the Plowshare Division of Lawrence Radiation Laboratory in a journal article.[26] Technical feasibility and capability have been demonstrated by several underground experiments in hard rock. Limitations arising from safety considerations were not excessive and will permit the use of nuclear explosives at a wide choice of sites. Tonnage curves showing rock yield as a function of explosive yield and depth of burial, fragment size distribution data, and per-ton cost estimates using nuclear explosives were presented and the cost of energy on a per-unit basis for various explosives was compared. The approximate cost per million B.t.u. for various blasting agents was calculated as follows: TNT $115; dynamite $100; ammonium nitrate-fuel oil $30; 10-kiloton nuclear $8.75; 100-kiloton nuclear $1.12; 2-megaton nuclear $0.075. On a per-ton cost basis (including explosive emplacement) the cost per ton of rock broken was estimated at 9.2 cents using a 10-kiloton explosive and 1.8 cents with a 100-kiloton device. Methods for mining with different nuclear explosive configurations were diagrammed.

Increased aggregate mining using subterranean nuclear or conventional techniques would develop ancillary aesthetic benefits by eliminating open pit quarries in some areas. In addition, some of the work-out operations might later prove useful for underground storage or as factory sites.[27] Easily controlled temperature and humidity as well as security from theft, fire,

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[21] Harrington, V. R. Production of Aggregates in Malaya. Quarry Manager's J. (London), v. 49, No. 12, December 1965, pp. 479–484.

[22] Holz Peter. New South African Dolomite Plant Supplies Steel Mill and Other Needs. Pit and Quarry, v. 58, No. 4, October 1965, pp. 134–138.

[23] Cement, Lime, and Gravel (London) Grinding Limestone at Minera. V. 40, No. 3, March 1965, pp. 83–88.

Mining and Minerals Engineering (London). High Pressure Vole Drilling in Leicestershire Granite. V. 1, No. 16, December 1965, pp. 610–615.

———. Development at Hawes Quarry. V. 1, No. 16, December 1965, pp. 627–629.

Quarry Managers Journal (London). Quarrying Limestone at Minera. V. 49, No. 5, May 1965, pp. 173–180.

———. New Installations at Graig Quarry. V. 49, No. 7, July 1965, pp. 287–290.

———. Cookswood Quarry. V. 49, No. 10, October 1965, pp. 387–390.

[24] Stearn, E. W. In Southern California: Aggregate Producers Face Critical Land Shortage. Rock Products, v. 68, No. 12, December 1965, pp. 68–70.

[25] Goodwin, W. A. Research on Utilization of Aggregates in the National Cooperative Highway Research Program. Limestone, v. 2, No. 4, June 1965, pp. 9–13.

[26] Hansen, S. M., and J. Toman. Rock Breaking Takes a Giant Step Into the Space Age. Rock Products, v. 68, No. 6, June 1965, pp. 53–59.

[27] Stearn, E. W. Underground Storage: How Does It Look Today? Rock Products, v. 68, No. 12, December 1965, pp. 86-87, 96.

or atomic attack are among the advantages of such sites. Rental of the rooms or galleries created by mining may in some cases represent potentially greater profit to the owner than may have been realized from sale of the extracted rock products. A quantitative estimate of potential future demand for underground space, however, has not been made. As a result secondary use has not been a prime consideration for conversion to underground mining in the past or at present.

A symposium on rock drilling was published.[28] Subjects covered included rotary percussion drilling, jumbo design, silent drills, underground big bore drilling, drill maintenance, and determination of effective rock drill service life. Many of the new, unconventional methods of penetrating rock were discussed in another article.[29] Such techniques include vibration drilling, waterjet penetration. thermal and electrical rock fracture, the use of chemicals, and abrasive jets. Another drilling innovation utilizes superheated steam and liquid nitrogen to subject rock to alternating hot and cold shock.[30] The thermal-cryogenic shock results in a deep shattering effect at the face of the drill. Mechanical boring of large diameter rock tunnels and shafts was becoming of more importance as technological process in the field appeared to be accelerating.[31]

Bureau of Mines research on explosives continued. During the year, publication of results centered on work performed in granite.[32] Performance of various explosives in granite were compared and explosive properties related to rock breakage. Methods of detonation were also discussed. Presplitting techniques continued to become more common practice as a means of preventing overbreakage and to yield clean, oriented excavations walls.[33] The Bureau of Mines published the results of a mining methods and cost study of one presplit shaft in Massachusetts.[34] Explosive slurry developments were reviewed.[35] Such blasting agents are readily compacted to permit most effective utilization of available explosive energy, and they are also relatively insensitive to accidental detonation under mechanical impact. The detonation pressures of commonly commercially available slurries (including metallized) ranged from 90 to 19 kilobars but most were determined to be in a narrow range from 80 to 57 kilobars. In the 8 years since their introduction, slurry explosives have earned a prominent place.

A large number of crushed stone operations were described in detail.The Bureau of Mines published one circular on crushed quartzite mining methods and costs, and a variety of stone quarries and plants were the subject of articles in periodicals.[36] Of particular interest were the publications describing new plants with automatic control equipment.

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[28] Metal Mining and Processing. Rock Drilling Roundup. V. 2, No. 2, February 1965, pp. 19–33.

[29] Farmer, I. W. New Methods of Fracturing Rocks. Min. and Miner. Eng. (London), v. 1, No. 5, January 1965, pp. 177–184.

[30] Engineering and Mining Journal. New Drill Subjects Rock to "Hot and Cold" Shock. V. 166, No. 3, March 1965, p. 103.

[31] Otter, J. V. Tunneling in Sandstone. Min. Cong. J., v. 51, No. 6, June 1965, pp. 44–45.

Williamson, T. N. History and Problems of Rock Boring. Min. Cong. J., v. 51, No. 6, June 1965, pp. 39–40, 43–44.

[32] Duvall, Wilbur I., and Joseph M. Pugliese. Comparison Between End and Axial Methods of Detonating an Explosive in Granite. BuMines Rept. of Inv. 6700, 1965, 11 pp.

Nicholls, Harry R., and Verne E. Hooker. Comparative Study of Explosives in Granite. Third Series of Tests. BuMines Rept. of Inv. 6693, 1965, 46 pp.

[33] Devine, James F., Richard H. Beck, Alfred V. C. Meyer, and Wilbur I. Duvall. Vibration Levels Transmitted Across a Presplit Fracture Plane. BuMines Rept. of Inv. 6695, 1965, 29 pp.

[34] Paine, Robt. S., and N. A. Eilertsen. Mining Method, Technique, and Cost of Presplitting the Flood Control Gate Shaft, Littleville Dam, Huntington, Mass. BuMines Inf. Circ. 8273, 1965, 28 pp.

[35] Nelson, R. G. Blasting Slurries. Limestone, v. 2, No. 1, March 1965, pp. 36–39.

[36] Harris, A. T., Jr., and W. T. Millar. Quartzite Mining and Processing Methods and Costs at the Honey Brook, Pa., Plant of George F. Pettinos, Inc. BuMines, Inf. Circ. 8248, 1965, 21 pp.

———. New Site + New Plant = Top Service. Pit and Quarry, v. 57, No. 8, February 1965, pp. 114–124.

———. Full Range of Road Materials From New Crushed Stone Plant. Pit and Quarry, v. 57, No. 12, June 1965, pp. 82–83, 86, 90.

Herod, B. C. Crushed Stone Plant Key Factor in Harnessing Water Power. Pit and Quarry, v. 58, No. 4, October 1965, pp. 78–83.

Utley, H. F. Granite Rock Builds Automated Base Rock Plant. Pit and Quarry, v. 57, No. 9, March 1965, pp. 136–139.

Some communities have, upon occasion, complained of dust nuisance arising from operations of the rock products industry. The emission of incidental dust can be controlled and this can be done within the scope of existing technology and at realistic costs. A review of dust collection practices and available equipment was published.[37] The article included an outline of factors involved in defining and solving rock dust control problems, examples of representative air pollution codes, and cutaway diagrams of basic equipment.

Stone conservation technology has been of significance in many market areas due to resource depletion and high relative transportation costs for this bulk commodity. Longer transportation hauls result in increased crushed stone costs at the market site and concomitantly encourages investigation of means of lessening aggregate requirements for various end uses. A typical example of such research was carried out by the Japanese National Railways and inidcated that maintenance of railroad right-of-ways can be substantially lessened by using asphalt concrete or macadam to stabilize roadbeds.[38] Asphalt stabilization not only improved subgrade conditions but also lessened substantially ballast settlement rates. The concomitant increase in bed bearing-power and durability resulted in less frequent reballasting with savings in aggregates, labor, and downtime on the right-of-way. If these new methods prove economically feasible over extensive systems, such as the planned high-speed, heavy traffic line from Washington to Boston, stone and gravel ballast requirements could be substantially lessened in the future. A more comfortable and safer ride are ancillary benefits to be anticipated for passengers.

[37] Levine, Sidney. What You Should Know About Dust Collectors. Rock Products, v. 68, No. 4, April 1965, pp. 53–65, 68.

[38] Asphalt. Railroads With a Difference. V. 17, No. 4, October 1965, p. 12.

Sulfur and Pyrites

By Paul M. Ambrose [1]

In 1965, the third successive year that demand for sulfur exceeded production, requirements was largely met by tremendously expanded production at some mines and heavy withdrawals of producer stocks. The United States continued to be the leading nation in production, imports, exports, and consumption of elemental sulfur. Among the leading nations in sulfur production, U.S. output exceeded some early expectations, Canada and France each produced as anticipated, and production and exports from Mexico were less than planned. Decreased availability of sulfur from Mexico was the principal but not the sole reason for the free world shortage of approximately 1 million long tons.

In 1963 only 40 percent of the sulfur consumed in the United States was used in making fertilizer. It has been estimated that 77 percent of the increased domestic demand was for the fertilizer industry. This resulted in the fertilizer industry using 45 percent of the sulfur in 1965.

Louisiana with production of more than 3.5 million long tons was the leading State. The next was Texas where almost 3.2 million tons of Frasch and recovered sulfur was produced. Shipments of elemental sulfur consisting of current production and withdrawals from stocks in Texas were more than 700,000 tons greater than shipments from Louisiana.

Prices became more firm and higher returns were realized by elimination of allowances and discounts to recover most of the transportation and terminal costs for Frasch sulfur within the United States. The price for export sulfur increased more than that for the domestic market.

Legislation and Government Programs.—Sulfur rights on 72,000 acres of offshore land in 50 separate tracts of 1,440 acres each were leased to seven companies or combines for $33 million, an average price of $468.61 per acre, the highest price ever

[1] Commodity specialist, Division of Minerals.

Table 1.—Salient sulfur statistics

(Long tons, sulfur content)

	1956–60 (average)	1961	1962	1963	1964	1965
United States:						
Production (native)	5,277,099	5,477,493	5,025,418	4,881,927	5,228,365	6,116,273
All forms	6,758,290	7,172,479	6,757,211	6,643,802	7,092,734	8,211,767
Exports, sulfur	1,658,517	1,596,043	1,553,986	1,612,637	1,928,092	2,651,735
Imports, pyrites and sulfur	694,529	966,417	1,185,073	1,460,680	[1] 1,582,211	[1] 1,625,093
Stocks Dec. 31: Producer, Frasch and recovered sulfur	4,196,460	4,813,521	4,934,238	4,682,496	[r] 4,226,524	3,425,161
Consumption, apparent, all forms [2]	5,667,980	5,893,000	6,243,600	6,607,000	[r] 7,259,711	7,958,547
World: Production:						
Sulfur, elemental	9,139,000	11,490,000	11,990,000	12,590,000	13,870,000	15,120,000
Pyrites	7,980,000	8,750,000	8,900,000	8,900,000	9,200,000	9,600,000

[r] Revised.
[1] Includes estimated 120,000 tons of sulfur in pyrites imports for 1964 and 160,000 tons for 1965.
[2] Measured by quantity sold, plus import, minus exports.

received for mineral lease rights except for certain oil and gas drainage tracts. Lease rights would last for 10 years and provide for a royalty rate of 10 percent of the gross production or value of the sulfur at the well head but would not be less than $2 per long ton. Successful bidders, number of tracts, and prices were Humble Oil Co., 26 tracts for $14,603,000; Freeport Sulphur Co., 5 tracts for $11,964,260; Atlantic Refining Co., 5 tracts for $4,451,270; Texas Gulf Sulphur Co. and Gulf Oil Corp., 7 tracts for $2,447,440; Shell Oil Co., 3 tracts for $123,784.80; Continental Oil Co., Atlantic Refining Co., and Cities Service Oil Co., 1 tract for $92,354 and Continental Oil Co., 1 tract for $57,600.[2]

DOMESTIC PRODUCTION

Native Sulfur.—The 10 Frasch process mines in operation through 1965 were the 4 mines of Freeport Sulphur Co. at Grande Ecaille, Garden Island Bay, and Lake Pelto in Louisiana, and Grand Isle, 7 miles off the Louisiana coast in the Gulf of Mexico; 4 mines of Texas Gulf Sulphur Co. at Newgulf, Fannett, Moss Bluff, and Spindletop in Texas; 1 mine of Duval Corp. at Orchard Dome, Tex.; and 1 mine of Jefferson Lake Sulphur Co. at Long Point Dome in Texas. Texas Gulf Sulphur Co. rehabilitated the mine at Gulf, Tex., and started production in October. At yearend Texas Gulf Sulphur Co. was operating five mines, all in Texas.

In 1965 Freeport Sulphur Co. was the only major producer of sulfur in the world to achieve a substantial increase in output. That company's production was approximately 30 percent greater than in 1964 and resulted in the production and sale of more than 3.5 million tons of sulfur. Output would have been greater except for the loss of the equivalent of about 9 days production because of Hurricane Betsy in September.[3]

[2] U.S. Department of the Interior, Bureau of Land Management. Interior Leases Sulphur Rights on Continental Shelf. News Release, Dec. 21, 1965, 1 p.

[3] Freeport Sulphur Co., Annual Report 1965, 1966, pp. 3, 6.

Table 2.—Production of sulfur and sulfur-containing raw materials by products in the United States

(Long tons)

	1956–60 (average)		1961		1962		1963		1964		1965	
	Gross weight	Sulfur content	Gross weight	Sulfur content	Gross weight	Sulfur content	Gross weight	Sulfur content	Gross weight	Sulfur content	Gross weight	Sulfur content
Native sulfur or sulfur ore:												
Frasch-process	5,210,981	5,210,981	5,385,468	5,385,468	4,984,578	4,984,578	4,881,512	4,881,512	5,228,207	5,228,207	6,116,273	6,116,273
Other mines	241,188	66,118	400,015	92,025	162,186	40,840	1,371	415	794	158	2,592	(1)
Total	---------	5,277,099	---------	5,477,493	---------	5,025,418	---------	4,881,927	---------	5,228,365	---------	6,116,273
Recovered elemental sulfur:												
Brimstone	615,696	613,601	861,413	858,169	902,124	899,598	949,567	946,753	1,024,649	1,021,358	1,219,312	1,215,168
Paste	148	67	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------
Total	---------	613,668	---------	858,169	---------	899,598	---------	946,753	---------	1,021,358	---------	1,215,168
Pyrites	1,036,859	424,831	987,309	398,519	915,890	379,046	824,800	343,566	847,493	353,831	874,957	353,645
Byproduct sulfuric acid (basis 100 percent) produced at Cu, Zn, and Pb plants	1,077,392	351,949	1,016,731	331,963	1,088,397	355,362	1,089,523	355,730	1,119,976	365,706	1,330,912	388,021
Other byproduct sulfur compounds [2]	106,046	90,743	126,923	106,335	115,670	97,787	136,509	115,826	143,689	123,474	162,668	138,660
Total	---------	6,758,290	---------	7,172,479	---------	6,757,211	---------	6,643,802	---------	7,092,734	---------	8,211,767

[1] Less than ½ unit, not included in total.
[2] Hydrogen sulfide and liquid sulfur dioxide. In addition, a quantity of acid sludge is converted to H_2SO_4 but it is excluded from the above figures.

Table 3.—Sulfur produced and shipped from Frasch mines in the United States

Year	Produced (long tons)			Shipped	
	Texas	Louisiana	Total	Long tons	Approximate value (thousands)
1956–60 (average)	3,029,252	2,181,729	5,210,981	5,116,004	$123,963
1961	2,777,674	2,607,794	5,385,468	5,082,585	117,884
1962	2,621,974	2,362,604	4,984,578	4,917,466	107,069
1963	2,412,653	2,468,859	4,881,512	4,995,023	99,014
1964	2,488,975	2,739,232	5,228,207	r 6,035,670	r 120,777
1965	2,534,045	3,582,228	6,116,273	7,250,907	146,921

r Revised.

Table 4.—Sulfur ore (10 to 70 percent S) produced and shipped in the United States [1]

Year	Produced (long tons)	Shipped	
		Long tons	Value (thousands)
1956–60 (average)	241,188	168,926	$1,551
1961	400,015	177,549	1,694
1962	162,186	150,550	1,439
1963	1,371	1,371	15
1964	794	794	8
1965	2,592	2,852	11

[1] California, Nevada, and Utah.

During 1965, Texas Gulf Sulphur Co. produced more than 2.6 million tons of sulfur, an increase of 6.4 percent over 1964 production.[4] The foregoing dates include that for the United States and Canada. In 1965 several hundred thousand tons of sulfur was withdrawn and sold from company stocks. This large withdrawal for use tended to alleviate an already tight sulfur market.

The greater part of the sulfur produced by Jefferson Lake Sulphur Co. in 1965 was exported. During the year 232,000 long tons was exported from Long Point and 90,300 tons shipped to domestic customers from Long Point and the Tilden, Tex. sulfur recovery plant owned jointly with Transcontinental Gas Pipeline Corp.[5]

Sulfur production at the Orchard Dome mine of Duval Corp. was 118,550 tons in 1965. Sales of 215,000 tons was 12 percent greater than in 1964.[6]

Increased technical knowledge and higher demand for sulfur permitted the reopening of the Frasch-type Gulf sulfur mine in Matagorda County, Tex. Closed in 1932 because operations were uneconomic, reopening became practical partly because greater efficiencies can now be achieved in the production of hot water and in its transmission under pressure. Advances also have been made in drilling, spacing, and casing of wells for sulfur recovery by the Frasch process, and experience has been gained in controlling subsidence. The Frasch mine, scheduled for production in November, went into production in October—a month ahead of schedule.

The newest liquid sulfur ship, the *S.S. Louisiana Brimstone*, completed her maiden voyage in March carrying sulfur from the Freeport Sulphur Co. main shipping point at Port Sulphur, La., to terminals in Florida and on the eastern seaboard. The capacity of the 612-foot vessel, operated under a long-term contract to Freeport Sulphur Co., is reported to be 24,000 tons. It supplemented the 16,000-ton *Louisiana Sulphur* that has been chartered by Freeport since 1961. The new ship will supply liquid-sulfur storage terminals at Tampa, Fla., Savannah, Ga., Charleston,

[4] Texas Gulf Sulphur Co. Annual Report 1965, 1966, p. 7.

[5] Occidental Petroleum Corporation Annual Report 1965, 1966, p. 16.

[6] Duval Corporation Annual Report 1965, 1966, pp. 2, 4.

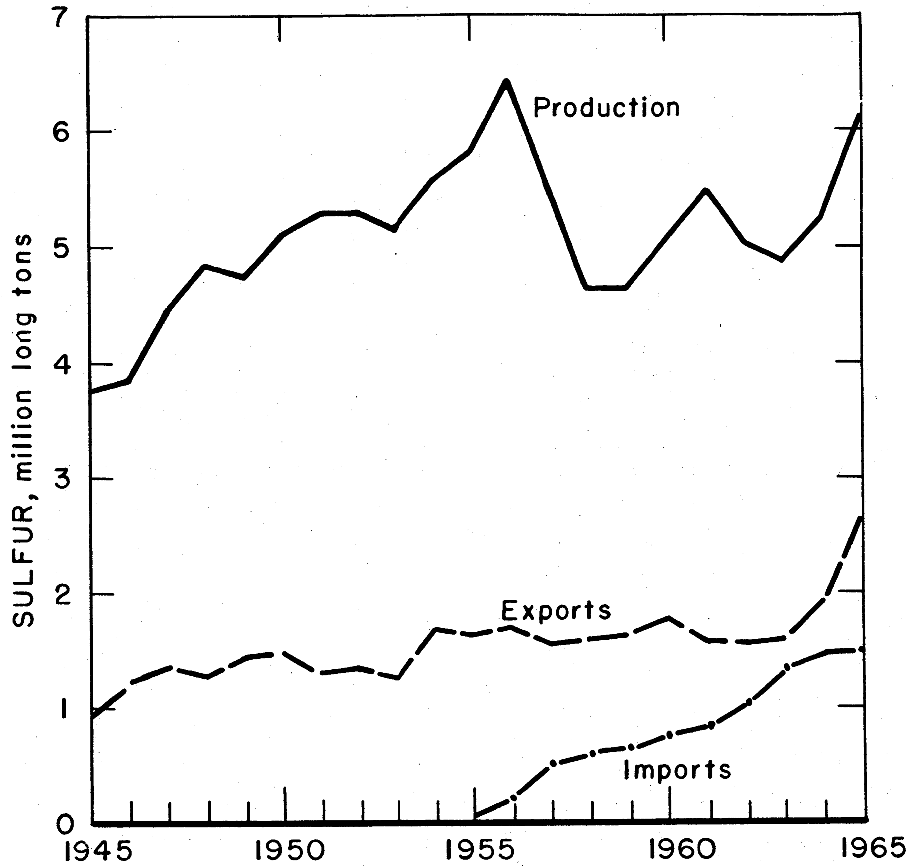

Figure 1.—Domestic production, imports, and exports of native sulfur.

S.C., Warners, N.Y., Everett, Mass., and Bucksport, Me.[7]

It has been reported that plans have been made by Union Texas Petroleum Division, a subsidiary of Allied Chemical Corp., to reestablish production at the former Union Sulphur Co. mine 6 miles northwest of Sulphur, La. The first successful installation of the Frasch process was at this mine in 1894.[8]

Chemicals Inc. at Bartow, Fla., was the largest single plant or plant-complex user of sulfur. When the fourth sulfuric acid plant was completed the complex might require more than 400,000 long tons of sulfur annually in making acid for the fertilizer industry.[9]

Recovered Sulfur.—Production of recovered sulfur from sour natural and refinery gases was 1,215,168 long tons, the highest ever reported. In 1965, 75 elemental sulfur recovery plants were operated by 48 companies in Arkansas, California, Delaware, Illinois, Indiana, Louisiana, Michigan, Minnesota, Mississippi, Montana, New Jersey, New Mexico, North Dakota, Ohio, Pennsylvania, Texas, Virginia, and Wyoming. The greatest gain in production over that of 1964 occurred in Texas where 462,844 tons were produced in 1964 and 638,312 tons were produced in 1965. The 1965 production in Texas was 53 per-

[7] Chemical Engineering. A New Liquid-Sulfur Ship Plies the Atlantic. V. 72, No. 7, Mar. 29, 1965, p. 32.

[8] New Orleans Times-Picayune, Aug. 17, 1965, p. 5.

[9] Chemical Age (London). Chemicals Inc. Have Biggest Sulphuric Complex in World. V. 93, No. 2391, May 8, 1965, p. 729.

Table 5.—Recovered sulfur produced and shipped in the United States

(Long tons)

Year	Production		Shipments		
	Gross weight	Sulfur content	Gross weight	Sulfur content	Value (thousands)
1956–60 (average)	615,697	613,601	594,107	592,030	$15,183
1961	861,413	858,169	834,046	831,001	18,861
1962	902,124	899,598	909,964	907,340	19,599
1963	949,567	946,753	932,147	929,369	19,401
1964	1,024,649	1,021,358	993,643	990,437	21,088
1965	1,219,312	1,215,168	1,172,840	1,168,831	24,574

cent of total U.S. production of recovered elemental sulfur. The only other State to produce more than 100,000 tons was California with 123,993 tons.

New recovered sulfur plants first reporting production in 1965 were National Sulphur Co., Loring, Miss.; Warren Petroleum Corp., Como, Tex.; Pan American Petroleum Corp., Beaver Creek, Wyo.; and Ralston Processors Associates, Ralston, Wyo. Only one plant, Pan American Petroleum Corp. at Cottonwood Creek, Wyo., ceased production in 1964 and did not report production in 1965.

Pyrites.—As in recent previous years Tennessee was the leading producing State followed in order by Pennsylvania, Arizona, Colorado, and South Carolina. Pyrite consumption by producers was 809,000 tons, having a sulfur content of 322,000 tons and valued at $5,030,000. The grade of concentrates marketed averaged 47.7 percent sulfur.

Byproduct Sulfur Compounds.—Copper and zinc plants in the United States produced sulfuric acid from smelting sulfide ores. Either hydrogen sulfide or sulfur dioxide was recovered from 10 plants owned by 9 companies in California, Louisiana, New Jersey, Pennsylvania, and Tennessee. The hydrogen sulfide production was from oil refinery gases and the sulfur dioxide was from smelter gases.

Additional recovery of acid from smelters was planned. American Metal Climax Inc., The Bunker Hill Co., and The New Jersey Zinc Co. are among those that may have new or expanded plants operating before yearend 1966.

Table 6.—Production and shipments of pyrites (ores and concentrates in the United States)

(Long tons)

Year	Production			Shipments		
	Gross weight	Sulfur content	Value (thousands)	Gross weight	Sulfur content	Value (thousands)
1956–60 (average)	1,036,859	424,831	$8,580	139,805	67,050	$946
1961	987,309	398,519	7,418	117,957	56,870	816
1962	915,890	379,046	6,809	64,476	31,382	359
1963	824,800	343,566	5,698	72,618	33,449	303
1964	847,493	353,831	5,471	49,829	23,832	239
1965	874,957	353,645	5,333	57,184	27,278	272

Table 7.—Byproduct sulfuric acid [1] (basis, 100 percent) produced at copper, zinc, and lead plants in the United States

(Short tons)

Plants	1956–60 (average)	1961	1962	1963	1964	1965
Copper [2]	411,544	362,630	403,683	358,503	330,273	369,321
Zinc [3]	795,134	776,109	815,322	861,763	924,100	961,591
Total	1,206,678	1,138,739	1,219,005	1,220,266	1,254,373	1,330,912

[1] Includes acid from foreign materials.
[2] Includes acid produced at a lead smelter. Excludes acid made from pyrites concentrates in Arizona, Montana, Tennessee, and Utah.
[3] Excludes acid made from native sulfur.

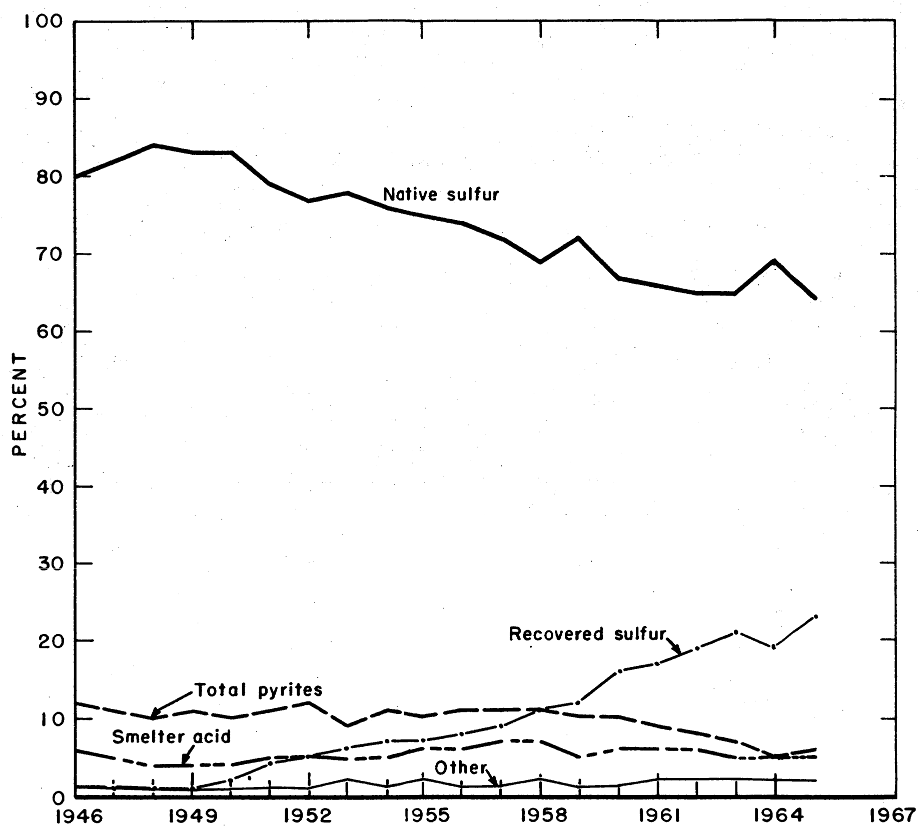

Figure 2.—Sulfur supply sources as a percent of total apparent consumption based on sulfur content.

CONSUMPTION

Apparent consumption of sulfur in all forms in the U.S. attained a new record of 7.96 million long tons, 10 percent greater than in 1964. The increase in apparent consumption of native sulfur was 8 percent; recovered sulfur consumption increased 17 percent and pyrite consumption increased 8 percent. Other increases occurred in smelter acid as well as in sulfur dioxide and hydrogen sulfide.

Estimates of free world consumption of all forms of sulfur prepared late in 1965 by the two leading producing companies of the world ranged from 23.3 to 23.6 million tons, compared with 21.475 and 21.812 million tons by the same estimators for 1964. The 1965 reduction in free world sulfur stocks exceeded 1 million tons.[10]

Table 8.—Apparent consumption of native sulfur in the United States

(Short tons)

	1956–60 (average)	1961	1962	1963	1964	1965
Apparent sales to consumers [1]	5,167,926	4,854,809	4,873,021	5,050,923	r 5,775,399	6,938,147
Imports	510,408	648,910	745,772	863,385	890,604	809,537
Total	5,678,334	5,503,719	5,618,793	5,914,308	r 6,666,003	7,747,684
Exports:						
Crude	1,639,054	1,585,531	1,537,419	1,603,438	1,920,392	2,624,052
Refined	19,463	10,512	16,567	9,199	r 7,700	27,683
Total	1,658,517	1,596,043	1,553,986	1,612,637	r 1,928,092	2,651,735
Apparent consumption	4,019,817	3,907,676	4,064,807	4,301,671	r 4,737,911	5,095,949

r Revised.
[1] Production adjusted for net change in stocks during year.

Table 9.—Apparent consumption of sulfur in all forms in the United States [1]

(Long tons)

	1956–60 (average)	1961	1962	1963	1964	1965
Native sulfur	4,019,820	3,907,700	4,064,800	4,301,700	r 4,737,911	5,095,949
Recovered sulfur:						
Sales	596,020	831,000	907,300	929,400	987,600	1,166,716
Imports	26,820	182,600	294,700	487,800	571,200	655,556
Pyrites:						
Domestic production	424,840	398,500	379,000	343,600	353,800	353,645
Imports	157,800	134,900	144,600	93,000	e 120,000	e 160,000
Total pyrites	582,640	533,400	523,600	436,600	473,800	513,645
Smelter-acid production	351,960	332,000	355,400	335,700	365,700	388,021
Other productions [2]	90,720	106,300	97,800	115,800	123,500	138,660
Grand total	5,667,980	5,893,000	6,243,600	6,607,000	r 7,259,711	7,958,547

e Estimate. r Revised.
[1] Crude sulfur or sulfur content.
[2] Hydrogen sulfide and liquid sulfur dioxide. In addition, a quantity of acid sludge is converted to H_2SO_4 but is excluded from the above figure.

STOCKS

On December 31, producer stocks of Frasch sulfur totaled 3,302,000 tons, a drawdown of 822,000 tons. Stocks comprised 2,136,000 tons at the mines and 1,166,000 tons elsewhere. Producer stocks of recovered sulfur were 123,000 tons, an accumulation of 21,000 tons during the year. Pyrite stock data were unavailable.

Since approximately 90 percent of the elemental sulfur shipped by producers was in the liquid state, storage capacity for this form of sulfur became increasingly more important. At the end of the year there were 28 producer-owned distribution terminals with 47 tanks having a combined capacity of 458,100 tons. There

[10] Gittinger, L. B., Jr. Sulphur—1965. Eng. and Min. J., v. 166, No. 2, February 1966, pp. 146–149.
Levitsky, Serge L. Sulphur. Mining Cong. J., v. 52, No. 2, February 1966, pp. 170–174.

Table 10.—Liquid sulfur regional storage and transshipment terminals in operation in 1965 [1]

Producer-controlled terminals	Number of storage tanks	Total storage capacity (thousand long tons)
Freeport Sulphur Co.:		
Baton Rouge, La	1	6.5
Bucksport, Maine	2	20.0
Charleston, S. C	1	10.0
Everett, Mass	1	10.0
Joilet, Ill	3	30.0
Nitro, W. Va	2	18.0
Tampa, Fla	6	60.0
Warners, N. J	2	12.5
Wellsville, Ohio	2	20.0
Total	20	187.0
Gulf Sulphur Co.:		
Baltimore, Md	1	10.0
Tampa, Fla	2	22.0
Total	3	32.0
Pan American Sulphur Co.:		
Newark, N. J	1	10.0
Tampa, Fla	4	40.0
Total	5	50.0
Texas Gulf Sulphur Co.:		
Baltimore, Md	2	24.0
Carteret, N. J	2	26.0
Cincinnati, Ohio	3	16.8
Jacksonville, Fla	1	11.0
Marseilles, Ill	1	10.0
Nashville, Tenn	1	8.0
Newell, Pa	1	10.0
Norfolk, Va	2	20.8
Paulsboro, N. J	2	24.0
Savannah, Ga	1	11.0
Tampa, Fla	2	19.5
Wilmington, N. C	1	8.0
Total	19	189.1

[1] Levitsky, Serge L. Sulphur. Min. Cong. J., v. 52, No. 2, February 1966, pp. 170–174.

were also 2 producer-storage terminals near the mines with 26 tanks with combined storage capacity of 230,600 tons.

In certain instances producers marketed some sulfur through customer owned terminals.

PRICES

Published prices for domestic sales remained unchanged throughout the year at \$27.00 per long ton f.o.b. Gulf ports and \$25.50 per long ton f.o.b. mines, with \$1 per ton less for dark or acid grade sulfur.

New prices effective in late March and early April for spot sales and on October 1 for term contracts were adjusted to eliminate certain discounts and were reported to reflect most of the transportation and terminal costs incurred by the producers in delivering sulfur.

Regional terminal prices of one large producer of Frasch sulfur under the new schedule for dark sulfur (bright sulfur \$1 higher) were as follows:

	Per long ton
Gulf Coast	\$28.00
Florida	28.50
Midwest	29.50
East Central	31.00
South Atlantic	31.00
Mid Atlantic	31.75
New England	32.50

Adjustments made by other producers were not formally announced. Export prices for sulfur on January 1 were \$27.50

for bright and $26.50 for dark per long ton f.o.b. vessels Gulf ports. Effective February 15, 1965, the prices on new or renewal contracts were increased to $31 for bright and $30 for dark. Effective mid-June prices were raised to $36 for bright and $35 for dark. These later prices prevailed at yearend.

FOREIGN TRADE

Both imports and exports of sulfur for 1965 increased, with the increase in exports much greater than the increase in imports.

Information from Canadian and U.S. consumers indicate that 1965 imports of pyrites totaled about 340,000 tons that contained 160,000 tons of sulfur. Official Census Bureau data which does not include all shipments reported a much lower figure.

Table 11.—U.S. exports and imports for consumption of sulfur

(Thousand long tons and thousand dollars)

Year	Exports				Imports	
	Crude		Crushed, ground, refined, sublimed, and flowers		Quantity	Value
	Quantity	Value	Quantity	Value		
1956–60 (average)	1,639	$42,521	19	$1,721	537	$12,094
1961	1,586	35,370	11	1,254	832	17,152
1962	1,537	35,496	17	1,799	1,040	20,310
1963	1,603	33,531	9	1,057	1,351	23,942
1964	1,920	39,651	8	1,287	1,462	26,100
1965	2,624	64,278	28	1,271	1,465	26,759

Table 12.—U.S. exports of sulfur by countries

Destination	Crude				Crushed, ground, refined, sublimed, and flowers			
	1964		1965		1964		1965	
	Long tons	Value (thousands)	Long tons	Value (thousands)	Long tons	Value (thousands)	Long tons	Value (thousands)
North America:								
Canada	136,207	$3,790	145,076	$3,755	920	$230	5,770	$241
Central America	18,408	374	2,215	79	381	32	1,018	54
Mexico	197	4	72	1	180	80	2,017	86
West Indies	1,000	19	20,919	495	2	(1)	20	1
Total	155,812	4,187	168,282	4,330	1,483	342	8,825	382
South America:								
Argentina	45,301	912	48,315	1,162	88	41	954	47
Brazil	128,723	2,591	173,796	4,166	448	163	2,021	96
Chile	8,874	183	13,615	349	9	3	1,008	56
Colombia	-	-	-	-	68	23	706	31
Ecuador	76	3	104	4	41	9	277	13
Paraguay	159	5	173	7	100	3	-	-
Peru	15,726	319	11,482	289	102	29	680	28
Uruguay	10,176	203	8,576	207	4	2	108	4
Venezuela	162	5	2,385	58	341	65	1,029	47
Total	209,197	4,221	258,446	6,242	1,201	338	6,783	322
Europe:								
Austria	38,215	778	43,492	1,068	-	-	-	-
Belgium-Luxembourg	46,000	932	6,150	152	27	12	4	1
Czechoslovakia	28,500	567	34,000	798	-	-	-	-
France	52,710	1,059	111,920	2,654	66	13	307	16
Germany, West	106,910	2,192	150,412	3,625	18	3	112	5
Ireland	-	-	44,788	1,143	-	-	-	-
Netherlands	456,562	9,203	644,643	15,519	16	1	14	1
Norway	-	-	3,975	99	36	2	38	2
Spain	5,406	110	4,060	101	44	20	832	33
Sweden	-	-	7,050	175	35	13	122	6
Switzerland	25,650	501	40,200	992	-	-	5	1
United Kingdom	21,170	464	295,265	7,263	-	-	5	1
Yugoslavia	7,000	128	-	-	10	3	40	2
Other	33,090	646	47,405	1,129	1	1	1	(1)
Total	821,213	16,580	1,433,360	34,718	253	68	1,480	68
Africa:								
South Africa, Republic of	11,169	426	22,891	660	452	97	1,548	71
Morocco	-	-	25,014	629	-	-	-	-
Tunisia	9,600	203	54,244	1,370	-	-	-	-
Other	8,478	172	6,922	169	73	7	61	4
Total	29,247	801	109,071	2,828	525	104	1,609	75
Asia:								
Bahrain	40	1	84	4	40	1	-	-
India	296,400	5,832	274,926	6,739	1,319	130	3,248	165
Indonesia	3,000	79	600	19	71	7	26	2
Iraq	8,020	301	365	18	149	5	100	4
Israel	60,900	1,201	48,104	1,141	151	17	276	12
Japan	-	-	-	-	14	7	174	7
Jordan	-	-	385	18	502	25	176	8
Korea, South	9,142	201	9,785	407	-	-	-	-
Lebanon	3,000	62	22,078	594	206	17	89	4
Malaysia	1,000	20	1,000	35	12	4	79	3
Pakistan	-	-	-	-	219	12	119	5
Philippines	109	3	542	16	584	64	1,010	44
Saudi Arabia	2,808	87	976	34	327	14	387	16
Taiwan	-	-	48,660	1,198	170	25	29	1
Other	7,634	158	5,211	122	184	15	1,103	57
Total	392,053	7,945	412,716	10,345	3,948	343	6,816	328
Oceania:								
Australia	165,244	3,127	140,541	3,434	183	58	1,376	63
New Zealand	147,626	2,790	101,636	2,381	107	34	794	33
Total	312,870	5,917	242,177	5,815	290	92	2,170	96
Grand total	1,920,392	39,651	2,624,052	64,278	7,700	1,287	27,683	1,271

[1] Less than ½ unit.

Table 13.—U.S. imports for consumption of sulfur by countries

Country	1964		1965	
	Long tons	Value (thousands)	Long tons	Value (thousands)
North America:				
Canada	568,372	$7,779	655,347	$8,934
Mexico	890,604	18,249	809,537	17,818
South America: British Guiana	284	4		
Europe:				
France	2,863	63		
Germany, West	25	4	19	3
United Kingdom	(1)	(1)		
Asia:				
India	63	1		
Japan			190	4
Total	1,462,211	26,100	1,465,093	26,759

[1] Less than ½ unit.

WORLD REVIEW

NORTH AMERICA

Canada.—Texas Gulf Sulphur Co. completed a major addition to its sulfur recovery plant at Whitecourt, Alberta. This addition, which was placed on stream in January, increased the daily capacity of the plant from 750 to 1,225 long tons per day. This was the second largest sulfur recovery plant in operation in Canada, exceeded only by the 1,500-ton-per-day plant of Shell Canada Ltd. at Waterton, Alberta.[11]

The importance of recovered sulfur is evident from production data from Canada, France, and the United States. Shell Canada, Ltd. with its 1,500-ton-per-day plant, the largest on the North American continent, recovered its millionth ton of sulfur at its Waterton plant in southern Alberta.[12]

A 26,000-ton cargo of sulfur from the Alberta, Canada, gasfields was loaded on the *S.S. Grimland* for export to Europe in August. This cargo, loaded from 385 railroad cars, was the largest sulfur shipment from Canada.[13]

Construction of a new sulfur recovery plant to produce 817 long tons of sulfur per day from 42 million cubic feet of gas was planned for the Harmattan area near Didsbury, Alberta. Construction was planned to start in the fall of 1965 with completion expected by mid-1966.[14]

Plant expansion by Jefferson Lake Petrochemicals of Canada Ltd. at Calgary, Alberta, scheduled for completion in 1967 will have a capacity to produce 1,900 tons per day of sulfur.[15] Capacity in 1965 approximated 870 tons per day.

Imperial Oil Ltd. planned a 35-ton-per-day sulfur recovery plant at its refinery at Dartmouth, Nova Scotia. The market area is expected to be in the Maritime Provinces.[16]

The Bay Steel Corp., a subsidiary of Brunswick Mining and Smelting Corp. Ltd., contracted for the use of a process for using pyrites developed in Finland. A plant to be built at Belledune Point on Chaleur Bay, New Brunswick, will produce elemental sulfur and sulfuric acid from pyrites. Annual production of 250,000 tons of elemental sulfur and an equal quantity as sulfuric acid was planned.[17]

As a result of five price increases in 6 months, the export price of sulfur from Canada increased from $18.50 to $31.50 per ton f.o.b. Vancouver. The new prices were effective for contracts coming up for renegotiation. Canadian producers expected to sell 1.9 million tons of sulfur in 1965.

[11] Canadian Mining Journal (Canada). V. 86, No. 3, March 1965, pp. 10, 12.

[12] Engineering and Mining Journal. V. 166, No. 11, November 1965, p. 146.

[13] European Chemical News (London). Big Sulphur Load for Europe. V. 8, No. 187, Aug. 13, 1965, p. 5.

[14] Chemical Trade Journal and Chemical Engineer (London). Canadian Superior Awards Fluor Contract for $6 Million Sulphur Plant. V. 157, No. 4080, Aug. 19, 1965, p. 209.

[15] Jefferson Lake Petrochemicals of Canada Ltd. Annual Report, 1965, p. 10.

[16] Oil, Paint and Drug Reporter. Sulfur Facility Is Planned by Imperial in Nova Scotia. V. 188, No. 22, Nov. 29, 1965, p. 3.

[17] Chemical Trade Journal & Chemical Engineer (London). Finnish Pyrites Treatment process. V. 157, No. 4092, Nov. 11, 1965, p. 573.

Table 14.—World production of elemental sulfur by countries [1]

(Long tons)

Country	1961	1962	1963	1964	1965 p
Native sulfur:					
Frasch:					
Mexico	1,148,494	1,350,375	1,456,656	1,635,773	1,481,241
United States	5,385,468	4,984,578	4,881,512	5,228,207	6,116,273
Total	6,533,962	6,334,953	6,338,168	6,863,980	7,597,514
From sulfur ore:					
Argentina	22,183	22,303	r 22,338	r 21,955	e 20,000
Bolivia (exports)	4,896	7,247	9,793	10,635	9,306
Canary Islands	r 4,921	r 5,905	r 6,889	e 6,900	e 7,000
Chile	43,994	63,228	r 56,405	r 58,612	44,880
China, mainland e	120,000	120,000	120,000	120,000	120,000
Columbia	9,941	10,046	12,795	11,942	18,114
Italy	68,668	r 53,454	41,128	r 28,472	35,654
Japan [2]	238,456	220,438	219,095	r 237,413	209,885
Mexico	25,116	26,751	28,968		33,000
Philippines	158	926	47	68	------------
Poland	130,900	206,684	231,486	289,948	424,195
Taiwan	5,732	7,462	7,144	6,389	4,424
Turkey	15,506	18,247	19,123	21,849	17,223
U.S.S.R. e	900,000	950,000	950,000	950,000	1,000,000
United Arab Republic (Egypt)	8,858	e r 5,900	e r 490	------------	------------
United States	92,025	40,840	415	158	133
Total e [3]	r 1,690,000	r 1,760,000	r 1,725,000	r 1,790,000	1,950,000
Total native sulfur	r 8,220,000	r 8,100,000	r 8,060,000	r 8,650,000	9,550,000
Other elemental:					
Recovered:					
Austria [4]	------------	------------	------------	5,905	e 6,000
Bulgaria [5]	4,949	5,502	6,291	r 6,720	e 7,000
Canada (sales) [6]	352,465	620,622	1,115,968	r 1,596,574	1,703,321
China, mainland e [4] [5]	130,000	130,000	130,000	130,000	130,000
Finland	------------	------------	37,611	67,063	72,606
France [7]	1,080,013	1,325,538	r 1,386,285	r 1,486,846	1,497,968
Germany:					
East	115,153	118,105	118,105	e 118,110	e 118,100
West	82,861	89,268	84,949	76,602	75,412
Iran e [4]	20,000	15,000	20,000	r 20,000	20,000
Italy	1,968	2,067	1,279	787	e 980
Japan [4]	8,163	8,549	11,429	r 18,499	e 20,000
Mexico [7]	51,086	46,545	43,308	36,296	45,201
Netherlands [5]	27,952	30,511	r 34,472	r 28,444	e 30,000
Netherlands Antilles: Aruba and Curacao e	40,000	40,000	30,000	30,000	30,000
Norway [5]	61,156	45,175	------------	------------	------------
Portugal [5]	8,813	6,677	2,963	------------	------------
South Africa, Republic of [4]	2,163	1,913	1,981	5,701	7,102
Spain [5]	48,324	41,836	68,036	r 75,452	e 75,000
Sweden [8]	r 30,491	29,980	25,885	r 26,967	e 27,000
Taiwan [4]	1,968	2,130	2,310	2,780	2,348
Trinidad e [4]	5,000	5,000	7,000	7,000	7,000
U.S.S.R. e	275,000	370,000	400,000	400,000	420,000
United Arab Republic (Egypt)	2,545	2,039	r 4,394	2,427	3,648
United Kingdom [9]	58,406	51,929	r 46,529	r 53,701	54,131
United States	858,169	899,598	946,753	1,021,358	1,215,168
Total other elemental e	r 3,270,000	3,890,000	r 4,530,000	r 5,220,000	5,570,000
World total e	r 11,490,000	r 11,990,000	r 12,590,000	r 13,870,000	15,120,000

e Estimate. p Preliminary. r Revised.

[1] Compiled mostly from data available July 1966.

[2] Includes sulfur from mixed sulfur-sulfide ore.

[3] In some years Iran produces mine sulfur equivalent to 250–1,500 tons of sulfur. No estimates in total.

[4] From refinery gases.

[5] From sulfide ore.

[6] Produced from natural gas, includes a small quantity derived from treatment of nickel-sulfide matte at Port Colborne, Ontario.

[7] From natural gas.

[8] From shale oil.

[9] Including sulfur recovered from petroleum refineries.

Table 15.—World production of pyrites (including cupreous pyrites) [1]

(Thousand long tons)

Country	1961		1962		1963		1964		1965 [p] [2]	
	Gross weight	Sulfur content	Gross weight	Sulfur content	Gross weight	Sulfur content	Gross weight	Sulfur content	Gross weight	Sulfur content
North America:										
Canada (sales)	462	228	462	[r] 230	425	218	[r] 314	157	315	[e] 155
Cuba [e]	20	9	26	12	33	15	30	13	[e] 30	[e] 13
United States	987	399	916	379	825	344	847	354	875	354
Europe:										
Bulgaria	120	50	140	59	128	54	144	61	[e] 150	[e] 62
Czechoslovakia	363	141	395	155	342	[r] 134	355	140	364	[r] 140
Finland	270	114	[r] 467	[r] 118	[r] 533	[r] 224	539	258	573	278
France	281	118	299	125	[r] 248	[r] 107	[r] 188	[r] 78	132	57
Germany:										
East	[e] 115	40	[e] 120	41	[e] 125	[e] 43	[e] [r] 120	[r] 41	[e] 120	[e] 41
West	[r] 500	[r] 213	[r] 380	[r] 165	[r] 349	[r] 158	[r] 417	[r] 184	432	194
Greece	185	86	142	65	[r] 136	[r] 62	138	[e] 62	[e] 150	[e] 66
Italy	1,555	716	[r] 1,559	[r] 721	[r] 1,380	[r] 638	[r] 1,373	[r] 618	1,379	609
Norway	722	319	[r] 797	[r] 355	710	[r] 323	698	314	698	335
Poland	198	76	219	82	213	85	[r] 230	[r] 87	[e] 235	[e] 90
Portugal	643	296	631	290	593	273	[r] 598	[r] 275	604	278
Rumania	259	103	300	120	328	131	[r] 403	[r] 160	[e] 405	[e] 160
Spain	2,097	1,001	2,095	997	1,995	941	[r] 2,355	[r] 1,117	2,350	1,110
Sweden	431	220	[r] 372	[r] 188	396	[r] 186	[r] 438	[e] [r] 220	[e] 440	[e] 220
U.S.S.R. [e]	2,750	1,460	2,950	1,565	3,150	1,670	3,150	1,670	3,250	1,720
United Kingdom	(3)	(3)	27	[e] 11	26	[e] 10	[e] 26	[e] 10	[e] 26	[e] 10
Yugoslavia	[r] 359	143	[r] 408	163	[r] 351	140	421	168	401	160
Africa:										
Algeria	48	22	42	19	37	17	[r] 60	28	56	26
Morocco	14	5	20	7	23	7	21	6	18	5
Rhodesia, Southern	58	23	50	19	65	[r] 24	81	30	[e] 81	[e] 30
South Africa, Republic of	440	176	434	[e] 175	412	[e] 165	426	[e] 175	422	[e] 170

Asia:										
China, mainland [e]	985	440	1,080	490	1,180	530	1,280	575	1,480	665
Cyprus [4]	824	396	809	388	905	440	[r] 655	[r] 319	947	462
Japan [5]	3,869	1,624	3,952	1,664	3,833	1,623	[r] 4,081	[r] 1,743	4,255	1,817
Korea:										
North [e]	295	118	345	138	395	157	415	167	445	177
South	1	(3)	--------	--------	(3)	(3)	(3)	(3)	NA	NA
Philippines	51	[r] 24	55	26	57	27	[r] 43	[r] 21	104	48
Taiwan	47	20	45	20	46	17	46	17	39	16
Turkey	97	46	105	51	96	44	111	51	130	60
Oceania: Australia	213	102	149	65	194	[r] 85	[r] 220	[r] 95	209	94
World total [e]	[r] 19,250	[r] 8,750	[r] 19,800	[r] 8,900	[r] 19,550	[r] 8,900	[r] 20,200	[r] 9,200	21,100	9,600

[e] Estimate. [p] Preliminary. [r] Revised. NA Not available.

[1] Brazil produces pyrites, but production data are not available; no estimate is included in the total.

[2] Compiled mostly from data available July 1966.

[3] Less than ½ unit.

[4] Tons of ore mined containing pyrites in thousand long tons: 1961, 1,842; 1962, 1,860; 1963, 2,139; 1964, 1,631; and 1965, NA.

[5] Years 1961–63 include pyrrhotite, cupreous pyrites, sulfur ore, and zinc concentrates. Pyrite data covering pyrites, cupreous pyrites, and pyrrhotite only are as follows: (in thousand long tons) 1961, 2,855; 1962, 2,977; 1963, 2,954; 1964, 2,721 includes pyrites and pyrrhotite only; and 1965, NA.

Of this quantity, 1.75 million tons would be produced and 150,000 tons would be taken from stocks. About 60 percent of Canadian sulfur shipments has been equally divided between Canadian and U.S. consumers, and the remainder was sold elsewhere.[18] Various prices, some exceeding $40.00 per ton at Vancouver were reported by yearend.

A new sulfur recovery plant was started by Socony Mobil Oil of Canada Ltd., 65 miles northeast of Calgary, Alberta. Socony will operate the plant for 20 company owners and is expected to produce 275 tons of sulfur per day.[19]

Mexico.—Pan American Sulphur Co.'s new 15,000-ton liquid sulfur carrier, the *S.S. Harold H. Jaquet,* completed its maiden voyage from Coatzacoalcos, Veracruz, Mexico, to Tampa, Fla., in April. The company planned to place the 22,000-ton ship, the *S.S. Harry C. Webb,* in operation in May. The *S.S. Harry C. Webb* would be used to transport liquid sulfur from Mexico to Immingham, England.[20]

In April the Government of Mexico first placed restrictions on the export of sulfur to encourage exploration and assure adequate reserves and supplies for an anticipated industrial growth in Mexico.[21]

Gulf Sulphur Co. produced 338,500 long tons in 1965 compared with 347,400 tons in 1964 but sold 356,200 tons in 1965 which was about 13,000 tons greater than the previous year.[22]

The Government of Mexico limited permissibility for exports of sulfur by Pan American Sulphur Co. to 1,500,000 metric tons. This quantity was not realized. Production was 1,142,571 long tons. During the year total sales were 1,318,607 long tons compared with 1,629,890 long tons in 1964. Following installation of facilities for additional hot water and new and improved water-bleeding procedures and accelerated mudding operations production was expected to increase to more than 4,000 tons per day in 1966.[23]

SOUTH AMERICA

Venezuela.—A survey of sulfur resources in El Pilar district, State of Sucre, was planned by the Venezuelan Ministry of Mines. The survey was planned to start in 1966. The annual consumption of sulfur in Venezuela may rise from the present 25,000 tons per year to 170,000 tons per year within 5 years.[24]

EUROPE

Cyprus.—The Hephaetus Mining Co. Ltd. found a sulfide deposit in Cyprus after 6 years of prospecting. The large pyrite deposit had a sulfur content ranging from 45 to 48 percent. Open-pit mining methods could be used at the deposit that is covered with overburden ranging from 10 to 130 feet in thickness.[25]

Finland.—The pyrite roasting plant at Kokkola in western Finland was being doubled to produce 68 percent iron sinter for the steel plant at Rautarukki and also sulfur and sulfuric acid. Before expansion the plant was producing 80,000 tons of sulfur annually for shipment and another 65,000 tons for making sulfuric acid. Half the sulfur in the pyrites is recovered as elemental sulfur by heating and the remainder is recovered by roasting the pyrrhotite residue from the first decomposition step.[26]

Italy.—A program for reorganizing the Sicilian sulfur industry was being formulated. Following recommendations of a committee of the European Economic Community (EEC), the Sicilian Minerals Agency was expected to limit sulfur output to 750,000 metric tons of ore. Reorganization of the sulfur industry by mid-1966 would include special social measures for mines affected by the plan and the prevention of opening new mines which could not be judged economic.[27]

Norway.—Large pyrites deposits in Hjerkinn, Norway, are to be developed for the new 200,000-ton-per-year acid plant to be completed at Sarpsborg by the end

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[18] European Chemical News (London). Canadian Sulphur Export Price Rises Sharply. V. 7, No. 165, Mar. 12, 1965, p. 4.

[19] Chemical Week. Mobil Sulfur Plant Goes On Stream; Site Chosen for New Cement Plant. V. 96, No. 18, May 1, 1965, p. 23.

[20] Oil, Paint and Drug Reporter. Pan American Sulphur Puts Liquid Carrier Into Service. V. 187, No. 15, Apr. 12, 1965, p. 54.

[21] Wall Street Journal. Gulf Sulphur President Sees Buyers Hampered by Mexico's New Rules. V. 165, No. 84, Apr. 30, 1965, p. 23.

[22] Gulf Sulphur Co. Annual Report 1965, 1966, p. 1.

[23] Pan American Sulphur Co. Annual Report 1965, 1966, pp. 2, 3.

[24] Mining Journal (London). Venezuelan Sulphur Survey. V. 265, No. 6799, Dec. 10, 1965, p. 427.

[25] Mining Journal (London). Pyrite Deposits in Cyprus. V. 264, No. 6763, Apr. 2, 1965, p. 251.

[26] World Mining. Outokumpu Leases Smelting Process; Doubling Pyrite Mill. V. 18, No. 1, January 1965, p. 63.

[27] Mining Journal (London). Sicilian Sulphur Industry. V. 264, No. 6754, Jan. 29, 1965, p. 81.

Table 16.—Mexico: Exports of sulfur by countries [1]
(Long tons)

Destination	1964	1965
North America: United States	907,800	848,297
South America:		
Brazil	12,136	14,739
Colombia	1,476	3,000
Venezuela	5,500	----------
Europe:		
Belgium	61,842	42,608
France	175,716	92,403
Germany, West	12,969	----------
Netherlands	133,111	87,853
Poland	26,798	----------
United Kingdom	254,555	156,301
U.S.S.R.	18,585	----------
Africa:		
Morocco	3,148	9,846
South Africa, Republic of	75,169	49,414
Tunisia	60,080	63,874
Asia:		
Israel	17,609	10,499
Taiwan	10,344	11,614
Oceania:		
Australia	47,577	112,344
New Zealand	22,591	28,478
Total	1,847,006	1,531,270

[1] Compiled from U.S. Embassy, Mexico, D.F., Mexico. Department of State Airgram–829, Mar. 17, 1965, p. 2: and Airgram–987, Mar. 29, 1966, p. 2.

of 1966. This will be the largest sulfuric-acid plant in Norway.[28]

The opening of a pyrite mine in the mountainous region between Oslo and Trondheim, Norway, was planned. The deposit was estimated to contain between 7 and 8 million tons of ore containing from 30 to 42 percent sulfur. The annual production of up to 300,000 tons of ore will be transported to Sarpsborg. The pyrite roasting plant was expected to be on stream late in 1966.[29]

Poland.—Sulfur processing installations in Poland would permit an output of 500,000 tons of elemental sulfur and might be expanded to 1 million tons by 1970. Attempts to lower costs by using hot-water extraction by pumping hot water into the seams was to be tried. Experiments were also being made on the recovery of sulfur by using chemical solvents. Poland was exporting sulfur to Czechoslovakia to pay for assistance from Czechoslovak engineers in developing the deposits.[30]

Approximately 33 million cubic yards of overburden must be removed during the development of a second sulfur mine near the Tarnobrzeg plant at Machow, Poland. Several miles of approach roads have been built. It was planned that during 1965 a 700-cubic-meter wheel excavator will begin work on the site. A 3-mile-long belt conveyor would be used to remove material. The Machow mine is expected to be in production by 1970 and produce about 9 million tons of sulfur ore per year.[31]

A new field at the Piaseczno, Poland, sulfur mine, not expected to be mined before 1967–70, has been stripped of overburden. It was expected that 3.2 million tons of sulfur ore would be delivered to the Machow refinery in 1965. This would be about 0.8 million tons more than in 1964.[32]

Portugal.—Mason and Barry Ltd., announced the exhaustion of its pyrites mine at San Domingos in the province of Alemtejo, Portugal. The mine was operated for almost a century and produced 99,000 tons of pyrites in 1965.[33]

Sweden.—A sulfuric-acid plant to begin operating at Helsingborg, Sweden, in 1967

[28] Metal Bulletin (London). New Norwegian Pyrites Mine. No. 5014, July 16, 1965, p. 19.
[29] Mining Journal (London). Norwegian Pyrites Project. V. 265, No. 6796, Nov. 19, 1965, pp. 366–367.
[30] Chemical Trade Journal & Chemical Engineer (London). Plan to Double Sulphur Production Continues. V. 156, No. 4051, Jan. 28, 1965, p. 115.
[31] Mining Journal (London). New Polish Sulphur Mine. V. 264, No. 6763, Apr. 2, 1965, p. 251.
[32] Chemical Trade Journal & Chemical Engineer (London). New Sulphur Ore Field Ready. V. 157, No. 4084, Sept. 16, 1965, p. 330.
[33] Metal Bulletin (London). Mason and Barry Ends Mining. No. 5052, Nov. 30, 1965, p. 16.

will use pyrite concentrate from the Boliden Mining Co. Ltd. mines in Västerbotten. A new roasting method developed by Boliden's will be used to produce gas with a high sulfur dioxide content and a magnetic iron oxide residue that can be concentrated to a high-grade product.[34]

United Kingdom.—The need for more sulfur was being met in part by using more anhydrite. In England the need for 140,000 tons of additional imported sulfur per year would be met by processing 700,000 tons of anhydrite to make 400,000 tons of sulfuric acid. The residue from the decomposition of anhydrite would be used in manufacturing cement. Expanded use of anhydrite indicates that under certain conditions this mineral can be used as a source of sulfur that is competitive with imported sulfur.[35]

U.S.S.R.—More pyrites will be used in making sulfuric acid in the U.S.S.R. than elemental sulfur in new plants. Four of five new acid plants are expected to use pyrite to produce 800,000 short tons per year of sulfuric acid. Sulfur will be used at one new plant to produce 110,000 short tons per year of acid.[36]

AFRICA

Morocco.—Expanded production of copper-bearing pyrrhotite was planned by Cie. Minière Métallurgique, a French company, at Kettara, Morocco. Concentrates containing 38 percent sulfur and 0.7 percent copper would be roasted at Safi for sulfur content.[37]

Rhodesia, Southern.—An exploratory drilling program conducted at the Iron Duke pyrites mine at Mazoe in Rhodesia disclosed sufficient ore to increase the reserve by 1 to 1.5 million tons. The mine furnishes pyrites for the manufacture of sulfuric acid which is used by the fertilizer industry in Salisbury. Output at the mine was expected to exceed 80,000 tons in 1965.[38]

ASIA

Iran.—A plant for recovering 1,000 tons per day of sulfur from sour gas in the Bandar Shakpur-Nashur area is planned for Iran. The sulfur would be produced as one of the products of a vast petrochemical complex to be built and operated on a 50-50 basis by National Petrochemical Co., a subsidiary of National Iranian Oil Co. and Allied Chemical Corp. Initially the complex would produce ammonia, urea, sulfur, and mixed fertilizers and would require an investment of $100 million.[39]

Iraq.—A $20 million plant to recover sulfur from sour natural gas was planned for construction at Kirkuk, Iraq.[40]

India.—The shortage of sulfur in India was expected to increase because sulfur from the Sulphur Export Corp. likely will not meet that country's full requirements. Unless world sulfur production increases substantially the shortage in India may be even more acute in future years.[41]

Roasting pyrites to produce both elemental sulfur and sulfur dioxide appeared to be a highly promising alternative to importing sulfur in India.[42]

Although pyrites may be produced from the Amjor deposits in Bihar in 2 to 3 years India would continue to be dependent on imported sulfur for most of its needs.

A 300-ton-per-day plant for producing ammonium sulfate and conserving imported sulfur in byproduct gypsum from the manufacture of phosphoric acid was being constructed in India. Normally, byproduct gypsum is discarded as waste but research disclosed that waste gypsum could be reacted with ammonium carbonate thereby making the sulfur available for a component in fertilizer.[43]

An unusual price for sulfur was mentioned in an article discussing the acute sulfur shortage in India. It was reported that some prices for sulfur exceeded $300 per ton. In 1965, about 295,000 tons was

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[34] European Chemical News (London). Swedish H_2SO_4 Plant to Use New Pyrites Process. V. 8, No. 185, July 30, 1965, p. 19.

[35] Chemical Trade Journal & Chemical Engineer (London). Acid From Indigenous anhydrite. V. 156, No. 4067, May 20, 1965, p. 618.

[36] Bureau of Mines. Mineral Trade Notes. V. 61, No. 6, December 1965, p. 48.

[37] Metal Bulletin (London). No. 5041, Oct. 22, 1965, p. 27.

[38] South African Mining and Engineering Journal (Johannesburg). New Lease of Life for Old Mine. V. 76, pt. 1, No. 3752, Jan. 1, 1965, p. 29.

[39] Chemical Age (London). Allied Stake in £35 M. Iran Chemical Complex. V. 94, No. 2416, Oct. 30, 1965, p. 648.

[40] Bureau of Mines. Mineral Trade Notes. V. 60, No. 3, March 1965, p. 24.

[41] European Chemical News (London). Sulphur Shortage Foreseen in India. V. 7, No. 174, May 14, 1965, p. 6.

[42] Chemical Week. Finding New Value in Fool's Gold. V. 96, No. 1, Jan. 2, 1965, pp. 27, 29.

[43] Chemical Age (London). F.A.C.T. Fertiliser From Gypsum Process Wins Award. V. 93, No. 2384, Mar. 20, 1965, p. 468.

available to supply a demand ranging from 350,000 to 400,000 tons.[44]

Japan.—A shortage of 17,000 tons of sulfur in Japan was anticipated for 1965. The minimum desired stocks was 27,700 tons and in order to maintain this minimum Japanese producers were considering importing 17,000 tons from Canada, Mexico, France, or mainland China.[45] By yearend 1965 Japan had imported 53,000 long tons of crude sulfur from Canada and mainland China.

A mission from the Japanese Ministry of International Trade and Industry's advisory council was being sent to Canada to investigate the possibility of procuring immediate supplies and of making long-term arrangements.[46]

Jordan.—A deposit containing 35 million tons of sulfur, 12 miles north of the Dead Sea, was available for working on concessions to be granted by the Jordanian National Economy Ministry. Preliminary estimates indicated that the cost of extraction would be slightly less than $17 per ton if mining was conducted at the rate of 30,000 tons of sulfur per year.[47]

Saudi Arabia.—A new Saudi Arabia petrochemical company is planned at Dammam. The plant would have a capacity of 35 tons per day of sulfur, 600 tons per day of ammonia, and 1,125 tons per day of urea. Occidental Petroleum Corp. and its subsidiary, International Ore and Fertilizer Corp., will participate in constructing and initially operating the complex and assured sales at market prices for a period of 10 years on a take-or-pay basis.[48]

TECHNOLOGY

A sulfuric acid process for removing hydrocarbons from dark sulfur was announced by Southwest Research Institute and Pan American Sulphur Co. Dark sulfur usually contains from 0.08 to 0.7 percent carbon in the form of hydrocarbons. The process, tested at Jaltipan, Veracruz, Mexico, produced sulfur with a carbon content ranging from 0.012 to 0.018 percent carbon, and the plant investment and operating costs were stated to be lower than those for the clay adsorption process. The new process used 93 to 99 percent sulfuric acid which was mixed with molten sulfur. Gaseous products were vented and the reactants flowed down a column in a tower in which superheated water was rising. Impurities were removed with the water at the top of the tower and bright sulfur flowed from the bottom of the tower. Optimum quantities of acid ranged from 1 to 5 percent of the weight of the sulfur and the best operating temperature was from 125° to 135° C which avoided foaming and emulsification that would occur at higher temperatures.[49]

Gas containing 18 to 20 percent sulfur dioxide was produced from sulfur and air by using a pulsating or shock wave burner. This high-strength gas, containing almost the theoretical amount of sulfur dioxide possible from air oxidation of sulfur, would have advantages in making sulfite liquor and liquid sulfur dioxide.[50]

A method was developed for making a body with a high modulus of fracture from glass strands and sulfur in the allotropic form. Chopped glass strands and sulfur in a ratio of about 5 percent glass to 95 percent sulfur by weight were mixed and heated to melt the sulfur. During melting the fibers were wetted and upon cooling the amorphous sulfur was hindered from reverting to the crystalline form.[51]

A novel though small-quantity use of sulfur is a temporary core to steady the boring bar when drilling profiled interiors of shafts for gas turbine engines. Difficulties of swaying and bending of the boring bar were overcome by lining the interior of the roughly machined shaft with a layer of sulfur injected under pressure around a mandrel the same size as the boring bar to be used. The sulfur sleeve ranged from 1/8 to 3/16 inch in thickness. A

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[44] Chemical Age (London). Indian Industry Faces Acute Sulphur Shortage. V. 94, No. 2422, Dec. 11, 1965, p. 894.

[45] Oil, Paint and Drug Reporter. Sulfur Buying by Japan Seen a Necessary Move. V. 187, No. 13, Mar. 29, 1965, p. 28.

[46] Oil, Paint and Drug Reporter. Sulfur Purchase in Canada: Japan Weighing Possibility. V. 188, No. 24, Dec. 13, 1965, p. 7.

[47] Chemical Age (London). Jordan Sulphur Deposit Available for Working. V. 93, No. 2385, Mar. 27, 1965, p. 510.

[48] Chemical Trade Journal & Chemical Engineer (London). New Petrochemical Company. V. 157, No. 4086, Sept. 30, 1965, p. 393.

[49] Chemical Week. Sulfur Passes Acid Test. V. 96, No. 8, Feb. 20, 1965, p. 77.

[50] Chemical Trade Journal and Chemical Engineer (London). High Strength Sulphur Dioxide Gases. V. 156, No. 4066, May 13, 1965, p. 585.

[51] Harris, Ransom S. (assigned to Owens-Corning Fiberglas Corp., Delaware). Structural Shapes of Reinforced Sulfur and Method of Producing Same. U.S. Pat. 3,183,143, May 11, 1965.

tubular boring bar with a carbide cutter was pulled through the shaft and produced a smooth finish with a close tolerance and unmarked by drill chatter. Machining time was reduced from more than 4 hours to less than 2 hours.[52]

High-strength, low-cost, well-sealed buildings might be constructed with a saving of time and money by using glass-fiber-impregnated sulfur coatings. In this development tested in San Antonio, Tex., the effectiveness of a thin coating formed from a molten mixture of sulfur, property modifier, pigment, and glass fibers in joining block was determined. Concrete block walls laid without mortar were sprayed with the mixture which cooled within a few seconds to a hard impervious surface. Because of the tensile strength provided across the joints, test walls made in this manner proved stronger than walls made with mortar. This method is still subject to additional research to determine its safety and reliability for general use. No cracks or water leaks have developed in a one-story, 18- by 30-foot building constructed 2 years ago by Southwest Research Institute in Texas.[53]

Infrared spectrometry was being used to distinguish dark sulfur from bright sulfur in the liquid state. The amount of infrared radiation absorbed by liquid sulfur is a measure of hydrocarbon content. The apparatus was reported to detect hydrocarbon levels as low as 0.001 percent. A continuous record of analyses can be kept on a recorder. This procedure may largely replace a combustion method which took several hours because the sample had to be cooled, crushed, and ignited so the carbon dioxide could be measured. The older combustion method is used as a control on the infrared method.[54]

A new ion exchange method was announced for treatment of the waste pickle liquors of the steel industry to recover sulfuric acid and the iron values as an iron oxide pure enough for use in pigments or for making iron powder. Cation exchange resins remove iron and regenerate sulfuric acid. Nitric acid is used to restore the acid ion of the resin and recover the iron as a nitrate solution from which iron oxide is precipitated by heating above 350° F. The nitric acid is also recovered.[55]

[52] Steel. Sulfur Core Steadies Boring Bar in Shafts. V. 157, No. 2, July 12, 1965, pp. 68–69.

[53] Dale, John M. Sulphur-Fibre Coatings. Sulphur Institute J., v. 1, No. 1, fall 1965, pp. 11–13.

[54] Sulphur (London). Freeport Using Infra-Red Spectrophotometry of Molten Raw Sulphur. No. 59, Sept. 14, 1965, p. 24.

[55] Chemical Engineering. Ion Exchange Process Makes an Asset of Pickle Liquor. V. 72, No. 20, Sept. 27, 1965, p. 82.

Talc, Soapstone, and Pyrophyllite

By J. Robert Wells [1]

Although U.S. production of talc, soapstone, and pyrophyllite declined in 1965, it has increased in 14 of the last 20 years and has nearly doubled since World War II. In these two decades, the total value of the annual output, reflecting this increase in volume as well as a 50-percent rise in the average unit price, has grown almost threefold. In this same period, worldwide production has doubled and redoubled.

Legislation and Government Programs.—According to the Office of Emergency Planning, 17 tons of strategic-grade lump steatite talc was sold in the period January–June 1965 from the supply, over 1,200 tons, held in the national stockpile. Since the remainder substantially exceeds the stockpile objective, authorization, subject to Congressional action, was given for the eventual disposal of over 1,000 more tons. Also listed for elimination from Government inventories was about 4,000 tons of ground steatite talc not required for stockpile objectives. Prospective buyers were invited in July to submit bids for approximately 1,925 tons.

Table 1.—Salient talc, soapstone, and pyrophyllite statistics

(Thousand short tons and thousand dollars)

	1956–60 (average)	1961	1962	1963	1964	1965
United States:						
Mine production	749	762	772	804	890	863
Value	$5,078	$5,277	$5,278	$5,505	$6,218	$6,343
Sold by producers	725	727	777	794	875	838
Value	$15,357	$16,022	$17,882	$18,420	r $19,233	$19,794
Exports [1]	52	48	47	57	74	70
Value [1]	$1,480	$1,805	$2,230	$2,778	$3,391	$3,486
Imports for consumption	23	27	26	26	23	21
Value	$789	$1,055	$1,069	$1,088	$917	$833
World: Production	2,356	3,090	3,050	3,410	3,840	3,870

r Revised.
[1] Excludes powders—talcum (in package), face, and compact.

DOMESTIC PRODUCTION

In 1965 domestic production and sales of talc, soapstone, and pyrophyllite were under the record levels of 1964. Otherwise the operations of this industry virtually repeated the production pattern of 1964 with the same three States (and in the same order), New York, California, and North Carolina, foremost in output. For the first time Vermont joined these others to bring to 4 the number of States with annual productions greater than 100,000 tons each.

Grantham Mines, supplier of about 7 percent of the Nation's talc from properties in Death Valley, Calif., has met its ore handling problems, underground and on the surface, by adopting rubber-tired diesel loaders and diesel trucks.

[1] Commodity specialist, Division of Minerals.

Table 2.—Crude talc, soapstone, and pyrophyllite produced in the United States, by States

State	1964 Short tons	1964 Value (thousands)	1965 Short tons	1965 Value (thousands)
California	132,601	$1,631	141,074	$1,725
Georgia	40,400	135	44,800	313
Nevada	5,322	58	3,592	31
North Carolina	106,035	495	109,721	556
Texas	89,334	395	64,211	204
Virginia	3,775	9	3,549	9
Washington	2,680	18	2,861	17
Other States [1]	509,802	3,477	493,067	3,488
Total	889,949	6,218	862,875	6,343

[1] Includes Alabama, Arkansas, Maryland, Montana, New York, Pennsylvania, and Vermont.

Table 3.—Talc, soapstone, and pyrophyllite sold by producers in the United States, by classes

Year	Crude			Sawed and manufactured		
	Short tons	Value at shipping point: Total	Value at shipping point: Average per ton	Short tons	Value at shipping point: Total	Value at shipping point: Average per ton
1956–60 (average)	54,018	$306,959	$5.68	927	$437,661	$472.13
1961	65,705	344,660	5.25	695	407,000	585.61
1962	58,699	302,841	5.16	660	416,000	630.30
1963	63,924	310,752	4.86	(1)	(1)	(1)
1964	73,438	370,851	5.05	(1)	(1)	(1)
1965	63,345	254,681	4.02	(1)	(1)	(1)

Year	Ground [2]			Total [3]		
	Short tons	Value at shipping point: Total	Value at shipping point: Average per ton	Short tons	Value at shipping point: Total	Value at shipping point: Average per ton
1956–60 (average)	669,995	$14,612,282	$21.81	724,940	$15,356,902	$21.18
1961	661,053	15,270,294	23.10	727,453	16,021,954	22.02
1962	717,559	17,162,912	23.92	776,918	17,881,753	23.02
1963	[1] 730,087	[1] 18,109,581	[1] 24.80	794,011	18,420,333	23.20
1964	[1] 801,587	[r] [1] 18,862,560	[1] 23.53	875,025	[r] 19,233,411	21.98
1965	[1] 775,079	[1] 19,539,300	[1] 25.21	838,424	19,793,981	23.61

[r] Revised.
[1] Included with "Ground" to avoid disclosing individual company confidential data.
[2] Includes some crushed material.
[3] Owing to rounding, individual items may not add to totals shown.

CONSUMPTION AND USES

The Nation's consumption of talc, soapstone, and pyrophyllite in 1965 was approximately 4 percent less than in 1964. Ceramics, paints, and insecticides continued to be the principal outlets and repeated the 1964 use pattern in accounting, respectively, for 32 percent, 18 percent, and 8 percent of the total amount consumed. Both paper making and toilet preparations used record quantities of these mineral commodities.

Table 4.—Pyrophyllite [1] produced and sold by producers in the United States

Year	Production (short tons)	Sales total	
		Short tons	Value
1956–60 (average)	151,915	150,826	$1,995,660
1961	157,421	129,707	1,798,816
1962	125,247	133,336	1,779,075
1963	129,018	132,719	1,664,329
1964	136,108	142,532	1,843,283
1965	126,266	136,308	1,823,946

[1] Includes sericite schist.

Table 5.—Talc, soapstone, and pyrophyllite sold or used by producers in the United States, by uses
(Short tons)

Use	Talc and soapstone		Pyrophyllite	
	1964	1965	1964	1965
Ceramics	249,246	233,937	32,631	33,971
Foundry facings	4,797	4,721	W	W
Insecticides	38,927	38,841	27,661	29,080
Paint	160,653	149,516	W	W
Paper	31,585	46,956		W
Rice polishing	W	3,009		
Roofing	57,150	58,691	W	
Rubber	32,352	26,990	W	W
Textile	7,057	8,627		
Toilet preparations	16,739	26,108		
Other	[1] 133,987	[1] 104,720	[2] 82,240	[2] 73,257
Total	732,493	702,116	142,532	136,308

W Withheld to avoid disclosing individual company confidential data.
[1] Includes uses indicated by symbol W and asphalt filler, composition floor and wall tile, crayons, exports, grease manufacture, insulated wire and cable, joint cement, patching compound, plastics, refractories, vault manufacturing, and miscellaneous products.
[2] Includes uses indicated by symbol W and asphalt filler, joint cement, plaster products, refractories, and related products.

PRICES

Although trade journal quotations, unchanged from those cited in the 1963 Minerals Yearbook, represented the general range of talc prices in 1965, actual sales were arranged, as customarily, at negotiated prices influenced, in any specific transaction, by the quantity and the specifications of the material involved.

FOREIGN TRADE

Although 1965 exports of talc, soapstone, and pyrophyllite were 5 percent less in volume than those of 1964, a 12-percent rise in the average unit value of the material exported made the 1965 total value the highest in history. Canada and Mex-

Table 6.—U.S. exports of talc, pyrophyllite, and talcum powders

Year	Talc, steatite, soapstone, and pyrophyllite				Powders—talcum (in packages), face, and compact (value thousands)
	Crude and ground		Manufactures, n.e.c.[1]		
	Short tons	Value (thousands)	Short tons	Value (thousands)	
1956–60 (average)	51,835	$1,365	185	$114	$1,338
1961	47,912	1,721	134	84	1,396
1962	46,939	2,133	122	97	1,286
1963	56,483	2,690	107	88	1,140
1964	73,998	3,316	128	75	1,068
1965	69,597	3,486	(2)	(2)	[3] 4,045

[1] Not elsewhere classified.
[2] No longer separately classified, effective Jan. 1, 1965.
[3] Not strictly comparable with earlier years.

Table 7.—U.S. imports for consumption of talc, steatite, or soapstone, and French chalk, by classes and countries

Year	Crude and unground		Ground, washed, powdered, or pulverized, except toilet preparations		Cut and sawed		Total unmanufactured	
	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value
1956–60 (average)	199	$17,538	22,910	$734,776	83	$36,636	23,192	$788,950
1961	40	4,859	[1] 27,238	[1] 1,012,358	84	37,527	27,362	1,054,744
1962	27	3,536	25,650	1,015,131	100	50,577	25,777	1,069,244
1963	945	47,715	24,401	963,008	335	77,496	25,681	1,088,219
1964:								
Canada	35	490	2,327	46,400			2,362	46,890
France			5,396	122,751	1	254	5,397	123,005
India	6	700	499	16,726			505	17,426
Italy	330	14,402	14,039	669,336	2	810	14,371	684,548
Japan					74	44,320	74	44,320
Sweden					5	942	5	942
Total	371	15,592	22,261	855,213	82	46,326	22,714	917,131
1965:								
Canada			3,136	62,021			3,136	62,021
France			4,924	114,986			4,924	114,986
India	33	4,100	187	6,533			220	10,633
Italy			12,101	535,274	6	2,475	12,107	537,749
Japan					148	87,462	148	87,462
Korea, South			469	19,365			469	19,365
Rumania			18	703			18	703
Total	33	4,100	20,835	738,882	154	89,937	21,022	832,919

[1] Data adjusted by Bureau of Mines to exclude less than 1 ton ($930) of ground, washed, powdered, or pulverized, valued not over $14 per ton from Hong Kong.

ico received the largest tonnages, 29,850 and 15,519 tons, respectively, but the total value of Mexico's share, $427,153, was exceeded by the $451,416 paid for the 4,740 tons shipped to Sweden. About 53 other countries received smaller quantities of talc exported from the United States.

The quantity of talc imported by the United States in 1965 was the smallest since 1957 and the eighth smallest since the resumption of international trade at the end of World War II. Shipments from Italy, even after 4 successive years of decline, amounted to 58 percent of imports, while France supplied 23 percent and Canada 15 percent.

WORLD REVIEW

World production of talc, soapstone, and pyrophyllite rose in 1965 to a volume greater than that of any previous year and more than four times the annual total at the close of World War II.

Belgium.—In Ghent, Sierra Talc and Chemical Division of Cyprus Mines Corp. started construction of a mill for processing talc that Sierra will mine at Indian Creek, Mont. and bulk ship by rail to Tacoma and from there by steamer to Belgium. The ground product will be sold to European papermakers.

Canada.—Cyprus Mines Corp. of Los Angeles, Calif., arranged an option and began exploration preparatory to starting exploitation of a talc deposit near Kichener, British Columbia. In southern Quebec, development showed that Baker Talc, Inc., has about 200,000 tons of minable talc in the No. 2 zone of the underground Van Reet mine near South Bolton. This is sufficient for about 20 years of operations at the current rate.

Finland.—Lohjan Kalkkitehdas Oy started investigating the use of the flotation treatment of talc from its Lohnaslampi deposit to produce a suitable replacement for kaolin for use as paper filler.

Mexico.—Ladrillera Monterrey, S.A., currently turning out over 5 million floor and wall tile monthly from Mexican wollastonite mixed with ball clay and talc, both imported from the United States, planned a twofold expansion of its factory.

Spain.—To meet growing domestic and export demands, modernization of mining operations was begun at Lillo, Provincia de Leon, where nearly one half of Spain's current output of talc originates.

Table 8.—World production of talc, soapstone, and pyrophyllite by countries [1]
(Short tons)

Country [1]	1961	1962	1963	1964	1965 p [2]
North America:					
Canada (shipments)	48,116	46,161	54,250	r 58,132	55,034
Mexico	4,616	e 4,400	e 4,400	e 4,400	e 4,400
United States	762,380	771,728	804,358	889,949	862,875
South America:					
Argentina	r 32,042	r 31,645	r 30,932	r 26,904	e 28,000
Brazil	26,209	42,218	38,487	r 53,038	e 53,000
Chile	2,056	2,095	2,846	3,042	1,641
Colombia	600	720	720	805	440
Paraguay				52	154
Peru	3,236	1,896	r 2,870	2,943	5,602
Uruguay	1,857	1,890	1,890	r 2,341	2,618
Europe:					
Austria	93,639	83,523	72,360	79,225	82,675
Finland	6,967	7,088	7,447	r 7,000	8,000
France	245,427	206,000	174,298	r 226,000	218,000
Germany, West (marketable)	32,696	30,411	r 29,000	30,975	34,000
Greece	2,044	2,662	e 3,000	e 3,000	e 4,000
Italy	148,706	r 142,860	r 153,590	r 145,707	131,481
Norway	r 100,799	r 100,040	r 80,537	r 84,986	88,000
Portugal	794	359	595	r 880	783
Spain	30,498	30,562	30,317	r 29,550	e 30,000
Sweden	17,270	19,201	r 20,696	r 18,409	e 19,000
U.S.S.R. e	330,000	340,000	385,000	385,000	395,000
United Kingdom	7,761	8,240	r 8,933	r 11,374	e 11,000
Africa:					
Rhodesia, Southern		23	21	r 15	e 90
South Africa, Republic of	3,279	13,921	7,566	7,294	10,187
Swaziland	2,955	3,902	3,052	2,199	1,014
United Arab Republic (Egypt)	6,565	6,753	7,861	18,542	43,682
Asia:					
China, mainland e	165,000	165,000	165,000	165,000	165,000
India	106,696	121,749	r 133,357	r 147,710	164,646
Japan	699,510	649,651	944,551	r 1,162,646	e 1,163,000
Korea:					
North e	r 17,000	22,000	22,000	22,000	22,000
South	50,330	51,235	70,772	99,272	93,306
Pakistan (soapstone)	1,361	1,235	2,061	r 2,821	3,135
Philippines	209	130	105	108	654
Taiwan	14,824	14,781	16,300	18,718	16,787
Oceania: Australia	16,613	16,790	r 15,616	r 19,146	e 21,000
World total e	r 3,090,000	r 3,050,000	r 3,410,000	r 3,840,000	3,870,000

e Estimate. p Preliminary. r Revised.
[1] Talc or pyrophyllite is reported in Rumania, but data are not available; estimates are included in the total.
[2] Compiled mostly from data available July 1966.

Table 9.—Austria, France and Italy: Exports of talc and soapstone by countries
(Short tons)

Destination	Exporting countries					
	Austria		France		Italy	
	1964	1965	1964	1965	1964	1965
Algeria			4,215	7,241		
Belgium-Luxembourg	5,677	5,501	5,305	4,646		
Denmark	345	373	202	168		
Finland			271	312		
France	1,829	1,769			[1] 3,958	[1] 3,614
Germany:						
East	3,491	4,201				
West	30,750	33,388	13.359	11,929	6,330	3,905
Hungary	2,359	4,008				
Israel	198	394	871	486		
Italy	7,858	7,917	808	777		
Ivory Coast			315	365		
Japan						544
Mexico						1,080
Morocco			1,109	1,395		
Netherlands	2,354	2,981	2,027	3,025	[1] 513	[1] 520
Poland	940	1,011		375		
Portugal	2	13	1,139	683	[1] 335	NA
Rumania	183	219				
Spain	5	44	396	778		
Sweden	77	93	946	922	191	NA
Switzerland	4,351	4,454	8,026	6,965	[1] 1,477	1,887
Tunisia			742	325		
United Kingdom	463	305	9,987	9,467	7,361	4,386
United States			5,493	4,728	14,809	7,192
Yugoslavia	581					
Other countries	41	8	1,313	1,829	13,167	3,219
Total	61,504	66,679	56,524	56,416	48,141	26,347

NA Not available.
[1] From import detail of trade returns of the respective country.

TECHNOLOGY

According to a responsible prediction, a large expansion of the powdered metals industry and increased talc consumption may result from current technological developments.[2] Illustrative of these innovations is the recent introduction by a division of Chas. Pfizer & Co. of composite metal/mineral powders—nickel/alumina, cobalt/silica, and copper/talc exemplify the dozens of combinations being produced—for a variety of specialized applications such as for catalysts and materials for flame spraying and in ablation layers, refractory coatings, specialty paints, hardfacing agents, and fillers for rubber and plastics.[3]

A journal article related the experience of a New Jersey manufacturer in an extensive conversion from wet molding to dry pressing for fabricating steatite and semi-steatite electrical porcelain products. Important advantages of the dry process included better product uniformity, greater ease in holding to dimensional tolerances, and a 50-percent increase in the rate of production, all of which more than balanced the extra expense of the required presses and dies. Although precalcining the talc used for the body formulations resulted in further improvement in the dimensional stability of the products, it was still considered necessary to test each new lot of talc received to determine the degree of shrinkage.[4]

Technological advances are far from belonging exclusively to our modern age. Scientists now believe that inventive metallurgists learned more than 5,000 years ago to cast objects of copper in molds cut from blocks of talc or soapstone.[5]

[2] Steel. V. 156, No. 12, Mar. 22, 1965, p. 28.
[3] Product Engineering. V. 36, No. 3, Feb. 1, 1965, p. 37.
[4] Taeler, David H. Dry Pressing Electrical Porcelain Depends on Die Design and Material Control. Ceramic Age, v. 81, No. 2, February 1965, pp. 28–31.
[5] Groves, R. The Story of Metals—Part VIII. Canadian Min. J., v. 86, No. 4, April 1965, pp. 96–97.

When sorting the lumps of an ore and rock mixture, talc and not-talc for example, a workman depends upon the actions of eye, mind, and hand. These human operations are closely paralleled by the performance of the Sortex 621M, an efficient electronic classifier recently devised in England for dealing with this tedious job cheaper, faster, and better. The Sortex photoelectrically scans a falling stream, up to 50 tons a day, of ¼- to ¾-inch fragments of intermingled rock and ore, and by comparison with preset standards, decides electronically whether the color of all the faces of each particle is or is not within predetermined limits. The machine uses momentary blasts of compressed air to toss rejected pieces aside into a waste chute. One operator can supervise several ore sorters simultaneously.[6]

Patents were issued for a fluid energy mill for grinding talc with minimum production of static electricity in the process,[7] and for a pulverizer-classifier to be used for grinding and upgrading talc and other minerals.[8]

Patents were issued for the use of talc an essential ingredient for the formulation of the following preparations: A fireproofing composition,[9] a fire-extinguisher compound,[10] a covering to prevent corrosion of buried pipes,[11] a heat-conserving insulation coating for the molten-metal reservoirs used for die casting,[12] a polymeric-base caulking compound,[13] and a buffing, grinding, or sanding paste for use on metals, glass, wood, ceramics, or other materials.[14]

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[6] Mining Journal (London). New Electronic Machine for Separating Mineral Particles. V. 265, No. 6790, Oct. 8, 1965, p. 254.

[7] Mandle, R. M., and T. O. Tongue (assigned to W. R. Grace & Co., New York). Fluid Energy Mill. U.S. Pat. 3,186,648, June 1, 1965.

[8] Lykken, W. H. (assigned to The Microcyclomat Co., Minneapolis, Minn.). Pulverizer and Classifier. U.S. Pat. 3,221,998, Dec. 7, 1965.

[9] Hodnefield, O. T. (assigned 50 percent to Kay O. Anderson). Fireproofing Composition. U.S. Pat. 3,201,265, Aug. 17, 1965.

[10] Evans, L. O. British Pat. 980,976, Jan. 20, 1965.

[11] Parker, W. D. (assigned to Winn & Coales, Ltd.). Canadian Pat. 701,290, Jan. 5, 1965.

[12] Franks, A., S. E. Jones, and A. H. Hale (assigned to P. D. Page Co., Ltd.). British Pat. 976,197, Nov. 25, 1964.

[13] Hambling, J. K., and J. M. Squire (assigned to the British Petroleum Co., Ltd.). British Pat. 984,391, Feb. 24, 1965.

[14] Meyer, E., and C. Seibel. British Pat. 1,007,566, Oct. 13, 1965.

Thorium

By Charles T. Baroch [1]

Production of monazite, the only domestic source of thorium, dropped nearly one-third in 1965 because of curtailed production in Florida. Nonenergy uses eased slightly, but an increased quantity was withdrawn from inventories for nuclear purposes.

Legislation and Government Programs.—The Atomic Energy Commission (AEC) amended Part 40 of its regulations to permit the use, without licensing, of small quantities of thorium in electric lamps. Electric lamps to be used in the home or near individuals for prolonged periods of time may contain no more than 50 milligrams of thorium. In germicidal (ultraviolet) lamps, sunlamps, and lamps for outdoor or industrial lighting, the quantity of thorium authorized is 2 grams per lamp.[2]

DOMESTIC PRODUCTION

Mine Production.—Titanium Alloy Manufacturing Division, National Lead Co., was the only firm to report domestic production of monazite. This was recovered from beach sands at the Skinner Mine, Duval County, Fla., as a byproduct of ilmenite and zircon. The company stated that operations were ending in Florida and were being moved to Georgia. Production was about 30 percent less than in 1964.

Sawyer Petroleum Co. signed a profit-sharing contract permitting Lemhi Minerals Co., Tendoy, Idaho, to mine and process thorium, yttrium, and the rare-earth elements in ore from a 100-acre portion of the Sawyer holdings in Beaverhead County, Mont.[3] In the Lemhi Pass area, AEC geologists spent the summer studying the quality, quantity, and location of the thorium deposits which lie in an ore zone about 20 miles long in Idaho and Montana.

Refinery Production.—American Potash & Chemical Corp. and Davidson Chemical Division of W. R. Grace & Co. were the only thorium processors to report the reduction of any substantial quantities of monazite. Thoria, a coproduct of the production of rare-earth compounds, was often supplied to other firms for purification and fabrication. W. R. Grace & Co. took over the Chattanooga plant and operations of Vitro Chemical Co., a division of Vitro Corporation of America, about midyear and operated it along with their plant at Pompton Plains, N.J. Other plants that had capabilities for fabricating thorium nuclear-fuel elements are listed in table 6 of the "Uranium" chapter of this volume.

Table 1.—Principal processors of thorium

Company	Plant location
American Potash & Chemical Corp.	West Chicago, Ill.
The Babcock & Wilcox Co.	Lynchburg, Va.
The Dow Chemical Co.	Midland, Mich.
General Dynamics Corp.	San Diego, Calif.
W. R. Grace & Co.	Chattanooga, Tenn.
Kerr-McGee Corp.	Oklahoma City, Okla.
Metal Hydrides, Inc.	Beverly, Mass.
National Lead Co.	Albany, N.Y.
Nuclear Fuel Services, Inc.	Erwin, Tenn.
Nuclear Materials & Equipment Corp.	Apollo, Pa.
United Nuclear Corp.	Hematite, Mo.

W. R. Grace & Co. was the only domestic producer of magnesium-thorium master alloy (magnesium hardener), but other suppliers of imported hardener were

[1] Commodity specialist, Division of Minerals.
[2] 30 FR 15802, Dec. 22, 1965.
[3] Engineering and Mining Journal. V. 166, No. 18, October 1965, p. 138.

The Dow Chemical Co. (from Canada) and Magnesium Elektron, Inc., New York (from England). Among the principal producers of commercial magnesium alloyed with about 3 percent thorium were Bendix Foundries, Teterboro, N.J.; Brooks and Perkins, Inc., Detroit, Mich.; The Dow Chemical Co., Midland and Madison, Mich.; and The Wellman Bronze & Aluminum Co., Bay City, Mich.

CONSUMPTION AND USES

Nonenergy Uses.—Apparent consumption of thorium, as reported by shipments of compounds, was below that of 1964. Major uses were in alloys and thoriated-gas mantles; lesser quantities were used in refractories, chemical processing, and electrical and electronic applications.

E. I. du Pont de Nemours & Co., Inc., Wilmington, Del., continued to develop TD Nickel, which is nickel metal containing about 2 percent of finely divided thorium oxide dispersed throughout its structure. Du Pont offered sheets, bar, plate, wire, foil, and tube, in addition to information on metalworking techniques. The quantity used was small, but commercial applications were being developed.[4] The same type of thoria dispersion enhances the machinability of tungsten without deteriorating its high-temperature properties. Developed by the Lamp Metals Department of the General Electric Co., it was placed on the market late in 1965 in bars and slabs.[5]

Energy Uses.—The Elk River, Minn., reactor, of Rural Cooperative Power Association, operated at nearly full capacity, 22 megawatts (Mw), for about 78 percent of the time in 1965. It was shut down during August for repairs. This powerplant prototype had an initial fuel loading of 8,412 pounds of thorium, 410 pounds of U^{238}, and 380 pounds of U^{235}. This fuel was in the form of UO_2-ThO_2 pellets in stainless steel tubes. In November, the United States and Italy signed a contract under which the "spent" fuel elements from the Elk River reactor will be reprocessed and refabricated by an Italian plant.

The other powerplant prototype reactor using thorium in its fuel assembly, the Peach Bottom, Pa., Atomic Power Station of Philadelphia Electric Co. (40 Mw), was scheduled for operation in 1966. A fire in February delayed construction work. The fuel elements are carbon-coated uranium-thorium carbide particles in a graphite matrix.

Reactor uses for thorium continued to be developed. The Babcock & Wilcox Co. worked on the thorium-fuel-cycle portion of the Heavy Water Organic-Cooled Reactor program. This is a major effort in the development of a thorium-breeder reactor and is closely coupled to the thorium utilization work at Oak Ridge National Laboratory (ORNL). At ORNL, the Molten Salt Reactor Experiment achieved criticality after 4 years of construction. This experimental reactor, which uses as fuel a circulating molten-salt mixture of lithium, beryllium, zirconium, and uranium fluorides, is one of the advanced concepts which may prove adaptable to breeding by using a thorium-uranium fuel cycle. Using molten fuel eliminates the costly fabrication of fuel elements. The 525-Mw seed-blanket reactor, which had been proposed by the Department of Water Resources of California, was abandoned because development work had identified technical problems that would prevent its economic operation.

Nuclear experts continued their high interest in U^{233} as an atomic fuel, and AEC increased its production at both the Hanford and Savannah River reactors which are used principally for the production of plutonium. U^{233} is fissionable. It is produced when thorium is bombarded by neutrons, just as the bombardment of U^{238} produces plutonium. These reactions are basic to converting and breeding, wherein the surplus neutrons derived from fission in a reactor are utilized to produce new fissionable material. The ultimate aim of breeder reactors is the production of more fissionable fuel than that burned. AEC expanded its facilities at Oak Ridge for purifying and storing U^{233} to accommodate up to 220 pounds of solids and 1,300 pounds in solutions.[6]

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[4] Ruth, John P. TD Nickel Nearing Use in Jet Engine Parts. Am. Metal Market, v. 72, No. 112, June 14, 1965, Section 2, p. 3.

[5] American Metal Market. Thoria Dispersed Tungsten Ups Machinability and Tool Life. V. 72, No. 244, Dec. 22, 1965, p. 15.

[6] Chemical Engineering. AEC Builds Up Its Facilities for U-233. V. 72, No. 14, July 5, 1965, p. 60.

PRICES

Early in 1965 monazite prices, quoted nominally in E&MJ Metal and Mineral Markets, showed the first change since 1960. Sand concentrates ranged from 8 cents per pound for 55-percent rare-earth oxide (REO) to 12 cents for 66-percent REO grade. These quotations represented reductions ranging between 20 and 40 percent. Furthermore, specifications, formerly based on REO content including thoria, were quoted in 1965 on the basis of REO alone, with no mention of thoria content.

Thorium oxide was quoted at $5.80 to $7.00 per pound for ceramic grade and $8.30 to $10.00 per pound for high-density material, both of 99.9-percent quality. The price ranged according to the quantity purchased; 10 pounds was the minimum purchase. Other grades ranged from $9.37 to $20.00 per pound in lots of 50 to 99 pounds. Thorium nitrate was $2.50 per pound for wire grade and $2.65 per pound for mantle grade, both in lots above 5 tons with price increments for lesser quantities; other qualities ranged to $6.00 per pound for lots of 50 to 99 pounds. Thorium metal (pellets) was quoted at $15 per pound, and thorium-magnesium hardener (30 to 40 percent thorium) was $9.18 per pound of contained thorium plus the contained magnesium at 36.25 cents per pound.

FOREIGN TRADE

Exports of thorium ores and concentrates contained 39,702 pounds of ThO_2 valued at $79,005, mostly going to the United Kingdom. AEC distributed abroad through sale, lease, and deferred payment sales, 102 grams of U^{233} of which 67 grams went to France, 20 grams to Switzerland, and 11 grams to West Germany; the balance went to Belgium, Euratom, and International Atomic Energy Agency for Austria. Additionally, AEC commitments for U^{233} totaled 3.74 pounds in 1965 to nations having Agreements for Cooperation with the United States. The aggregate commitment to the end of 1965 was 71 pounds out of 99 pounds determined by the President to be available.

Imports of monazite as reported by Bureau of the Census in 1965 consisted of 1,278 short tons from Australia, 64 tons from Brazil, 141 tons from Ceylon, 22 tons from Korea, 447 tons from Malaysia, and 76 tons from Nigeria, a total of 2,028 tons valued at $188,817. This was about 4 percent less than the quantity received in 1964.

Thorium metal imported from Canada totaled 5,000 pounds valued at $50,546. Other imports included 115 pounds of thorium oxide and other compounds from West Germany, Switzerland, and the United Kingdom with a value of $10,000.

Thoriated gas mantles, imported mostly from the United Kingdom, aggregated 2.43 million, almost 10 percent greater than 1964. Their value was $222,151.

WORLD REVIEW

World production of monazite, the principal thorium ore, is detailed in the "Rare-Earth Minerals and Metals" chapter in this volume.

Canada.—Rio Tinto Dow Ltd., which was set up by Dow Chemical of Canada Ltd., and Rio Algom Mines Ltd., became wholly owned by Rio Algom. The firm was set up to recover thorium from waste solutions from the Rio Algom Nordic mill at Elliot Lake.[7]

Atomic Energy of Canada, Ltd., the Government-owned corporation responsible for the national atomic energy research and development program, announced its intention to pursue the development of a Th-U^{233} fuel system for its Candu type of reactor. The 20-Mw deuterium-moderated, pressurized, natural-uranium-fueled demonstration reactor at Rolphton, Ontario, may be converted to boiling-deuterium oxide (D_2O) cooling, a preferred method of conducting the Th-U^{233} fuel cycle.[8]

Egypt.—Radioactive deposits were prospected in four regions of the Eastern Desert. In the area between Port Said and Damietta, preliminary estimates of reserves

[7] Mining in Canada (Winnipeg, Canada). Thorium Plant Wholly Owned by Rio Algom. V. 38, No. 11, November 1965, p. 18.

[8] Nucleonics. AECL to Develop New Candu Fuel System. V. 23, No. 11, November 1965, p. 27.

were stated to be 80 million tons of ore containing one-half million tons of monazite, 25,000 tons of thorium, and 2,000 tons of uranium.[9]

Germany, West.—The research center at Karlsruhe worked on a high-temperature, gas-cooled, pebble-bed breeder reactor. The fuel was about five parts thorium and one part uranium, both as dicarbides, formed into 60-millimeter spheres encased in pyrolytic graphite, following the pattern set at Peach Bottom, Pa., and the Dragon project in England.[10]

Italy.—The United States and Italy signed a contract under which spent thorium-uranium fuel elements from the Elk River, Minn., reactor will be reprocessed and refabricated at an Italian plant and returned for reuse in the reactor. This is part of a cooperative program to develop the technology of using thorium-uranium fuel. Allis-Chalmers Manufacturing Co. constructed the facility.

WORLD RESERVES

Because of its potential use in nuclear power production, thorium was of increasing worldwide interest. At the beginning of 1965, the Steering Committee of the European Nuclear Agency set up a study group on the long-term role of nuclear energy in Western Europe. One of its duties is to establish resources of uranium and thorium at regular intervals of 12 to 18 months. The first estimate was presented in August 1965. Estimates are difficult to make because thorium production costs usually depend on the marketability of other coproducts, such as zircon, rutile, uranium, and the rare-earth elements. The study group, consisting of 11 experts from six countries, intends to be conservative in its estimates and to underestimate resources when available data are meager. No estimates were attempted for the Communist countries.

Table 2.—Estimated world resources of thorium at a cost of less than \$10 per pound ThO_2

(Thousand short tons Th_2O)

Country	Reasonably assured resources	Possible additional resources
India	300	250
United States	100	500
Canada	80	150
Central and South Africa and Malagasy	50	50
Australia	10	----
Denmark (Greenland)	15	----
Brazil	10	20
Total	565	----

Source: Organization for Economic Co-Operation and Development, European Nuclear Energy Agency. World Uranium and Thorium Resources. Paris, France, August 1965, pp. 19–20.

TECHNOLOGY

An alkalic rock complex covering approximately 12 square miles near Powderhorn, Colo., was described in detail, based on information obtained by drilling about 50 holes. E. I. du Pont de Nemours & Co., Inc., had acquired mineral rights covering more than half the complex, which contains one of the largest titanium-columbium deposits in the United States. Most of the rocks also contain rare-earth elements and from 0.01 to 0.05 percent thorium, while chip samples from some thorium veins range as high as 5 percent ThO_2. Thorium-bearing minerals recorded included thorite and thorogummite.[11]

Conditions were established for the selective flotation of monazite from associated minerals like ilmenite, rutile, garnet, zircon, and sillimanite from the beach sands of Manavalakurichi, Madras State, India. Monazite could be separated from the other minerals in the presence of about 11 pounds per ton of 1:1 sodium silicate. Actinols (mixtures of oleic and linoleic acids) were the best collectors, and concentrate containing 72.4 percent monazite was produced with 93.8 percent recovery. Flotation recovery might be more economical than the current electrostatic and magnetic methods which require drying of the sands.[12]

Spheroidal particles of thorium dicarbide

[9] Mining Journal (London). Uranium Mines in Egypt. V. 264, No. 6762, Mar. 26, 1965, p. 231.

[10] Nuclear Engineering (London). The Pebble-Bed Reactor. V. 10, No. 12, September 1965, pp. 333–334.

[11] Temple, A. K., and R. M. Grogan. Carbonatite and Related Alkalic Rocks at Powderhorn, Colorado. Econ. Geol., v. 60, No. 4, June–July 1965, pp. 672–692.

[12] Viswanathan, K. V., T. R. Madhavan, and K. K. Majumdar. Selective Flotation of Beach Sand Monazite. Min. Magazine (London), v. 113, No. 1, July 1965, pp. 17–23.

and thorium-uranium dicarbide having diameters of 100 to 300 microns were prepared from nitrate solutions on a laboratory scale by a simple sol-gel process. Thorium oxide, prepared by the steam denitration of thorium nitrate, was dispersed to a sol in an aqueous nitrate solution and high-surface-area carbon was added. The resultant ThO_2-C was formed into spheroids by dispersing the sol into carbon tetrachloride. The spheroids were set to a gel by adding isopropyl alcohol, and the resultant 150- to 450-micron spheroids were recovered, washed, dried, and fired to produce the dicarbide and to somewhat shrink the spheroids. Such particles, when coated with pyrolytic carbon or silicon carbide are of interest as fuel materials for high-temperature nuclear reactor fuel. A typical firing at 1,600° C in a vacuum gave greater than 98-percent conversion to ThC_2.[13]

Hot hardness and recrystallization temperatures up to 750° C were used as screening tests to indicate the effectiveness of alloying elements in strengthening thorium at high temperatures. Zirconium and indium showed promise as alloying additions. Thorium with 5 percent zirconium is four times as hard as unalloyed thorium at 750° C, and the 4-percent indium alloy is five times as hard. These additions harden thorium principally by solid-solution strengthening, but with some intermetallic hardening in the case of indium.[14]

The dispersion-strengthened nickel alloys, known as TD Nickel, consist of an ultrafine, uniform dispersion of 2 volume-percent of ThO_2 in a pure nickel matrix. They were evaluated, and their applications and mechanical properties were discussed. TD Nickel is stable, has more oxidation resistance, and is stronger above 1,900° F than most other superalloys. However, it has low strength at lower temperatures and low ductility at elevated temperatures, and new design concepts and joining techniques are needed. The alloy is recommended for turbine blades, nozzle partitions, afterburner flame holders, and combustion and afterburner liners in jet engines.[15]

A series of alloys in the Ni-ThO_2 and Ni-12 percent Mo-ThO_2 system, containing from 3 to 9 volume-percent ThO_2, were prepared by selective hydrogen reduction of mixed submicron oxides. Room-temperature strength and ductility were excellent, as were creep-rupture properties at 982° C. At 12 weight-percent molybdenum, the alloy showed significant improvements in strength and stability.[16]

Research has shown that the ductility of tungsten and tungsten alloys at 0° C can be increased by adding ThO_2 to the metal. It has been postulated that the presence of ThO_2 particles tend to blunt and arrest transverse cracks which would otherwise propagate to failure.[17] Another investigation was made of the tensile properties of recrystallized high-purity tungsten and a dispersed-phase alloy of tungsten with 1 percent ThO_2 The thoria additions resulted in a modest strengthening effect over the entire temperature region tested, 800° to 2,400° C. The increase in strength is not explained by current theories, but metallographic examination suggests that it is apparently caused by the effect of thoria on the microstructure.[18]

ORNL issued a report for the International Atomic Energy Agency (IAEA) Panel on Utilization of Thorium in Power Reactors, Vienna, Austria, which presented a discussion of the factors which should be considered in the refabrication of fuel bred in the thorium-U^{233} fuel cycle. Low nuclear-power costs depend to a large extent upon the cost of fuel-cycle operations. Included is a discussion of the types and features of refabrication plants that should be employed, and methods of minimizing refabrication costs. The ORNL refabrication program and the Thorium-Uranium Recycle Facility were also described.[19]

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[13] Kelly, James L., A. Todd Kleinsteuber, Sam D. Clinton, and Orelen C. Dean. Sol-Gel Process for Preparing Spheroidal Particles of the Dicarbides of Thorium and Thorium-Uranium Mixtures. Process Design & Devel.: Ind. and Eng. Chem., v. 4, No. 2, April 1965, pp. 212–216.

[14] Burka, J. A., and J. P. Hammond. Evaluation of Thorium-Base Alloys for High-Temperature Strength. U.S. Dept. of Commerce, Clearinghouse for Federal Scientific and Technical Information, ORNL-377D, April 1965, 27 pp.

[15] Redden, Thomas K., and James F. Barker. Making TD Nickel Parts. Metal Prog., v. 87, No. 1, January 1965, pp. 107–113.

[16] Rasmussen, Jens G. ThO_2-Dispersion-Strengthened Nickel and Nickel-Molybdenum Alloys Produced by Selective Reduction. Powder Met., v. 8, No. 15, March 1965, pp. 92–113.

[17] Battelle Technical Review. Crack Arresters in Metals. V. 14, No. 2, February 1965, p. 11.

[18] King, G. W., and H. G. Sill. The Effect of Thoria on the Elevated-Temperature Tensile Properties of Recrystallized High-Purity Tungsten. Trans. Met. Soc. AIME, v. 233, No. 6, June 1965, pp. 1104–1113.

[19] Lotts, A. L., and D. A. Douglas, Jr. Refabrication Technology for the Thorium-Uranium 233 Fuel Cycle. U.S. Dept. of Commerce, Clearinghouse for Federal Scientific and Technical Information, ORNL-TM-1141, 1965, 52 pp.

The possibilities of the combined use of the Th-U^{233} and U^{238}-Pu^{239} cycles in a fast reactor was discussed. The thorium would be placed in the reflector zone of the fuel assembly and the U^{233}, U^{238}, and Pu^{239} would be in the active zone in a fast reactor. Fast reactors use no moderators to slow down the neutrons, and the relatively compact fuel core is surrounded by a blanket of the thorium which becomes the main breeding element in the mixed fuel cycle. Neutron efficiency is expected to be very high, leading to much lower doubling time—the time required to breed sufficient new fissionable fuel to double the starting quantity.[20]

Interferometric determinations of wavelengths emitted by a thorium lamp have been measured to provide improved wavelengths for 510 radiations ranging from 3269.6089A to 7020.504A. Previous determinations were limited to 222 intense radiations of thorium.[21]

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[20] Leipunskii, A. I., O. D. Kozachkovskii, S. B. Shikhov, and V. M. Murogov. (The Possibility of Using Thorium in Fast Power Reactors) Atomic Energy (U.S.S.R.), v. 18, No. 4, April 1965, pp. 342–350.

[21] Meggers, William F., and Robert W. Stanley. More Wavelengths From Thorium Lamps. NBS J. Res., V. 69A (Phys. and Chem.), No. 2, March–April 1965, pp. 109–118.

Tin

By George T. Engel[1]

Prices for tin attained alltime average highs in 1965, reflecting continued high demand and short supply.

Production in almost all major producing countries increased but consumption continued to exceed production. Sales of surplus tin from the U.S. national stockpile continued to help fill the deficit.

Exploration and development throughout the world increased; new deposits were discovered, new smelting facilities were established, and new areas showed promise of becoming tin producers.

Several publications dealt with the political, social, and economic aspects of tin.[2]

A new center for tinplate research was set up by four companies in Thionville, France, to be known as Centre de Recherches du Fer Blanc, or the Franco-Saar Research Center.[3]

Legislation and Government Programs.—The U.S. General Services Administration (GSA) continued to dispose of pig tin declared surplus to national stockpile needs. Previous to the GSA disposal year beginning on March 22, 1965, a total of 40,983 long tons had been disposed of since inception of the tin disposal programs. On this date, 28,000 tons was announced as available for disposal in the following disposal year. By the end of December 1965, a total of 21,733 tons had been sold under the current program and a grand total of 64,906 tons since inception of disposals.

[1] Commodity specialist, Division of Minerals.
[2] Hedges, E. S. Tin in Social and Economic History. Edward Arnold (Publishers) Ltd., London, 1964, 194 pp.
Metal Bulletin (London). Singapore's Withdrawal From Malaysia. No. 5022, Aug. 13, 1965, pp. 11, 23.
———. What Future for Tin? No. 4998, May 18, 1965, pp. 11–12.
Mining Magazine (London). The Prerequisites to Increased Tin Production. V. 112, No. 1, January 1965, pp. 4–17.
[3] Metal Bulletin (London). Franco-Saar Research Centre. No. 4988, Apr. 9, 1965, p. 12.

Table 1.—Salient tin statistics

(Long tons)

	1956–60 (average)	1961	1962	1963	1964	1965
United States:						
Production:						
Mine	12	W	W	W	W	47
Smelter	W	W	W	W	W	3,098
Secondary	24,452	21,690	21,040	22,332	23,508	25,076
Imports for consumption:						
Metal	48,603	39,893	41,401	43,283	r 32,132	40,816
Ore (tin content)	9,404	8,917	5,364	1,650	5,190	4,326
Exports (exports and reexports)	1,198	800	435	1,625	4,041	2,829
Consumption:						
Primary	52,052	50,288	54,602	55,209	r 58,586	58,550
Secondary	28,618	27,962	24,483	23,094	24,304	25,461
Price: Straits tin, in New York average cents per pound	99.19	113.27	114.61	116.64	157.72	178.17
World:						
Production:						
Mine	179,060	184,100	186,600	190,300	194,500	199,200
Smelter	179,900	184,000	189,500	191,600	188,900	194,100

r Revised.
W Withheld to avoid disclosing individual company confidential data.

Of the grand total, 59,888 tons had been sold commercially, 4,514 tons went to the Agency for International Development (AID), 34 tons to other government agencies, and 470 tons for upgrading.

On December 31, there was 287,008 tons of tin in the national stockpile, of which 279,503 tons was in the strategic stockpile and 7,505 tons in the supplemental stockpile.

The destination of tin shipments from the United States was limited under the Export Control Act. A general license was in effect except to China, Cuba, North Korea, North Viet-Nam, and the Pacific region of the U.S.S.R. The Office of Export Control in the U.S. Department of Commerce required a license, except to Canada, for exports of detinned tinplate, terneplate scrap, and detinned cans. Exports of tinplate, terneplate scrap, and old cans were exempt from licensing except to the Sino-Soviet bloc, Hong Kong, and Macao.

The foreign assets control regulations of the U.S. Treasury Department prohibited the entry of Chinese tin. Soviet tin could enter the United States under a license (none did) under the assumption that it might be of Chinese origin. Alloys possibly including Chinese and/or Soviet tin were prohibited.

DOMESTIC PRODUCTION

MINE PRODUCTION

Small quantities of tin ore were produced in Alaska, Arizona, California, and New Mexico and minor quantities of tin concentrate were recovered as a byproduct of molybdenum mining in Colorado.

SMELTER PRODUCTION

Tin smelting was continued by Wah Chang Corp. at the Texas City, Tex., tin smelter purchased from the U.S. Government. GSA administered the terms of the sales contract involving a note at 4-percent interest.

U.S. smelter production in 1965 was 3,098 tons.

SECONDARY TIN

Production of secondary tin in 1965 increased almost 7 percent. Value of recovered scrap increased 20 percent. Recovery of secondary tin was made at secondary smelters, brass mills, foundries, refineries, detinning plants, and others. Copper-base scrap such as red and yellow brass produced the most secondary tin; lead-base scrap was in second place from items such as solder, drosses, and type metal. Tin-base scrap yielded most of its supply from drosses and residues.

Tonnage of tinplate scrap treated increased for the second year and for the second time in 19 years. The percentage increase was more than 4 percent.

The International Tin Council indicates world secondary tin production in 1965 to have been 8,200 tons.

Table 2.—Secondary tin recovered from scrap processed at detinning plants in the United States

	1964	1965
Tinplate scrap treated [1] ... long tons	761,178	794,500
Tin recovered in the form of—		
Metal ... do	2,774	2,725
Compounds (tin content) ... do	631	675
Total [2] ... do	3,405	3,400
Weight of tin compounds produced ... do	1,191	1,212
Average quantity of tin recovered per long ton of tinplate scrap used ... pounds	10.02	9.59
Average delivered cost of tinplate scrap ... per long ton	$31.26	$32.38

[1] Tinplate clippings and old tin-coated containers have been combined to avoid disclosing individual company confidential data.
[2] Recovery from tinplate scrap treated only. In addition, detinners recovered 547 long tons (455 tons in 1964) of tin as metal and in compounds from tin-base scrap and residues in 1965.

Table 3.—Tin recovered from scrap processed in the United States, by form of recovery

(Long tons)

Form of recovery	1964	1965
Tin metal:		
At detinning plants	2,992	3,062
At other plants	342	339
Total	3,334	3,401
Bronze and brass:		
From copper-base scrap	10,218	11,504
From lead and tin-base scrap	422	440
Total	10,640	11,944
Solder	5,525	5,403
Type metal	1,527	1,964
Babbitt	1,079	1,053
Antimonial lead	328	304
Chemical compounds	969	924
Miscellaneous [1]	106	83
Total	9,534	9,731
Grand total	23,508	25,076
Value (thousands)	$83,050	$99,983

[1] Includes foil, cable lead, and terne metal.

CONSUMPTION

Tin consumption in the United States was slightly lower than in 1964; however, new mills producing double-reduced tinplate came on stream in 1965 using less tin per unit but producing more units.

The total 1965 figure was 121.3 million base boxes [4] for metal used in cans, of which 116.8 million base boxes were tinplate and 4.5 million base boxes were aluminum.

There were no significant changes in amounts of tin used as classified by finished products.

The use of molten tin in float-glass plants showed a substantial increase in 1965 over that in 1964.

Tin metal consumed in manufactured products during the year showed an increase, reflecting a general rise in use of tin as a result of slight increases in a number of uses.

More hot-dipping facilities ceased production in 1965; thus tinplate was produced almost entirely by electrolytic facilities, and the electrolytic tin in turn was largely used for double-reduced tinplate. The effect of this tendency can be seen by comparing the quantity of steel consumed for tinplate cans with that for tin used in tinplate:

Year:	*Steel (short tons)*	*Tin (long tons)*
1957	4,595,000	32,046
1958	4,761,000	32,504
1959	4,949,000	32,275
1960	4,677,000	33,238
1961	4,775,000	31,185
1962	4,858,000	28,708
1963	4,621,000	28,351
1964	4,737,000	31,219
1965	4,878,000	30,064

Tin used for tinplate was down from 1964 but total tin processed was up 1,400 tons. Use of primary tin was about the same as in 1964, but use of secondary tin increased 1,157 tons.

[4] A base box (basis box) is a unit of area equivalent to 31,360 square inches. Tinplate is rated in pounds of tin per base box, usually ¼, ½, or ¾ pound per base box.

Shipments of metal cans

Product	Base boxes 1964	Base boxes 1965	Change, percent
Beer	21,792,049	22,939,315	+5.3
Vegetables and vegetable juice	18,088,380	19,904,765	+10.0
Fruit and fruit juices	16,826,305	15,483,866	−8.0
Soft drinks	5,590,722	7,755,596	+38.7
Pet foods	4,832,120	5,136,612	+6.3
Coffee	4,373,937	4,461,348	+2.0
Evaporated and condensed milk	4,226,192	3,878,056	−8.2
Meat and poultry	3,961,258	3,563,002	−10.1
Fish and seafood	2,752,126	2,989,241	+8.6
Lard and shortening	2,053,289	1,907,805	−7.1
All other foods	14,155,853	14,636,632	+3.4

Source: U.S. Department of Commerce.

Table 4.—Stocks, receipts, and consumption of new and old scrap and tin recovered in the United States in 1965

(Long tons)

Type of scrap and class of consumer	Gross weight of scrap						Tin recovered		
	Stocks Jan. 1	Receipts	Consumption			Stocks Dec. 31			
			New	Old	Total		New	Old	Total
Copper-base scrap:									
Secondary Smelters:									
Auto radiators (unsweated)	4,530	47,732	------	49,214	49,214	3,048	-----	2,116	2,116
Brass, composition or red	4,145	93,529	28,363	65,450	93,813	3,861	1,210	2,458	3,668
Brass, low (silicon bronze)	280	2,883	1,745	1,149	2,894	269	-----	5	5
Brass, yellow	5,772	57,821	8,254	49,637	57,891	5,702	23	478	501
Bronze	1,586	31,141	5,830	25,479	31,309	1,418	453	2,017	2,470
Low-grade scrap and residues	4,959	39,338	28,581	9,817	38,398	5,899	26	-----	26
Nickel silver	748	4,248	446	3,877	4,323	673	1	30	31
Railroad-car boxes	71	1,075	------	860	860	286	-----	41	41
Total	22,091	277,767	73,219	205,483	278,702	21,156	1,713	7,145	8,858
Brass mills: [1]									
Brass, low (silicon bronze)	r 2,594	36,157	36,157	------	36,157	2,480	-----	-----	-----
Brass, yellow	9,757	231,583	231,583	------	231,583	13,076	48	-----	48
Bronze	745	2,752	2,752	------	2,752	623	133	-----	133
Mixed alloy scrap	9,594	19,452	19,452	------	19,452	10,993	120	-----	120
Nickel silver	3,729	11,956	11,956	------	11,956	3,595	-----	-----	-----
Total	r 26,419	301,900	301,900	------	301,900	30,767	301	-----	301
Foundries and other plants: [2]									
Auto radiators (unsweated)	2,457	6,245	------	7,488	7,488	1,214	-----	337	337
Brass, composition or red	698	3,988	1,563	2,549	4,112	574	73	121	194
Brass, low, (silicon bronze)	167	799	298	474	772	194	-----	-----	-----
Brass, yellow	1,051	7,466	3,517	4,118	7,635	882	5	35	40
Bronze	746	1,620	859	1,158	2,017	349	71	88	159
Low-grade scrap and residues	r 1,327	11,074	2,450	6,517	8,967	3,434	-----	-----	-----
Nickel silver	3	104	------	104	104	3	-----	-----	-----
Railroad-car boxes	1,785	34,496	------	35,271	35,271	1,010	-----	1,675	1,675
Total	r 8,234	65,792	8,687	57,679	66,366	7,660	149	2,256	2,405
Total tin from copper-base scrap							2,163	9,401	11,564
Lead-base scrap:									
Smelters, refiners, and others:									
Babbitt	325	14,207	------	14,236	14,236	296	-----	691	691
Battery lead plates	r 34,191	404,161	------	418,242	418,242	20,110	-----	439	439
Drosses and residues	21,864	91,435	90,803	------	90,803	22,496	1,895	-----	1,895
Solder and tinny lead	303	12,121	------	12,252	12,252	172	-----	2,139	2,139
Type metals	1,005	32,813	------	31,783	31,783	2,035	-----	1,510	1,510
Total	r 57,688	554,737	90,803	476,513	567,316	45,109	1,895	4,779	6,674
Tin-base scrap:									
Smelters, refiners, and others:									
Babbitt	35	428	3	431	434	29	3	360	363
Block-tin pipe	13	442	------	446	446	9	-----	441	441
Drossess and residues	488	4,147	4,152	------	4,152	483	2,606	-----	2,606
Pewter	1	32	------	32	32	1	-----	28	28
Total	537	5,049	4,155	909	5,064	522	2,609	829	3,438
Tinplate scrap: Detinning plants			794,500				3,400	-----	3,400
Total tin recovered							10,067	15,009	25,076

r Revised.

[1] Lines in brass mills and total sections do not balance as stocks include home scrap and purchased scrap assumed to equal receipts.

[2] Omits "machine shop scrap."

Table 5.—Consumption of primary and secondary tin in the United States

(Long tons)

	1956–60 (average)	1961	1962	1963	1964	1965
Stocks Jan. 1 [1]	30,751	33,459	36,209	30,876	29,548	32,427
Net receipts during year:						
Primary	53,960	54,154	50,694	54,411	r 62,775	64,288
Secondary	2,453	2,897	2,409	2,290	2,524	2,530
Scrap	27,540	25,755	22,542	22,041	22,985	24,676
Total	83,953	82,806	75,645	78,742	r 88,284	91,494
Available	114,704	116,265	111,854	109,618	r 117,832	123,921
Stocks December 31 [1]	31,892	36,209	30,876	29,548	32,427	37,099
Total processed during year	82,812	80,056	80,978	80,070	r 85,405	86,822
Intercompany transactions in scrap	2,142	1,806	1,893	1,767	2,515	2,811
Tin consumed in manufactured products	80,670	78,250	79,085	78,303	r 82,890	84,011
Primary	52,052	50,288	54,602	55,209	r 58,586	58,550
Secondary	28,618	27,962	24,483	23,094	24,304	25,461

r Revised.

[1] Stocks shown exclude tin in transit or in other warehouses on Jan. 1, as follows: 1956–60 (average), 1,907 tons; 1961, 2,570 tons; 1962, 425 tons; 1963, 115 tons; 1964, 175 tons; 1965, 220 tons; and 1966, 135 tons.

Table 6.—Tin content of tinplate produced in the United States

Year	Tinplate (hot-dripped)			Tinplate (electrolytic)			Tinplate waste—waste, strips, cobbles, etc., gross weight (short tons)	Total tinplate (all forms)		
	Gross weight (short tons)	Tin content (long tons)	Tin per short ton of plate (pounds)	Gross weight (short tons)	Tin content (long tons)	Tin per short ton of plate (pounds)		Gross weight (short tons)	Tin content (long tons) [1]	Tin per short ton of plate (pounds)
1956–60 average)	604,211	7,466	27.4	4,537,217	23,425	11.6	416,613	5,558,041	30,891	12.5
1961	296,919	3,610	27.2	5,143,839	27,575	12.0	499,258	5,940,016	31,185	11.8
1962	212,525	2,291	24.1	4,989,463	26,417	11.9	545,623	5,747,611	28,708	11.2
1963	174,618	2,188	28.1	4,671,358	26,163	12.6	515,042	5,361,018	28,351	11.9
1964	138,178	1,347	21.8	5,204,541	29,782	12.9	637,481	5,980,200	31,219	11.7
1965	80,645	914	25.4	5,245,642	29,150	12.6	599,400	5,925,687	30,064	11.4

[1] Includes small tonnage of secondary tin and tin acquired in chemicals.

Table 7.—Consumer receipts of primary tin, by brands

(Long tons)

Year	Banka	English	Katanga	Straits	Thaisarco	Others	Total
1956–60 (average)	8,261	4,810	2,756	33,356	----------	4,777	53,960
1961	7,763	2,074	579	37,420	----------	6,318	54,154
1962	8,978	1,448	1,369	34,341	----------	4,558	50,694
1963	3,393	2,708	1,027	36,413	----------	10,870	54,411
1964	1,271	1,441	1,839	r 38,823	----------	1[illegible],401	r 62,775
1965	3,112	425	850	38,420	1,950	21,481	66,238

r Revised.

Table 8.—Consumption of tin in the United States, by finished products

(Long tons of contained tin)

Product	1964 Primary	1964 Secondary	1964 Total	1965 Primary	1965 Secondary	1965 Total
Alloys (miscellaneous)	277	187	464	302	174	476
Babbitt	2,133	1,327	3,460	2,304	1,362	3,666
Bar tin	1,596	66	1,662	1,756	76	1,832
Bronze and brass	4,633	11,951	16,584	4,569	12,307	16,876
Chemicals including tin oxide	1,130	1,678	2,808	1,141	1,692	2,833
Collapsible tubes and foil	1,038	61	1,099	999	61	1,060
Pipe and tubing	29	40	69	31	35	66
Solder	12,617	7,400	20,017	13,648	8,114	21,762
Terne metal	323	295	618	306	272	578
Tinning	r 2,297	89	r 2,386	2,404	83	2,487
Tinplate [1]	31,219		31,219	30,064		30,064
Type metal	171	1,105	1,276	123	1,177	1,300
White metal	1,066	76	1,142	839	74	913
Other	57	29	86	64	34	98
Total	r 58,586	24,304	r 82,890	58,550	25,461	84,011

r Revised.
[1] Includes secondary pig tin and tin acquired in chemicals.

STOCKS

Tin stocks at yearend were 4,672 tons higher than at the end of 1964. Tinplate mills held 70 percent of the stocks of pig tin and increases were noted in stocks of pig tin held for float-glass plants. Stocks at other plants than tinplate mills increased 2,174 tons. Tin in process at tinplate mills was down 300 tons, while other tin in process was up 362 tons.

Tinplate mills had increased their stocks of tinplate in anticipation of a steel strike and these stocks carried over to yearend.

Table 9.—U.S. industry tin stocks

(Long tons)

	1956–60 (average)	1961	1962	1963	1964	1965
Plant raw materials:						
Pig tin:						
Virgin	19,660	23,679	19,201	17,834	20,926	25,319
Secondary	288	249	193	220	247	202
In process [1]	11,944	12,281	11,482	11,494	11,254	11,578
Total	31,892	36,209	30,876	29,548	32,427	37,099
Additional pig tin:						
In transit in United States	1,907	425	115	175	220	135
Jobbers-importers	1,073	2,675	[2] 2,145	[3] 11,135	[4] 2,950	[5] 2,000
Afloat to United States	2,748	3,170	4,140	5,060	1,740	1,875
Total	5,728	6,270	6,400	16,370	4,910	4,010
Grand total	37,620	42,479	37,276	45,918	37,337	41,109

[1] Tin content, including scrap.
[2] Includes 1,600 tons, representing bids rejected by GSA, from tin offered by Defense Materials Services of GSA in DMS–MET–20, Aug. 31 (1,600 tons), and in DEM–MET–25, Oct. 19 (1,400 tons). Does not include 1,000 tons representing total of weekly tin offerings in January 1963 (DMS–MET–25, Dec. 31).
[3] Includes GSA as follows: 10,780 tons end of December (bids rejected plus tonnage to be offered through Mar. 27, 1964).
[4] Includes GSA as follows: 1,590 tons end of December 1964, sold but not delivered.
[5] Includes GSA as follows: 975 tons end of December 1965, sold but not delivered.

PRICES

Tin prices reacted to the continued high demand and short supply in 1965. The highest price of Straits tin for prompt delivery in New York was 200.88 cents per pound, the lowest was 148.50 cents per pound, and the average price was 178.172 cents per pound, for the second year, the highest average price recorded.

The average cash price on the London market was £1,413 6s. 6d. per long ton; the 1964 average was £1,239.4. The highest price was £1,625 in May, and the lowest was £1,190 in January.

The average price of Straits tin exworks on the Penang market was £1,380 11 shillings per ton, the highest price was £1,483 in May, and the lowest £1,207 in February.

The GSA average selling price was 181.-614 cents per pound.

Table 10.—Monthly prices of Straits tin for prompt delivery in New York

(Cents per pound)

Month	1964			1965		
	High	Low	Average	High	Low	Average
January	135.500	132.500	134.017	170.000	148.500	157.256
February	159.000	134.250	140.125	156.750	152.250	154.979
March	137.500	132.000	134.815	171.625	158.000	164.984
April	134.875	131.375	133.506	186.000	172.250	180.673
May	140.000	132.750	134.850	200.875	184.125	191.950
June	156.750	138.875	150.602	197.375	177.250	188.943
July	166.000	154.000	159.648	192.000	178.000	184.119
August	171.000	159.500	161.667	190.250	182.500	186.955
September	200.000	171.000	185.375	194.000	188.000	191.905
October	217.000	193.500	204.614	189.250	180.375	185.315
November	206.000	182.500	190.271	188.000	173.750	176.763
December	180.750	154.750	163.114	178.250	170.500	174.226
Average cents per pound	217.000	131.375	157.717	200.875	148.500	178.172

Source: American Metal Market.

FOREIGN TRADE

The principal tin items in the foreign trade of the United States were imports of metallic tin and tin concentrates and exports of tinplate and tin cans. Significant quantities of tin ingot, miscellaneous tin manufactures, and tin compounds were exported. Tin contained in babbitt, solder, type metal, and bronze imported and exported is shown in the "Lead" and "Copper" chapters of the Minerals Yearbook. Ferrous scrap exports including tinplate and terneplate scrap are not separately classified.

Table 11.—U.S. exports of tin; imports for consumption and exports of tinplate and terneplate in various forms

Year	Ingots, pigs, and bars				Tinplate and terneplate		Tinplate circles, strips, and cobbles	Tinplate scrap
	Exports		Reexports		Imports	Exports	Exports	Imports
	Long tons	Value (thousands)	Long tons	Value (thousands)	Long tons	Long tons	Long tons	Long tons
1956–60 (average)	804	$1,373	394	$871	15,620	487,965	18,538	33,379
1961	543	1,264	257	626	13,527	358,707	20,960	29,499
1962	335	840	100	267	46,857	294,510	21,994	18,832
1963	1,544	4,225	81	207	74,055	305,682	20,853	19,486
1964	2,726	9,241	1,315	6,225	80,693	338,588	24,591	23,011
1965	2,605	10,078	224	880	108,876	239,034	12,362	16,954

Table 12.—U.S. imports for consumption and exports of miscellaneous tin, tin manufactures, and tin compounds

Year	Miscellaneous tin and manufactures: Imports: Tinfoil, tin powder, flitters, metallics, tin and manufactures n.s.p.f. value (thousands)	Imports: Dross, skimmings, scrap, residues, and tin alloys, n.s.p.f.: Long tons	Imports: Dross, skimmings, scrap, residues, and tin alloys, n.s.p.f.: Value (thousands)	Exports: Tin cans, finished or unfinished: Long tons	Exports: Tin cans, finished or unfinished: Value (thousands)	Exports: Tin scrap and other tin-bearing material, except tinplate scrap value (thousands)	Tin compounds[1]: Imports (long tons)
1956–60 (average)	$725	3,503	$6,559	33,142	$16,453	$1,963	8
1961	676	612	1,299	30,929	15,093	3,352	22
1962	819	2,185	913	25,531	13,927	2,111	58
1963	731	2,683	1,703	21,595	12,169	2,423	81
1964	300	1,210	714	23,963	14,244	2,151	223
1965	261	[2] 502	[2] 883	(1)	(1)	1,220	163

[1] Exports of tin compounds beginning Jan. 1, 1958, and tin cans, finished or unfinished, beginning Jan. 1, 1965, no longer separately classified.
[2] Not strictly comparable with earlier years.

Table 13.—U.S. imports for consumption of tin,[1] by countries

Country	1964: Long tons	1964: Value (thousands)	1965: Long tons	1965: Value (thousands)
Belgium-Luxembourg	229	$838	172	$559
Bolivia	1,034	3,195	418	1,516
Canada	(2)	10	(2)	10
Indonesia	225	676	235	951
Italy	5	21		
Japan	967	2,980	537	2,054
Macao			45	152
Malagasy Republic			10	38
Malaysia	r 25,375	r 79,260	32,001	124,191
Netherlands	523	1,590	475	1,995
Nigeria	1,817	5,752	1,965	7,670
Peru	76	237	42	150
Philippines			17	59
Portugal	343	1,097	189	760
Spain	90	327	75	320
Thailand			3,650	15,152
United Kingdom	1,448	5,066	985	3,929
Uruguay	(2)	(2)		
Total	r 32,132	r 101,049	40,816	159,506

r Revised.
[1] Bars, blocks, pigs, grain, or granulated.
[2] Less than ½ unit.

Table 14.—U.S. imports for consumption of tin concentrate, by countries

Country	1964: Long tons[1] (tin content)	1964: Value	1965: Long tons (tin content)	1965: Value
Bolivia	5,148	$11,532,286	4,252	$12,992,375
Canada	(2)	590		
Mexico	42	5,702		
Peru			[3] 74	[3] 235,584
Total	5,190	11,538,578	4,326	13,227,959

[1] Reported by the Bureau of the Census as gross weight, adjusted by the Bureau of Mines to tin content.
[2] Less than ½ unit.
[3] Reported by the Bureau of the Census as coming from Peru, but believed to be from Bolivia by the Bureau of Mines.

WORLD REVIEW

INTERNATIONAL TIN AGREEMENT

The International Tin Council held meetings in New York, Istanbul, Vienna, and London in 1965. These meetings concerned the U.S. surplus tin disposals and the new International Tin Agreement. The Third International Tin Agreement, adopted at a United Nations tin conference in April 1965, was open for signature to December 31, 1965. The next step is ratification by the countries that have signed. The agreement will enter into force as soon after June 30, 1966, as ratified by governments representing at least nine consuming countries holding at least 400 votes and at least six producing countries holding at least 950 votes. The signatures made to the Third Agreement cover 16 consuming countries with 518 votes and 7 producing countries with 1,000 votes. Signatories to the Third International Tin Agreement by December 31, 1965, were as follows:

Producing countries:

Bolivia
Congo (Léopoldville)
Indonesia
Malaysia
Nigeria
Rwanda
Thailand

Consuming countries:

Australia
Austria
Belgium
Canada
Czechoslovakia
Denmark
France
Israel
Italy
Japan
Korea, South
Mexico
Netherlands
Spain
Turkey
United Kingdom

Czechoslovakia, Israel, and Rwanda were new members. The presence of Czechoslovakia as a new signatory to the Third International Tin Agreement was significant in that it was the first Soviet-oriented country to join and also to reveal tin trade statistics.

REVIEW BY COUNTRIES

Australia.—Aside from the six major tin-producing countries, Australia was the only country with substantial tin production. In the last 5 years, Australian production has substantially increased and several mining projects were being started which may push production much higher.

The new and expanded tin mines are widely scattered from Tableland Tin in Queensland and the Ardlethan area in New South Wales to Greenbushes in Western Australia and Renison Bell and Mt. Cleveland in Tasmania. Mining methods range from dredging of alluvial deposits to opencast mining of massive sulfide lenses, to ocean dredging of offshore deposits.

A trade review of Australian mineral industry indicated Australia will be a net exporter of tin in 1966 and should continue to export tin into the 1970's.

Table 15.—World mine production of tin (content of ore), by countries

(Long tons)

Country	1961	1962	1963	1964	1965 p 1
North America:					
Canada	500	291	414	r 157	183
Mexico	530	576	1,055	r 1,207	503
United States	2 W	2 W	2 W	2 W	47
Total	2 W	2 W	2 W	2 W	733
South America:					
Argentina	515	231	r 225	r 343	345
Bolivia	3 20,408	3 21,492	3 22,752	r 4 24,186	r 4 23,349
Brazil 5	582	731	1,150	r 1,300	1,400
Peru (recoverable)	14	11	22	22	20
Total	21,519	22,465	r 24,149	r 25,851	25,114
Europe:					
Czechoslovakia 6	200	200	200	200	220
France	r 154	r 314	r 272	r 486	461
Germany, East e	720	720	720	720	720
Portugal 7	729	679	718	r 676	570
Spain	230	231	158	91	110
U.S.S.R. 8 9	17,000	17,000	20,000	20,000	21,000
United Kingdom	1,210	1,181	1,226	1,226	1,313
Total e 9	20,200	20,300	23,300	23,400	24,400
Africa:					
Burundi			r 16	r 85	100
Cameroon, Republic of	65	23	r 25	r 40	40
Congo, Republic of (Brazzaville)	46	46	43	34	48
Congo, Republic of the (Léopoldville)	6,314	6,875	6,883	7,688	6,211
Morocco	11	r 11	r 9	r 14	15
Niger, Republic of	47	41	54	48	52
Nigeria	7,779	8,210	8,723	8,721	9,547
Rhodesia, Southern	r 715	r 706	498	512	510
Rwanda	1,474	r 1,325	1,271	e 1,680	1,424
South Africa, Republic of	1,430	1,408	1,530	1,586	1,671
South-West Africa	302	369	443	474	537
Swaziland	5	5	3	3	2
Tanzania	r 181	r 218	r 234	r 287	255
Uganda	33	r 74	163	213	176
Zambia	1	5	1	8	15
Total	r 18,403	r 19,316	r 19,896	r 21,393	20,603
Asia:					
Burma 7	r 1,140	r 1,040	r 1,005	r 750	e 900
China 8	30,000	28,000	28,000	25,000	25,000
Indonesia	18,574	17,310	r 12,927	16,345	14,823
Japan	853	859	857	r 796	786
Laos	335	367	326	336	284
Malaysia	56,028	58,603	59,947	60,004	63,670
Thailand	13,270	14,679	r 15,585	r 15,597	18,843
Total e 9	120,200	120,900	r 118,600	r 118,800	124,300
Oceania: Australia	2,745	2,715	r 2,860	r 3,638	e 4,000
World total e	184,100	186,600	r 190,300	r 194,500	199,200

e Estimate. p Preliminary. r Revised.
W Withheld to avoid disclosing individual company confidential data.
1 Compiled mostly from data available June 1966.
2 Included in world total.
3 Exports.
4 Comibol production plus exports by small and medium mines and smelters.
5 Estimated by authors of the chapter and in a few instances from the Statistical Bulletin of the International Tin Council, London.
6 Estimate, according to the 51st annual issue of Metal Statistics (Metallgesellschaft) through 1964.
7 Includes tin content of mixed concentrates.
8 Estimated smelter production.
9 Output from U.S.S.R. in Asia included with U.S.S.R. in Europe.

Table 16.—World smelter production of tin, by countries

(Long tons)

Country	1961	1962	1963	1964	1965 [p] [1]
North America:					
Mexico	559	520	1,055	1,145	459
United States [2]	[3] 8,917	[3] 5,364	[3] 1,650	[3] 5,190	3,098
Total	9,476	5,884	2,705	6,335	3,557
South America:					
Bolivia	2,016	2,023	2,462	3,610	3,406
Brazil	1,525	2,317	2,051	1,731	1,753
Total	3,541	4,340	4,513	5,341	5,159
Europe:					
Belgium	6,002	8,607	7,044	5,458	4,232
Germany:					
East [e]	600	600	600	600	600
West	947	1,309	1,052	1,178	1,462
Netherlands	2,729	4,282	5,762	15,858	18,114
Portugal	784	766	[r] 663	[r] 589	587
Spain	731	[r] 910	[r] 1,286	[r] 1,774	1,676
U.S.S.R. [4] [5] [6]	17,000	17,000	20,000	20,000	21,000
United Kingdom	24,449	18,749	17,411	16,849	16,494
Total [4] [5]	53,200	52,200	[r] 53,800	[r] 62,300	64,200
Africa:					
Congo, Republic of the (Leopoldville)	275	945	1,441	[r] 1,485	1,800
Morocco [4]	10	10	10	10	12
Nigeria [7]	623	8,024	9,051	8,748	9,339
Rhodesia, Southern	673	679	499	[r] 511	494
South Africa, Republic of	870	821	[r] 962	[r] 1,016	962
Total	2,451	10,479	[r] 11,963	[r] 11,770	12,607
Asia:					
China [4]	30,000	28,000	28,000	25,000	25,000
Indonesia [4]	2,000	2,000	2,000	1,80r	1,800
Japan	1,644	1,822	1,976	1,954	1,634
Malaysia	79,114	82,073	84,001	71,351	72,469
Thailand					[e] 4,500
Total [4] [5]	112,800	113,900	116,000	100,100	105,400
Oceania: Australia	2,546	2,704	2,626	3,045	3,143
World total [e]	184,000	189,500	[r] 191,600	[r] 188,900	194,100

[e] Estimate. [p] Preliminary. [r] Revised.
[1] Compiled mostly from data available June 1966.
[2] Includes tin content of alloys made directly from ores.
[3] Imports into the United States of tin concentiates (tin content). 1963 and 1964 tin content estimated.
[4] Estimated by authors of the chapter and in a few instances from the Statistical Bulletin oi the International Tin Council, London.
[5] Output from U.S.S.R. in Asia included with U.S.S.R. in Europe.
[6] Includes secondary.
[7] Including a small amount smelted from imported concentrates.

Bolivia.—In 1965, Comibol showed a profit for the first time since nationalization of the major tin mines. A government decree stated all future contracts with foreign companies for the smelting of Bolivian tin can be canceled as Comibol acquires sufficient smelting capacity to accommodate ore production. Strikes slowed production but the opening of new mines, the impact of new laws granting equal advantages to foreign investors, and changed tax and capitalization procedures indicated betterment of tin production in the future. In 1965, Chile raised freight rates for tin on the Antofagasta Railway by 27 percent. This road carries most of the Bolivian tin production to seaports.

Congo, Republic of the (Léopoldville).—The Congo produced only about half as much tin as it did before independence. The tin-mining areas have been centers of political unrest, and operations have been conducted under difficult conditions.

The Geomines Co. reported its output of tin concentrates during the fiscal year 1964–65 totaled 2,410 tons, and 1,822 tons of refined tin was produced at the Manono smelter. There was a complete stoppage of operations in the Lualaba region for 2 months during this period.

Indonesia.—Production of tin in Indonesia continued at a relatively low level in 1965. However, Indonesia launched a large marine tin dredge and built a new smelter at Muntok on Banka Island with West German assistance.

Shipments of tin from Banka Island were reported as 8,640 long tons in 1965 and 6,058 tons from Billiton and Singkep Islands.

There were indications that the lode tin deposits on Banka, Billiton, and Singkep Islands were becoming exhausted.

Malaysia.—Malaysian tin production increased in 1965 and, although Malaysia was no longer receiving tin concentrate for smelting from several countries traditionally using its smelters, it was still the world's largest producer of tin metal.

At the end of December 1965, there were operating in Malaysia 65 dredges, 979 gravel-pump mines, and 59 other types of tin mines for a total of 1,103 active tin mines employing 45,345 persons.

The principal world sources of tin were the large plants of the Eastern Smelting Co. Ltd., on Penang Island, the Pulau Brani smelter at Singapore, the Butterworth smelter in Wellesley Province, and Oriental Tin Smelters Ltd., exporting from Port Swettenham.

Nigeria.—The output of cassiterite in Nigeria during 1965 increased about 9 percent to 12,885 tons. Since 1962, most of the tin ore produced in Nigeria has been smelted locally and exported as tin metal ingot; some concentrate was received from the Republic of Niger for smelting.

Exploration for tin deposits was begun in certain areas and indications of new deposits were found.

Thailand.—The continued increase in Thailand's output of tin placed Thailand in competition with Bolivia and Indonesia for the position of the world's second largest producer. In previous years, production in Thailand was difficult to assess because of the lack of official figures and because ores were shipped to various other countries for smelting.

The new Thaisarco tin smelter was opened in 1965 on Phuket Island. These smelting facilities were constructed by Union Carbide Corp. in cooperation with the Government of Thailand. Smelting capacity was approximately 15,000 long tons per year and new facilities were being added to bring production to 20,000 tons per year.

Exports of tin-in-concentrate from Thailand were banned beginning July 24, 1965, and only tin metal could be exported thereafter.

Other Producing Countries.—Other additions to world tin supply have come from the reopening of old tin mines and the development of new ones. New hardrock

Table 17.—Malaysia: Exports of tin in metal, by countries

(Long tons)

Destination	1963	1964	1965
Argentina	1,291	1,552	984
Australia-New Zealand	2,097	1,572	1,870
Belgium	4,815	740	670
Canada	3,851	3,848	3,968
Denmark	28	5	--------
France	3,423	2,439	1,930
Germany, West	702	450	200
India	3,958	4,220	3,544
Italy	5,485	3,797	3,636
Japan	13,524	14,370	12,969
Netherlands	1,901	1,779	2,321
United Kingdom	1,012	2,873	2,343
United States	35,579	25,734	31,522
Yugoslavia	1,850	1,581	1,998
Others	6,578	6,355	5,428
Total	86,094	71,315	73,383

Source: Statistical Bulletin of the International Tin Council.

Table 18.—Shipments of tin metal from Far Eastern Communist Countries

(Long tons)

Source and destination	1964	1965
From North Viet-Nam to—		
Japan	[r] 196	--------
From China to—		
Austria	107	87
Belgium	90	--------
Denmark	[r] 400	480
Finland	[r] 194	--------
France	[r] 1,404	1,845
Germany, West	938	460
Japan	[r] 1,454	1,679
Netherlands	409	413
Norway	131	208
Sweden	[r] 230	--------
Switzerland	88	--------
United Kingdom	480	330
Total	5,925	5,502
Grand total	6,121	5,502

[r] Revised.

Source: Statistical Bulletin of the International Tin Council.

Table 19.—The world tin smelting position

Country and smelters	Location	Annual capacity (long tons)	Ownership
Australia:			
O. T. Lempriere	Sydney, New South Wales.	3,500	O. T. Lempriere & Co.
Sydney Smelting Co., Pty., Ltd.	do	3,500	Consolidated Tin Smelters Ltd.
Belgium: Société Générale Métallurgique de Hoboken.	Hoboken	25,000	Société Générale Métallurgique de Hoboken.
Bolivia:			
Fundicion de Estaño Oruro	Oruro, Oruro	5,000	Pero and affiliate Comibol (Corporacion Minera de Bolivia).
Fundicion Metabol	do	5,000	Banco-Minero de Bolivia.
Hormet	La Paz	(1)	Cia. Hormet.
Brazil:			
Cia. Estanifera do Brasil	Volta Redonda, Rio de Janeiro.	6,000	Cia. Estanifera do Brasil.
Cia. Industrial Fluminense	São João del Rei, Minas Gerais.	1,000	Cia. Industrial Fluminense.
Diamantes Tocantins Ltd	Macapa, T do Amapa	1C0–200	Diamantes Tocantins Ltd.
Numerous small smelters: Paraiba, Minas Gerais, Rio Giande del Sud, and Rio Grande del		(1)	
China:			
Kochiu	Kochiu, Yunnan	29,000–39,000	Yunnan Tin Corp.
Kwangsı (pkma)	Papu, Ho-hsien Kwangsi		Ping Kwei Mining Administration.
Congo, Republic of the (Léopoldville): Compagnie Geologique et Miniere des Ingenieures et Industriels Belges (Geomines).	Manono	1,387	Compagnie Geologique et Miniere des Ingenieures et Industriels Belges (Geomines).
Germany, West:			
Th. Goldschmidt, A.G	Essen	1,C00	Th. Goldschmidt, A.G.
"Berzelius" Metalhutten, A.G.	Diusburg-Wanheim		Berzelius Metalhutten-Gesellschaft-G.M.B.H. (subsidiary of Metallgesellschaft A.G.)
Norddeutsche Affinerie	Hamburg		Norddeutsche Affiinerie.
Indonesia: Muntok	Banka Island	25,000	Indonesia State Tin Mining Enterprise.
Japan:			
Mitsubishi Metal Mining Co. Ltd.	Naoshima	(1)	Mitsubishi Metal Mining Co., Ltd.
Rasa Kogyo K.K	Oita	850	Rasa Kogyo K.K.
Mitsui Metal Mining & Smelting Co.	do	(1)	Mitsubishi Metal Mining Co. Ltd.
Nippon Mining Co. Ltd		(1)	Nippon Mining Co. Ltd.
Malaysia:			
Old plant		(2)	
Eastern Smelting Co. Ltd	Penang Isle	69,000–79,000	Eastern Smelting Co. Ltd. Subsidiary of Consolidated Tin Smelters Ltd.
Butterworth	Butterworth, Malaysia	69,000	Straits Trading Co. Ltd.
Pulau Brani [3]	Pulau Brani, Singapore		Do.
Oriental Tin Smelters Ltd. (Port Swettenham).	Klang, Malaya (near Kuala Lumpur).	12,000	Oriental Tin Smelters, Ltd. (Ishihara Sangyo Ltd.).
Mexico:			
Metales Potosi	San Luis Potosí S.L.P	120–150	Antonio Pizzuto.
Estaño Mexicanos	do	200–300	Martin del Rio Jaime.
Fundador de Estaño	do	1,000	Carlos Heinze Sierra.
Estaño Electro, S.A. de C.V	Mexico City	700	Jose Mata, Victor Cortez Cervantes, Pedro Goya, Lorenzo Servitje.
Netherlands: N. V. Hollandse Metallurgische Industrie Billiton.	Arnhem	15,858	N. V. Hollandsche Metallurgische Bedrijven, Subsidiary of N. V. Billiton Maaschappij.
Nigeria: Makeri Smelting Co. Ltd	Jos, Northern Nigeria	8,000–9,000	Williams, Harvey & Co. Ltd.
Portugal:			
Fregim	Amarante		Sociedad Industrielle Do Tamega, LDA.
Mangualde	Mangualde	600–700	Neostano (Nova Empresa Estanifera de Mangualde SARL).

See footnotes at end of table.

Table 19.—The world tin smelting position—Continued

Country and smelters	Location	Annual capacity (long tons)	Ownership
Spain:			
Villaralbo (Zamora)	Bilbao	2,176	Electrometalurgia del Agueda.
Ciudad Rodrigo (Salamanca)	do		Do.
Villagarcia de Arosa	Madrid		Metalurgica Quimica Industrial S.A. (Mequinsa).
Do	Pontevedra		Metalurgica del Noroeste, S.A.
Asua	Bilbao		"Indumental" Industrias Reunidas Minero-Metalurgicas S.A.
Villaverde	Madrid		Minero Metalurgica del Estano S.A.
South Africa, Republic of:			
Zaaiplaats	Potgietersrust, Transvaal	1,018	Zaaiplaats Tin Mining Co. Ltd.
Vanderbijlpark	Vanderbijlpark	1,000	ISCOR
Southern Rhodesia: Kamativi Smelting & Refining Co. Ltd.	Kamativi	564	Kamativi Tin Mines Ltd.
Thailand:			
(3)	Bangkok	1	Thai Department of Mines.
Thaisarco	Phuket	20,000	Thai Smelting & Refining Co. (Union Carbide Corp. & Thailand Government).
United Kingdom:			
Capper Pass & Son Ltd	Bristol & Hull	50,000	Capper Pass & Son Ltd.
Williams, Harvey & Co. Ltd	Liverpool		Williams, Harvey & Co. Ltd.
United States: Longhorn tin smelter	Texas City, Tex	20,000	Wah Chang Corp.

[1] Small quantity.
[2] At one time capacity was about 30,000 metric tons; now processing only about 1,000 tons per year.
[3] Reportedly a pilot smelter for test purposes. Produced several hundred tons of tin metal in 1963.

Source: U.S. Embassy, London. State Department Dispatch A–1637, Jan. 13, 1966.

mines have been opened at the Mt. Pleasant deposit in New Brunswick, Canada; in the ancient tin-mining area in Cornwall, England; in South Africa; and in the Rondonia alluvial area of the upper Amazon basin in Brazil. However, none of these areas produced significant amounts of tin in 1965.

TECHNOLOGY

Exploration for tin deposits continued at a high level. An English firm announced development of a portable isotope fluorescense analyzer (PIF) weighing only 20 pounds for spot determination of lode tin.[5]

The British Standards Institute published B.S. 3338, Methods for the Sampling and Analysis of Tin and Tin alloys.[6]

Spectographic analysis of low-grade tin ores was described.[7]

A technique for automated soldering of printed circuit boards was developed by Radio Corporation of America.[8]

A small engine manufacturer, making gasoline engines for power mowers, chain saws, etc., is now adding tin to cast-iron engine blocks to improve quality.[9]

Tin-coated steels (not terne) have proven to be valuable materials in gas tanks for small engines.[10]

A leading aluminum company has announced production of a 20 percent tin-aluminum alloy for steel-backed bearings which may be used in the automotive in-

[5] Steel Times (London). Analysis of Lode-Bearing Ores on the Spot. V. 191, No. 5066, Aug. 20, 1965, p. 245.
[6] British Standards Institute (London). Tin International. May 1965, p. 131.
[7] Murray, K. A., and J. F. Maritz. The Spectrographic Determination of Tin in Low-Grade Tin Ores. J. S. African Inst. Min. Met., June 1965. Also abstracted in Min. Mag. (London), v. 113, No. 3, September 1965, p. 249.
[8] Tin News. Cascade Soldering. V. 14, No. 3, Mar. 15, 1965, p. 6.
[9] Foundry. Tin in Iron. V. 93, No. 7, July 1965, p. 117.
[10] American Metal Market. Tin-Coated Steels Valuable Material in Gasoline Tanks. V. 72, No. 210, Nov. 1, 1965, p. 7.

dustry. This bearing insert is available in coiled sheet form.[11]

A possible use of tin-nickel alloy in automobiles was described.[12]

The world's largest marine tin dredge, capable of dredging to a depth of 130 feet, was launched in Glasgow for Indonesia.[13] The bucket ladder carries 142 buckets, each of 18-cubic-foot capacity. It has an annual capacity of about 1,000 tons of tin in ore and is designed to work deposits off the island of Banka. Called Banka I, it will evidently be used to supply the new Muntok smelter on Banka being built with West German assistance.

A superconducting magnet using niobium-tin wire was developed by the General Electric Co. This magnet, it is said, probably will advance research into the behavior of materials at temperatures near absolute zero.[14]

Other cryogenic research using tin was described.[15]

Bright tin in fine detail has been centrifugally cast in rubber molds for jewelry castings.[16]

An alloy of tin with aluminum, titanium, and vanadium has proven superior to some other alloys in certain physical characteristics and may be used in aircraft frames.[17]

Metallurgical research on tin continued with a number of publications.[18]

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[11] Metal Progress. High-Tin Aluminum Bearing Alloy in Coiled Sheet Form. V. 87, No. 6, June 1965, p. 25.

[12] Metallurgia (Manchester, England). Protecting Disc Brakes on Motor Cars. V. 72, No. 430, August 1965, p. 84.

[13] Mining Journal (London). V. 265, No. 678, Oct. 1, 1965, pp. 231–232.

[14] Tin News. V. 14, No. 8, Aug. 15, 1965, p. 6.

[15] Bachner, Gatos, and Banus. Peritectic Reaction in the Superconductor $Nb_3Sn(Cb_3Sn)$. Trans. AIME, v. 233, 1965, pp. 227–230.

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[16] Tin News. Tin Jewelry. V. 14, No. 1, Jan. 15, 1965, p. 8.

[17] American Metal Market. Titanium With Aluminum, Vanadium and 2% Tin Seen Promising for Air Frames. V. 72, No. 229, Dec. 1, 1965, p. 15.

[18] Bilone, Balling, and Cole. Segregation in Dilute Tin Alloys Displaying Two-Dimensional Cells. Trans. AIME, v. 233, 1965, pp. 251–252.

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Titanium

By John W. Stamper [1]

Growing domestic requirements for high performance, civilian and military aircraft resulted in a 23 percent increase in shipments of titanium mill products. Output of titanium pigment also increased markedly. A new ilmenite mine was opened in Georgia, however, two producers of ilmenite and rutile shut down mining operations in Florida and total output declined. Rutile output for the year was the lowest in 13 years.

Resurging demand for titanium metal in the United States and Europe resulted in increased output in all producing countries. Productive capacity was expanded 24 percent in Japan and 12 percent in the United States. A new titanium reduction plant became operational in the U.S.S.R., capacity of the plant in the United Kingdom was being doubled, and further expansion was underway in the United States.

The use of the chloride process for making titanium dioxide pigment continued to increase and world production of rutile, which is the principal raw material used, increased to a new record. New titanium pigment plants utilizing both the chloride and the sulfate process were being built or planned in eight countries, including the United States.

Table 1.—Salient titanium statistics

	1956–60 (average)	1961	1962	1963	1964	1965
United States:						
Ilmenite concentrate:						
Mine shipments short tons	702,005	782,629	809,037	890,071	1,003,997	948,832
Value thousands	$14,783	$13,320	$13,974	$16,529	$19,178	$18,058
Imports short tons	361,022	207,151	166,434	200,880	119,819	109,079
Consumption do	844,636	929,147	944,797	874,986	980,426	923,304
Titanium slag:						
Consumption do	132,060	130,184	138,205	152,416	128,203	148,184
Rutile concentrate:						
Mine shipments do	8,489	7,664	8,033	11,311	10,547	W
Value thousands	$1,067	$778	$933	$1,262	$1,016	W
Imports short tons	44,554	27,497	35,966	71,990	110,981	151,957
Consumption do	33,979	29,548	31,749	35,189	79,446	117,376
Sponge metal:						
Production do	9,128	6,727	6,730	7,879	W	W
Imports for consumption do	2,289	2,490	925	1,468	2,056	3,134
Consumption do	6,549	6,991	7,136	8,865	11,131	12,105
Price: Dec. 31 per pound	$2.00	$1.60	$1.50	$1.50	$1.50	$1.50
World production:						
Ilmenite concentrate short tons	1,923,860	2,331,500	2,170,220	2,190,200	2,587,700	2,728,000
Rutile concentrate do	120,440	128,700	150,200	221,800	212,100	242,500

W Withheld to avoid disclosing individual company confidential data.

Legislation and Government Programs.—The Food and Drug Administration approved the use of titanium dioxide—synthetically prepared and free from admixtures of other substances—for coloring foods. The manufactured titanium dioxide may be used in proportions up to 1 percent by weight, without harm.[2]

[1] Commodity specialist, Division of Minerals.

[2] Oil, Paint and Drug Reporter. TiO_2 Moves From Paints Into Food and Drug Field. V. 189, No. 5, Jan. 31, 1966, p. 4.

DOMESTIC PRODUCTION

Concentrates.—Titanium Alloy Manufacturing Division of National Lead Co. (TAM) ceased production of ilmenite and rutile at Skinner, near Jacksonville, Fla., and the Florida Minerals Co. stopped production at Vero Beach, Fla. As a result total ilmenite output dropped below the record of 1 million tons produced in 1964 and rutile production was the lowest in 13 years.

In addition to TAM and Florida Minerals, American Cyanamid Co., Piney River, Va.; E. I. du Pont de Nemours & Co., Inc., Starke and Lawtey, Fla.; Humphrey Mining Co., Skinner, Fla.; and Folkston, Ga.; M&T Chemicals, Inc., Hanover County, Va.; National Lead Co., Tahawus, N.Y.; and The Glidden Co., Lakehurst, N.J. also produced ilmenite. Porter Brothers Corp. shipped ilmenite from stockpiles at Boise, Idaho. Rutile was produced by M&T Chemicals, Inc., at Beaver Dam, Hanover County, Va., and Florida Minerals at Vero, Fla.

The Humphrey Mining Co. began producing a mixed product containing ilmenite, rutile, and leucoxene at Folkson, Ga., for Du Pont. The plant operated on a 3-shift, 7-day week schedule with about 110 full-time workers. Mining was by dredging.

The Bureau of Mineral Research of Rutgers University and Mineral Sands, Inc., were studying the heavy minerals in certain areas of Barnegat Bay in New Jersey as a potential economic source of ilmenite.

Metal.—Output of titanium sponge metal increased for the 6th successive year.

Reactive Metals, Inc. began a program to double its titanium sponge metal capacity at Ashtabula, Ohio, to 5,000 tons per year. A number of new reduction vessels was to be installed, and capacity of its vacuum annealing furnaces at Niles, Ohio, will be doubled. New machines to be installed at Niles include a slab grinder, a large billet cutting machine, and two round bar straighteners. Part of the new facilities being added were expected to be in operation by January 1966. The company which is jointly owned by United States Steel Corp. and National Distillers & Chemical Corp. started operations at Niles in a new forge shop for production of titanium blooms, slabs, bars, and billets.

Oregon Metallurgical Corp. (Ormet), a titanium casting and ingot producer announced it would build a plant of undisclosed size to make titanium sponge metal at Albany, Oreg. Earlier in the year Ormet indicated that it expected a continuing high rate of growth in demand for titanium castings.

Howmet Corp. (formerly Howe Sound Co.) was expected to complete construction of a $650,000 plant to produce titanium castings at White Hall, Mich. The company reportedly will use graphite molds

Table 2.—Production and mine shipments of titanium concentrates from domestic ores in the United States

Year	Production, short tons (gross weight)	Shipments: Short tons (gross weight)	Shipments: Short tons TiO_2 content	Shipments: Value (thousands)
Ilmenite:[1]				
1956–60 (average)	685,346	702,005	370,122	$14,783
1961	782,412	782,629	410,191	13,320
1962	807,725	809,037	420,606	13,974
1963	888,400	890,071	470,983	16,529
1964	1,001,132	1,003,997	526,642	19,178
1965	969,459	948,832	494,353	18,058
Rutile:				
1956–60 (average)	9,676	8,489	8,007	1,067
1961	9,045	7,664	7,251	778
1962	9,981	8,033	7,617	933
1963	11,915	11,311	10,839	1,262
1964	8,062	10,547	10,112	1,016
1965	W	W	W	W

W Withheld to avoid disclosing individual company confidential data.
[1] Includes a mixed product containing rutile, leucoxene, and altered ilmenite.

Table 3.—Titanium-metal data

(Short tons)

	1961	1962	1963	1964	1965
Sponge metal:					
Production	6,727	6,730	7,879	W	W
Imports for consumption	2,490	925	1,468	2,056	3,134
Industry stocks	1,200	1,300	1,100	r 800	700
Government stocks (DPA inventories)	22,461	22,461	22,371	22,254	22,339
Consumption	6,991	7,136	8,865	11,131	12,105
Scrap-metal consumption	2,501	3,160	2,335	2,877	3,303
Ingot: [1]					
Production	9,371	10,400	11,138	13,964	15,294
Consumption	8,878	9,773	10,506	13,501	14,694
Mill shape production [2]	5,147	[3] 6,521	[3] 6,112	[3] 7,708	[3] 9,483

r Revised.
W Withheld to avoid disclosing individual company confidential data.
[1] Includes alloy constituents.
[2] Bureau of the Census and Business and Defense Services Administration, Current Industrial Reports Series BDSAF-263(65).
[3] Net shipments derived by subtracting the sum of producers' receipts of each mill shape from the industry's gross shipments of that shape. Data not comparable with previous years.

in a process developed by Misco Precision Castings Co., Whitehall, and Péchiney Enterprises, Inc. (a U.S. subsidiary of Péchiney, Compagnie de Produits Chimiques et Electrometallurgiques of France). Péchiney also owns 40 percent of Howmet.

Titanium Metals Corporation of America (TMCA) completed the major portion of a new strip finishing facility at its Toronto, Ohio, titanium rolling mill and acquired a new sendzimir rolling mill, capable of producing titanium sheet up to 48 inches in width and down to 0.010 inch in thickness. Because of a strike at the end of the year, the company experienced a temporary work stoppage at its Henderson, Nev., facilities.

Aluminum Company of America (Alcoa), the world's largest producer of primary aluminum, announced that it would begin producing large titanium forgings at its special facilities at Cleveland, Ohio. Construction of the titanium facility was scheduled to start in 1965 and commercial production begun in mid–1967.

G. O. Carlson, Inc., began producing titanium plate and plate products at Thorndale, Pa.; Cameron Iron Works, Inc., Houston, Tex., reportedly made available heavy wall titanium pipe up to 30 inches in diameter and 30 feet in length.

Commercial producers of titanium sponge metal were Reactive Metals Inc., Ashtabula, Ohio, and TMCA, Henderson, Nev. Titanium melters were Harvey Aluminum, Inc., Torrance, Calif.; Reactive Metals Inc., Niles, Ohio; Oregon Metallurgical Corp., Albany, Oreg.; Crucible Steel Company of America, Midland, Pa.; Republic Steel Corp., Massillon and Canton, Ohio; and TMCA, Henderson, Nev.

Oregon Metallurgical Corp. produced ingots and castings. The other companies mentioned in the previous paragraph produced and processed ingots into mill products such as sheet, strip, plate, forging billets, and bars. Ladish Co., Wis., processed ingots into forged products.

The Babcock & Wilcox Co., Beaver Falls, Pa., and NTH Products, Division of the Carpenter Steel Co., El Cajon, Calif., produced titanium pipe, tubing, and extrusions. Western Pneumatic Tube Co. produced titanium pipe at Kirkland, Wash.

Pigments.—On a gross weight basis titanium dioxide pigment production was 15 percent higher than that in 1964.

Titanium pigments were produced by the following companies: American Cyanamid Co., Piney River, Va., and Savannah, Ga.; American Potash & Chemical Corp., Hamilton, Miss.; Cabot Titania Corp., Ashtabula, Ohio; E. I. du Pont de Nemours & Co., Inc., Edgemoor, Del., Baltimore, Md., Antioch, Calif., and New Johnsonville, Tenn.; The Glidden Co., Baltimore, Md.; National Lead Co., St. Louis, Mo., and Sayreville, N.J.; and The New Jersey Zinc Co., Gloucester City, N.J.

American Potash & Chemical Corp. started production of titanium dioxide by the chloride process at its new $13 million, 25,000-ton-per-year plant at Hamilton, Miss. National Lead Co. began producing

Table 4.—Titanium pigment data (TiO_2 content)

Year	Production (short tons)	Shipments [1] Quantity (short tons)	Shipments [1] Value, f.o.b. (thousands)
1956–60 (average)	459,999	445,961	$238,673
1961	502,879	491,122	262,255
1962	523,201	513,822	270,438
1963	519,458	528,416	278,477
1964	r 558,536	549,329	288,031
1965	[2] 575,295	NA	NA

r Revised.
NA Not available.
[1] Includes interplant transfers.
[2] Preliminary.

Source: Bureau of the Census.

from its new chloride titanium dioxide plant, which when fully operated is expected to add about 45,000 tons per year to the company's titanium pigment capacity.

Welding-Rod Coating.—A total of 326,000 tons of welding rods, containing titaniferous materials in their coatings, was produced. Of the total output, 51 percent contained rutile; 15 percent, ilmenite; 21 percent, a mixture of rutile and manufactured titanium dioxide; 9 percent, manufactured titanium dioxide; 1 percent, slag; and 3 percent, miscellaneous mixtures.

CONSUMPTION

Concentrates.—Consumption of ilmenite, which was used chiefly for making titanium dioxide pigment, decreased 6 percent. The use of titanium slag, which is used mainly for the same purpose, increased. Rutile consumption, which is used principally for producing titanium metal and pigment and also in welding rod coatings, increased 48 percent.

Metal.—According to information on shipments of titanium mill products, the use of titanium metal was 23 percent higher than in 1964.

Demand for titanium compressor wheels, hubs, spacers, shafts, and blades for aircraft engines increased substantially because of increased requirements for both military and civilian aircraft. About 20,000 to 40,000 pounds (flight weight) of titanium per airplane was expected to be used in each of the frames and engines of the new C–5A air cargo carriers. Lockheed Aircraft Corp. scheduled production of 58 of the 350-ton C–5A's by 1968 or 1970.

Missile and space uses of titanium continued to be significant, although this sector comprised only 30 percent of the total market compared with about 50 percent in 1964 because of the completion of production schedules for the Mercury and Gemini spacecraft.

Following the trend of recent years industrial uses of titanium increased.

A 750,000-gallon-per-day water desalting plant reportedly utilized about 100 miles of titanium tubing. The plant was being built on St. Croix, Virgin Islands, by Westinghouse Electric Corp. and was said to be the first such plant to use titanium in the multistage flash evaporation section.

Titanium rods, 20 feet in length, were used to mark a 2-mile-long entrance to a deep-water port being built in the Caribbean.

Porous titanium metal filters for applications involving high temperatures, rapid thermal cycling and high differential pressures were available in disk, cylinder, tube, and sheet form and in pore sizes ranging from 30 microns to 1.0 micron. A large titanium producer offered complex or hollow extrusions of titanium with a maximum cross section of 5.25 inches, in weights to 100 pounds, and lengths to 30 feet.

The four principal outlets for titanium metal scrap were export, remelting (for ingot), steelmaking, and anodizing and electroplating accessory equipment.[3] Tita-

[3] American Metal Market. Titanium Scene. Sec. 2 of v. 72, No. 53, Mar. 19, 1965, p. 29.

Table 5.—Consumption of titanium concentrates in the United States, by products
(Short tons)

Year and product	Ilmenite [1]		Titanium slag		Rutile	
	Gross weight	Estimated TiO_2 content	Gross weight	Estimated TiO_2 content	Gross weight	Estimated TiO_2 content
1956–60 (average)	844,636	443,825	132,060	93,366	33,979	32,261
1961	929,147	497,514	130,184	92,011	29,548	28,016
1962	944,797	501,196	138,205	98,632	31,749	30,235
1963	874,986	459,506	152,416	108,645	35,189	33,326
1964:						
Pigments	977,178	509,403	128,100	91,795	(2)	(2)
Titanium metal	(3)	(3)			(2)	(2)
Welding-rod coatings	576	341	103	73	19,847	18,751
Alloys and carbide	2,625	1,282	(3)	(3)	(4)	(4)
Ceramics	(2)	(2)			674	626
Fiberglas					813	785
Miscellaneous	47	27			58,112	56,166
Total	980,426	511,053	128,203	91,868	79,446	76,328
1965:						
Pigments	920,168	481,364	148,184	105,483	(2)	(2)
Titanium metal					(2)	(2)
Welding-rod coatings	(2)	(2)	(3)	(3)	22,402	21,212
Alloys and carbide	2,589	1,311	(3)	(3)	928	863
Ceramics	(2)	(2)			(5)	(5)
Fiberglas					945	918
Miscellaneous	547	327			93,101	90,024
Total	923,304	483,002	148,184	105,483	117,376	113,017

[1] Includes a mixed product containing rutile, leucoxene, and altered ilmenite used to make pigments and metal.
[2] Included with "Miscellaneous" to avoid disclosing individual company confidential data.
[3] Included with "Pigments" to avoid disclosing individual company confidential data.
[4] Included with "Fiberglas" to avoid disclosing individual company confidential data.
[5] Included with "Alloys and carbide" to avoid disclosing individual company confidential data.

nium scrap consists chiefly of trim from flat stock, mandrel wound bundles of sheet and strip edges, turnings, and slab ends. About one-half of the 7,000 tons of scrap generated in 1965 was remelted with titanium sponge metal and about one-fourth was exported. The rest was used in steelmaking and in the electroprocess industries.

The growing use of titanium castings, which have been produced in significant quantities only since 1956, was described.[4] By the end of 1962 the dollar volume of production of titanium castings for anticorrosive applications had jumped 1,100 percent over the comparable figure for 1959. In 1963 the price of titanium castings was lowered by an order of magnitude of 50 percent and sales were 15 times greater than in 1959. In 1964, sales were double those in 1963.

Pigments.—Consumption of titanium dioxide pigments on a gross weight basis and using shipments as a gage increased 5 percent.

Titanium dioxide was used to obtain opacity in gelatin capsules in a large plant in the United Kingdom.[5] A roof coating consisting of vinyl resin emulsion, pigmented with titanium dioxide, which reportedly reflected 80 to 86 percent of the sunlight and heat, was being marketed.[6]

Fourteen pounds of radioactive strontium titanate was used in the first commercial application of an "atomic battery." The 60-watt generator will be used to power flashing navigational lights and an electronic fog horn in the Gulf of Mexico off Cameron, La. The unit was expected to function for 5 years.[7]

[4] Wood, Nat. Titanium Castings. Foundry, v. 93, No. 4, April 1965, pp. 66–69.

[5] Chemical Age (London). New Gelatin Capsule Facilities for Lilly. V. 93, No. 2391, May 8, 1965, p. 726.

[6] Chemical Week. Roof Coatings. V. 96, No. 23, June 5, 1965, p. 56.

[7] American Metal Market. Strontium Titanate Used in Atom Cell on Oil Platform. V. 72, No. 41, Mar. 3, 1965, p. 10.

Table 6.—Distribution of titanium-pigment shipments, by industries
(Percent)

Industry	1956–60 (average)	1961	1962	1963	1964	1965
Distribution by gross weight:						
Paints, varnishes, and lacquers	65.2	63.4	61.9	63.3	62.6	62.9
Paper	11.1	12.5	13.0	12.5	12.4	12.6
Floor coverings	4.6	4.5	4.7	4.3	3.9	3.6
Rubber	3.8	4.1	4.2	4.0	3.1	4.2
Coated fabrics and textiles (oil cloth, shade cloth, artificial leather, etc.)	3.0	3.3	3.3	2.0	1.2	1.4
Printing ink	1.4	1.6	1.7	1.6	1.7	1.8
Roofing granules	(1)	(1)	(1)	2.1	1.6	1.3
Ceramics	(1)	(1)	(1)	1.2	1.5	1.5
Plastics (except floor covering and vinyl-coated fabrics and textiles)	(1)	(1)	(1)	2.9	4.4	3.6
Other (including export)	10.9	10.6	11.2	6.1	7.6	7.1
Total	100.0	100.0	100.0	100.0	100.0	100.0
Distribution by titanium dioxide content:						
Paints, varnishes, and lacquers	58.4	57.0	55.3	57.0	56.8	57.4
Paper	14.5	15.7	16.2	15.5	15.2	15.2
Floor coverings	5.8	5.6	5.8	5.2	4.7	4.3
Rubber	4.9	5.1	5.2	4.9	3.7	5.0
Coated fabrics and textiles (oil cloth, shade cloth, artificial leather etc.)	3.8	4.1	4.0	2.0	1.4	1.6
Printing ink	1.9	2.0	2.1	2.0	2.1	2.1
Roofing granules	(1)	(1)	(1)	2.6	1.9	1.7
Ceramics	(1)	(1)	(1)	1.5	1.9	1.8
Plastics (except floor covering and vinyl-coated fabrics and textiles)	(1)	(1)	(1)	3.7	5.4	4.3
Other (including export)	10.7	10.5	11.4	5.6	6.9	6.6
Total	100.0	100.0	100.0	100.0	100.0	100.0

1 Data not available. Included with "Other."

STOCKS

Industry stocks of rutile increased 17 percent to 164,000 tons, equivalent to more than a year's supply at the 1965 consumption rate. Ilmenite inventories also increased significantly, but stocks of titanium slag declined. Yearend stocks of titanium sponge metal held by producers, melters, and semifabricators totaled 710 tons compared with 760 tons on hand at the end of 1964. Titanium metal scrap held by melters and semifabricators at yearend was 3,300 tons, 200 tons less than at the end of 1964.

Table 7.—Stocks of titanium concentrates in the United States, Dec. 31
(Short tons)

Year and stock	Ilmenite: Gross weight	Ilmenite: TiO_2 content, estimated	Titanium slag: Gross weight	Titanium slag: TiO_2 content, estimated	Rutile: Gross weight	Rutile: TiO_2 content, estimated
1964:						
Mine	24,586	12,559	---------	---------	7,267	6,956
Distributor	126	73	117	85	10,753	r 10,323
Consumer	658,895	369,366	119,078	84,836	r 121,723	r 117,069
Total	683,607	381,998	119,195	84,921	r 139,743	r 134,348
1965:						
Mine	45,213	26,258	---------	---------	(1)	(1)
Distributor	212	126	(1)	(1)	13,870	13,318
Consumer	717,714	400,589	109,091	77,463	149,733	144,295
Total	763,139	426,973	109,091	77,463	163,603	157,613

r Revised.
1 Included with "Consumer" to avoid disclosing individual company confidential data.

PRICES

Concentrates.—The price, f.o.b. Atlantic ports, quoted in E&MJ Metal and Mineral Markets for ilmenite (59.5 percent TiO_2) and rutile (96 percent TiO_2) remained unchanged through August 16, 1965, at $23 to $26 per long ton and $104 per short ton, respectively. At the end of the year rutile prices were quoted at $107 to $111 per short ton and imported ilmenite (54 percent TiO_2) was quoted at $21 to $24 per long ton. Spot sales of rutile were reported at $119 to $121 per short ton.

Manufactured Titanium Dioxide.—The base prices of rutile and anatase grades of manufactured titanium dioxide pigment and calcium-rutile base titanium pigments were unchanged. Some reduction of the base price was given to purchasers of large lots. The following prices were quoted in Oil, Paint and Drug Reporter at yearend:

	Price per pound
Anastase, chalk-resistant, regular and ceramic:	
Carlots, delivered	$0.255
Less than carlots, delivered	.265
Rutile, nonchalking, bags:	
Carlots delivered East	.275
Less than carlots, delivered East	.285
Titanium pigment, calcium-rutile base, 30 percent TiO_2, bags:	
Carlots, delivered	.09375
Less than carlots, delivered	.09875

Titanium Pigment Corp., a subsidiary of National Lead Co., reduced the price of selected anatase grades by 2.5 cents per pound to 23 cents per pound.

Titanium trichloride prices were reduced by Stauffer Chemical Co. from $3.25 per pound to $2.95 per pound.

Metal.—Yearend prices per pound quoted for titanium sponge metal in E&MJ Metal and Mineral Markets were as follows:

Titanium sponge metal; titanium, 99.3 percent maximum; Brinell hardness number, 120 maximum	$1.32
Japanese titanium sponge	$1.23–$1.25
Titanium sponge; titanium, 99.9 percent; Brinell hardness number, 75 maximum	$4.00

Domestic prices per pound of titanium mill shapes (f.o.b. mill, commercially pure, in lots of 5 tons) quoted by a large producer remained unchanged during 1965.

Ferrotitanium.—Nominal prices at yearend for various grades of ferrotitanium were quoted in E&MJ Metal and Mineral Markets as follows:

	Price
Low-carbon, per pound	$1.35
Medium-carbon, per short ton	375
High-carbon, per short ton	310

FOREIGN TRADE

Exports.—Titanium dioxide exports were slightly below those in 1964, which was chiefly due to a drop in shipments to Canada, the principal destination. Canada received 10,084 short tons; Norway, 3,310 tons; the Netherlands, 1,846 tons; the Philippines, 2,211 tons; and Republic of Korea, 1,084 tons. Most of the remainder went to Brazil, Argentina, Sweden, United Kingdom, Belgium-Luxembourg, France, and Italy.

Exports of titanium ores and concentrates, which based on unit value were chiefly rutile, decreased drastically. Principal destinations included Canada, 409 tons; Mexico, 242 tons; Hong Kong, 179 tons; and Iran, 100 tons.

Titanium metal exports, which according to value consisted mostly of titanium scrap, increased substantially for the 4th successive year. Of the 2,132 tons exported, the United Kingdom received 1,734 tons. West Germany with 281 tons and the Netherlands with 37 tons received most of the remainder.

Exports of intermediate titanium mill shapes and other wrought titanium products totaled 605 tons. Of the total, Canada received 342 tons; West Germany 207 tons; and France, Sweden, and the United Kingdom most of the remainder.

Table 8.—U.S. exports of titanium products, by classes

Year	Ores and concentrates		Metal and alloy sponge and scrap		Intermediate mill shapes and mill products, n.e.c. [1]		Dioxide and pigments	
	Short tons	Value (thousands)	Short tons	Value (thousands)	Short tons	Value (thousands)	Short tons	Value (thousands)
1956–60 (average)	2,204	$243	311	$344	520	$6,267	44,944	$15,350
1961	1,436	190	886	927	384	2,702	31,104	9,216
1962	1,224	167	818	925	561	4,102	29,095	8,636
1963	1,212	176	1,261	1,232	494	3,444	26,702	8,051
1964	2,161	386	1,817	1,781	865	4,998	29,359	8,287
1965	1,201	203	2,132	2,070	605	5,144	26,896	7,249

[1] Not elsewhere classified.

Imports.—A threefold increase in imports of ilmenite from Australia was offset by a sharp drop in imports of titanium slag from Canada and total ilmenite imports were slightly lower than in 1964. Conversely, imports of rutile increased 38 percent to a record 152,000 tons, reflecting the growing demand for making titanium metal and pigment.

Imports for consumption of unwrought titanium and waste and scrap totaled 3,134 short tons. Material from Japan and the United Kingdom was virtually all sponge metal and was 2,260 tons and 677 tons, respectively. About 110 tons of sponge metal was imported from the U.S.S.R., about 38 tons from Canada; 49 tons from the Netherlands; and a few pounds from West Germany, mostly scrap.

About 115 tons of wrought titanium was imported. Virtually all of the metal under this category was imported from Japan (92 tons) and the United Kingdom (23 tons).

Imports of titanium dioxide and pigments increased for the 8th successive year and totaled 49,603 tons. The principal sources were Japan, 12,713 tons; Finland, 10,877 tons; West Germany, 8,234 tons; France, 6,477 tons; Canada, 3,202 tons; United Kingdom, 5,519 tons; and Italy, 1,727 tons. Most of the remainder came from Spain and Australia. About 149 tons of titanium compounds also were imported, principally from Japan.

Table 9.—U.S. imports for consumption of titanium concentrates,[1] by countries

(Short tons)

Country	1956–60 (average)	1961	1962	1963	1964	1965
Illmenite:						
Australia	20,668	35,362	57,941	52,883	17,122	49,312
Canada [2]	157,767	127,123	108,493	133,885	[r] 144,897	117,094
India	176,333	44,666	---------	14,112	11,200	---------
Other countries	6,254	---------	(3)	(3)	---------	---------
Total:						
Short tons	361,022	207,151	166,434	200,880	[r] 173,219	166,406
Value	$7,867,758	$5,017,911	$4,469,648	$5,087,539	[r] $5,471,835	$4,769,967
Rutile:						
Australia	44,179	26,047	35,542	71,990	110,981	151,748
Other countries	375	1,450	424	---------	---------	---------
Total:						
Short tons	44,554	27,497	35,966	71,990	110,981	151,748
Value	$6,011,587	$2,544,312	$2,646,174	$4,920,526	$7,723,749	$10,116,182

[r] Revised.
[1] Classified as "ore" by the Bureau of the Census.
[2] Chiefly titanium slag averaging about 70 percent TiO_2.
[3] Less than ½ unit.

WORLD REVIEW

In response to growing demand for rutile for making titanium dioxide pigment in the chloride process, producers in Australia, the principal source, planned to nearly double the current capacity. Development of the rutile deposit in Sierra Leone continued and initial output was scheduled for the latter part of 1966. Expansion of titanium slag production in Canada also was underway.

New titanium dioxide plants or expansion of existing facilities were underway in Canada, the United Kingdom, France, West Germany, Italy, Netherlands, and Norway, as well as in the United States.

In addition to the increased activity in the titanium metal industry in the United States, productive capacity of titanium sponge metal in the United Kingdom, Japan, and the U.S.S.R. also was being expanded.

NORTH AMERICA

Canada.—Quebec Iron & Titanium Corp. (QIT) operating at capacity for the 2nd successive year produced a record 546,000 tons of titanium slag. In anticipation of a continuation of the strong demand, the company began a Can$13.5 million program to expand capacity to about 650,000 tons per year by 1967. The expansion will include construction of a ninth furnace and an increase in transforming capacity to two of the existing furnaces. QIT has conducted development research toward producing titanium slag, which could be chlorinated and thus used in the chloride process for making titanium pigment. The company also planned to distribute laboratory samples of the high TiO_2 content slag to potential users.[8]

[8] Schneider, V. B. Titanium. Canadian Minerals Yearbook, 1964, 10 pp.

Table 10.—World production of titanium concentrates (ilmenite and rutile) by countries [1]

(Short tons)

Country [1]	1961	1962	1963	1964	1965 [p] [2]
Ilmenite:					
Australia (shipments)	186,369	[r] 200,332	[r] 225,102	[r] 340,248	503,686
Brazil [3]	8,005	5,891	6,484	9,117	10,796
Canada (titanium slag) [4]	463,361	301,448	379,320	544,721	545,916
Ceylon	11,199	4,652	21,041	50,880	54,222
Finland	21,272	96,110	103,461	127,937	117,947
India	192,018	152,241	28,619	11,849	33,132
Japan (titanium slag)	1,774	578	963	2,161	3,190
Malagasy Republic	3,640	3,510	4,027	[r] 5,291	6,945
Malaysia (exports)	119,693	113,854	164,656	[r] 144,774	136,154
Mexico	----------	----------	155	----------	----------
Norway	342,723	276,788	267,090	299,608	311,017
Portugal	109	75	45	[r] 63	34
Senegal	19,286	24,727	13,436	[r] 1,455	----------
South Africa, Republic of	99,010	87,096	31,039	----------	----------
Spain	33,184	45,935	55,745	[r] 48,418	35,458
United Arab Republic (Egypt)	[r] 47,475	49,210	596	23	----------
United States [5]	782,412	807,725	888,400	1,001,132	969,459
World total ilmenite (estimate) [1] [2]	[r] 2,331,500	[r] 2,170,200	[r] 2,190,200	[r] 2,587,700	2,728,000
Rutile:					
Australia	113,603	133,499	[r] 205,251	[r] 201,640	240,746
Brazil	[r] 422	[r] 388	[r] 429	315	[e] 300
India	898	1,781	2,062	2,062	1,452
Senegal	195	811	780	[r] 60	----------
South Africa, Republic of	3,483	3,575	1,385	----------	----------
United Arab Republic (Egypt)	[e] 1,100	198	4	----------	----------
United States	9,045	9,981	11,915	8,062	W
World total rutile (estimate) [1]	[r] 128,700	[r] 150,200	[r] 221,800	[r] 212,100	[6] 242,500

[e] Estimate. [p] Preliminary. [r] Revised. W Withheld to avoid disclosing individual company confidential data.

[1] Titanium concentrates are produced in U.S.S.R., but no reliable figures are available; no estimate is included in the total.

[2] Compiled from data available June 1966.

[3] Production—Comissao Nacional de Energia Nuclear only.

[4] Containing approximately 70–72 percent TiO_2.

[5] Includes a mixed product containing ilmenite, leucoxene, and rutile.

[6] Excludes U.S. data.

British Titan Products (Canada) Ltd. planned to boost capacity of its titanium pigment plant at Tracy, Quebec, from 22,000 tons per year to about 30,000 tons per year.

Canadian Titanium Pigments Ltd., a subsidiary of National Lead Co., expanded capacity of its titanium pigment plant at Varennes, Quebec, from 25,000 tons per year to 30,000 tons per year. The company, which utilizes titanium slag produced by QIT in the sulfate process, also expected to start construction of a 10,000-ton-a-year pigment plant to utilize the chloride process early in 1966.

Atlas Titanium Ltd., a producer of titanium mill products and forgings from imported ingots and billets, was offering titanium castings in the United Kingdom and Europe, produced by Oregon Metallurgical Corp. in the United States.[9]

SOUTH AMERICA

Brazil.—The National Nuclear Energy Commission (CNEN) reportedly approved an increase in the allowable monazite concentration in ilmenite concentrates consumed or exported from 0.8 to 1.3 percent. The move was made to encourage development of beach sand deposits for titanium. Ilmenite and rutile are produced as byproducts of monazite mining and processing at Barra de Itabapoana, located in the State of Rio de Janeiro about 43 miles from Campos (at the Espirito Santo Stateline), and at Cumuruxatiba, located in Bahia, 28 miles from Prado (near the Southern border of the State). Sales of ilmenite and rutile, which are mostly in the Sao Paulo area, have been less than the potential output, and rough concentrates containing rutile, ilmenite, and zircon have accumulated. A marine terminal to permit bulk shipments of the titanium minerals reportedly was being built at a small harbor in Cumuruxatiba.

EUROPE

United States Steel International, Inc. (New York) was expected to begin developing markets for titanium mill products such as bar, sheet, plate, tubing, and extrusion. U.S. Steel International Inc. is a subsidiary of United States Steel Corp. which owns 50 percent of Reactive Metals Inc., an integrated titanium producer with main production facilities located at Ashtabula and Niles, Ohio, in the United States.

European consumption (probably exclusive of Communist countries) of titanium pigment in 1964 was estimated at 380,000 tons.

France.—British Titan Products Co., Ltd., continued efforts to obtain approval for construction of a 25,000-ton-per-year titanium pigment plant. British Treasury approval of the proposed plant to be located at Calais reportedly was obtained.[10]

Germany, Federal Republic of.—Titan G.m.b.H., a subsidiary of National Lead Co., plans for a 140,000-ton-per-year titanium pigment plant at Wilhelmshaven apparently were dropped because of water pollution problems. The company reportedly planned to build a smaller plant (36,000 tons per year) at Nordenham, a port on the North Sea.

Consumption of titanium metal reportedly was about 450 tons in 1963 and 720 tons in 1964.

Italy.—Montecatini, Soc. Generale per l'Industria Mineraria e Chimica, planned to build a new titanium pigment plant with a capacity of 55,000 short tons per year at Scarlino (on the coast of Tuscany opposite the Isle of Alba) and was expanding the Spinetta-Marengo plant to enable it to produce up to 50,000 tons of titanium pigment annually.

Montecatini and Società Edison, two of Italy's largest firms, planned to merge, forming one of the largest chemical concerns in the world.

Netherlands.—Cyanamid International Development Corp., a subsidiary of American Cyanamid Co., obtained an interest in the 11,000-ton-per-year titanium pigment plant of N.V. Titaan Dioxydefabriek at Botlek. Capital of the firm reportedly was doubled as a result of Cyanamid's entry and capacity of the plant also will be doubled.[11]

In 1964 about 2,500 tons of titanium pigment was imported compared with about 7,000 tons exported. Of the total exports about 2,400 tons went to common market countries.

Norway.—Titan Co. A/S, a subsidiary of National Lead Co., planned to complete expansion of its titanium pigment

[9] Metal Bulletin (London). Titanium Castings for Europe. No. 4979, Mar. 9, 1965, p. 19.

[10] Oil, Paint and Drug Reporter. British Titan Firming Up Its French TiO_2 Venture. V. 187, No. 17, Apr. 26, 1965, p. 7.

[11] Chemical Age. Cyanamid Break Into TiO_2 Production in Europe. V. 94, No. 2413, Oct. 9, 1965, p. 549.

plant at Frederikstad to 15,000 tons per year in 1966. Titan which uses ilmenite supplied by another National Lead subsidiary, Titania A/S, reportedly manufactures standard grades of titanium pigment as well as the special grades which have been developed by National Lead in the United States, Titan G.m.b.H. in West Germany, and by Dérives du Titane S.A. in Belgium.[12]

United Kingdom.—It was indicated that British Titan Products Co., Ltd., operated a 5,000-ton-per-year titanium pigment plant at Billingham-on-tees using the chloride process.[13] Late in the year the company raised prices of its anatase-grade titanium pigment from about $450 per ton to about $484 per ton. Rutile grades were raised from about $507 per ton to $540 per ton. Chloride process titanium dioxide was unchanged at about $700 per ton.[14]

Imperial Metal Industries (Kynoch) Ltd. planned to double capacity of its titanium sponge metal plant at Wilton.[15] In 1958, capacity figures were reportedly about 1,800 tons per year; however, the plant was closed in 1959 and was not reopened until 1964. Cost of the new expansion was said to be about $2.8 million.

U.S.S.R.—The Government reportedly began production of titanium sponge metal at a new plant of undisclosed size at Ust-Kamengorsk, in Eastern Kazakhstan.

AFRICA

Senegal.—Société Minière Gaziello, a subsidiary of the French company, Fabriques de Produits Chimiques de Thann et de Mulhouse, decided not to develop a new ilmenite deposit in the M'Bour-Joal region because of the presence of excessive chromium in the ilmenite.[16] Gaziello had mined out an ilmenite deposit at Djifère Sangomar in 1964.

Sierra Leone.—Development of the Sherbro Minerals Ltd., rutile deposit in the Gbangbama area in the southwest continued. Construction of the treatment plant, the loading dock at Niti, a 112-foot-long by 30-foot-wide dredge, and a 3,000-kilowatt electric power station was expected to be completed, and full-scale mining operations began at a rate of 100,000 tons of rutile per year late in 1966.[17]

ASIA

India.—Output of ilmenite continued at the low level of recent years, and negotiations reportedly still were underway to increase exports to Japanese producers of titanium pigment. The Government owned Travancore Minerals Ltd. accounted for most of the output and a private company, F. X. Pereira Minerals Ltd., accounted for the remainder. F. X. Pereira also produced all of the rutile from tailing dumps.

Japan.—The seven producers of titanium pigments planned to form a cartel to control the quantity and price of pigment exports, which comprise about one-third of total output.[18] An industrial association for purchasing titanium ores also was to be organized.[19]

Titanium sponge metal production was 5,335 tons—a new record, 62 percent above 1964 production. Osaka Titanium Co., Ltd., and Toho Titanium Co. Ltd. were expected to expand annual capacity to 2,900 and 3,200 tons, respectively, by the end of the year. Output of titanium slag by Hokuetsu Electric Chemical Co., the only commercial producer, also increased. Osaka produces slag for its own use.

Malaysia.—Exports of ilmenite which were chiefly to Japan, France, and Belgium declined in 1964.

Papua.—The Premier Mining Company Pty., Ltd., was examining a rutile deposit off an island near Cape Blackwood and at Goaribari Island in the Gulf of Papua.[20]

OCEANIA

Australia.—Estimated data on capacity to produce rutile and ilmenite and plans for expansion of capacity shown in table 12 are based on information published by

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[12] Skilling's Mining Review. Norwegian Subsidiary of National Lead to Expand. V. 54, No. 10, Mar. 6, 1965, p. 13.
[13] Chemical Age (London). B.T.P. First on Stream With Chloride Route to Ti Pigment. V. 93, No. 2381, Feb. 27, 1965, p. 315.
[14] European Chemical News (London). British Titan Raises Sulphate TiO_2 Prices. V. 8, No. 199, Nov. 5, 1965, p. 6.
[15] Metal Bulletin (London). ICI Titanium Expansion. No. 5017, July 27, 1965, p. 22.
[16] Metal Bulletin (London). Senegal Ilmenite Unsatisfactory. No. 5052, Nov. 30, 1965, p. 23.
[17] Mining & Minerals Engineering (London). Rutile Mining in Sierra Leone. V. 1, No. 9, May 1965, p. 355.
[18] Oil, Paint and Drug Reporter. TiO_2 Cartel Planned by Japanese Industry. V. 188, No. 4, July 26, 1965, p. 7.
[19] Engineering and Mining Journal. Seven Japanese Manufactures. V. 167, No. 1, January 1966, p. 158.
[20] Chemical Trade Journal & Chemical Engineering (London). Titanium Found in Papua. V. 157, No. 4085, Sept. 23, 1965, p. 359.

Table 11.—Malaysia: Exports of ilmenite by countries
(Short tons)

Destination	1960	1961	1962	1963	1964
Belgium	11,466	5,616	----------	19,470	14,663
France	29,599	33,254	34,658	63,194	58,805
Japan	57,587	56,802	77,502	81,537	71,037
United Kingdom	33,603	24,019	1,372	112	224
Other countries	----------	4	324	343	45
Total	132,255	119,695	113,856	164,656	144,774

Metal Bulletin [21] and various other sources. Rutile capacity at yearend is estimated at 268,650 tons per year, and facilities for an additional 173,650 tons are being built or planned. Ilmenite capacity at yearend was estimated at 440,000 tons and plans were underway to expand output by 375,000 tons per year.

As in past years the United States was the principal market for rutile, followed by the United Kingdom, Japan and the Netherlands. The United Kingdom was the chief market for ilmenite followed by Japan, France, and the Republic of South Africa.

[21] Metal Bulletin. Beach Sand Minerals. November 1965, 48 pp.

Table 12.—Australia: Rutile and ilmenite productive capacity

(Short tons)

Company and location of dry separation plant	Estimated capacity Dec. 1965	Planned additional capacity
Rutile:		
Associated Minerals Consolidated Ltd. (AMA):		
Byron Bay, New South Wales	10,000	----------
Southport, Queensland	40,000	----------
Diamond Head, New South Wales	6,000	----------
Hexham, New South Wales	----------	60,000
Total	56,000	60,000
Wyong Minerals Ltd.:		
Budgewoi (Lake Munmora), New South Wales	22,000	----------
Cudgen R. Z., Pty.:		
Cudgen, New South Wales	33,000	----------
Consolidated Rutile Ltd.:		
Meeandah, Queensland	----------	33,000
N.S.W. Rutile Mining Co. Pty.:		
Cudgen, New South Wales	33,000	20,000
Rutile & Zircon Mines (New Castle) Ltd.:		
Port Macquarie, N.S.W. and Belmont, New South Wales	50,000	----------
Titanium & Zirconium Industries Pty. Ltd. (TAZI):		
Dunwich, Queensland	23,000	20,000
Titanium Alloy Manufacturing Co.:		
Cudgen, New South Wales	2,000	----------
Queensland Titanium Mines Pty. Ltd.:		
Inskip Point, Queensland	5,000	5,000
Mineral Deposits Pty. Ltd.:		
Crescent Head, New South Wales	25,000	
Port Stephens, Queensland	----------	25,000
Bilinga, Queensland	15,000	
Northern Rivers Rutile Pty.:		
Kincumber, New South Wales	4,000	10,000
Western Titanium N.L.:		
Capel, Western Australia	650	650
Grand total rutile	268,650	173,650
Ilmenite:		
Western Titanium N.L.:		
Capel, Western Australia	165,000	55,000
Westralian Oil, N.L.:		
Capel, Western Australia	88,000	----------
Ilmenite Minerals Pty. Ltd.:		
Wonnerup, Western Australia	[1] 33,000	----------
Western Mineral Sands Pty. Ltd.:		
Wonnerup, Western Australia	110,000	55,000
Cable (1956) Ltd.:		
Bunbury, Western Australia	44,000	45,000
Murphyores Inc., Pty. Ltd.:		
Gladstone, Queensland	----------	220,000
Total ilmenite	440,000	375,000

[1] Sold to Cable (1956) Ltd.

Table 13.—Australia: Exports of ilmenite concentrates by countries

(Short tons)

Destination	1961	1962	1963	1964	1965 [1]
France	4,563	115	1	45,406	
Japan	31,799	30,776	25,337	55,876	
Netherlands	12,533	46	1,127	411	
South Africa, Republic of	----------	----------	----------	20,017	[2]
United Kingdom	76,813	84,426	80,032	136,516	
United States	35,334	57,983	40,430	17,130	
Other Countries	248	338	23,358	227	
Total	161,290	173,684	170,285	275,583	159,058

[1] January through June, inclusive.
[2] Countries of destination not available for 1965.

Table 14.—Australia: Exports of rutile concentrates by countries
(Short tons)

Destination	1961	1962	1963	1964	1965 [1]
Belgium	2,846	3,725	3,212	4,287	(2)
France	8,084	8,211	6,938	9,803	(2)
Germany, West	9,855	9,521	4,972	10,625	(2)
Italy	6,030	7,587	7,158	6,851	(2)
Japan	13,765	9,298	12,460	17,832	10,729
Netherlands	13,590	17,387	10,626	15,206	7,158
Sweden	4,013	4,785	4,392	4,454	(2)
United Kingdom	15,989	19,017	16,386	17,187	13,107
United States	26,357	35,625	88,234	107,539	63,253
Other countries	11,081	16,210	18,671	23,376	32,154
Total	111,610	131,366	173,049	217,160	126,401

[1] January through June, inclusive.
[2] Data not separately recorded.

TECHNOLOGY

Studies on selective flotation of rutile and zircon in beach sands of India indicated that zircon could be floated from rutile under acidic conditions using sodium oleate as the collector.[22] The effect on the flotation of using several other soaps indicates that the pH range of flotation of the beach sand minerals is increased as the number of carbon atoms in the molecules of the collector is increased.[23]

The large number of research reports on the preparation and properties of various titanium compounds, which were published during the year, reflected interest in the commercial potential of titanium compounds. The Bureau of Mines grew whiskers (fibers) of pure titanium dioxide, which ranged in diameter from 0.01 to 0.1 millimeters and were up to 26 millimeters in length [24] and measured electrical properties of mixtures of the diboride of titanium with that of chromium.[25] Tensile strength of the whiskers probably exceeded 50,000 pounds per square inch. The National Bureau of Standards showed that strontium titanate, a semiconducting material at ordinary temperatures, exhibited superconductivity at temperatures approaching absolute zero.[26]

A report described the preparation of titanium phosphides by three different methods: (1) Direct combination of the elements; (2) the reaction of titanium hydrate with phosphine; and (3) solid or liquid state reactions between a titanium phosphide and titanium powder.[27] A patent for a method of producing a nitridized titanium flake pigment was granted to Du Pont.[28]

Commercial production of barium titanate for use in manufacturing piezoelectric transducers was described.[29] A 500- to 600-pound batch of barium carbonate and titanium dioxide is wet-mixed in a rubber-lined ball mill for a number of hours. The resulting slurry is screened and spray dried with a binder, pressed into slugs and calcined under a controlled atmosphere.

An electrolytic method for the production of titanium tetrachloride, an intermediate material in the commercial production of titanium metal and pigment, was patented.[30]

[22] Madhavan, T. R., V. M. Karve, and J. Y. Somnay. Selective Flotation of Beach Sand Sillimanite, Zircon and Rutile. Min. Mag. (London). V. 113, No. 3, September 1965, pp. 202–203, 205, 207.

[23] Pai, K. M., and R. Mallikarjunan. Flotation of Beach Sand Minerals. Min. Mag. (London). V. 112, No. 4, April 1965, pp. 242–245.

[24] Johnson, Robert C., and John K. Alley. Growth and Properties of Zirconia and Titania Whiskers From Fused Salt Baths. BuMines Rept. of Inv. 6667, 1965, 15 pp.

[25] Farrior, Gilbert M. Diborides in the Pseudobinary System TiB^2–CrB_2: Electrical Properties. BuMines Rept. of Inv. 6691, 1965, 26 pp.

[26] Ceramic Industry. $SrTiO_3$ Shows Cryogenic Super-Conductivity. V. 84, No. 6, June 1965, pp. 89, 91.

[27] Knausenberger, M., G. Brauer, and K. A. Gingerich. Preparation and Phase Studies of Titanium Phosphides. J. Less-Common Metals (Amsterdam, Netherlands), v. 8, No. 2, February 1965, pp. 136–148.

[28] Klein, Oscar J. C., Edward F. Klenke, Jr., and Charles W. Manger (assigned to E. I. du Pont de Nemours & Co., Inc.). Process for Making Nitridized Titanium Flake Pigment. U.S. Pat. 3,205,084, Apr. 18, 1962.

[29] Ceramic Industry. Transducer Manufacturer Designs Plant to Make Unusual Titanate Ceramics. V. 84, No. 2, February 1965, pp. 52–54, 58.

[30] Ancrum, Robert William, and Arthur Wallace Evans (assigned to British Titan Products Co., Ltd.). Electrolytic Production of Titanium Tetrachlorides. U.S. Pat. 3,203,880, Dec. 3, 1957.

Metal.—Under a program sponsored by the General Services Administration, the Bureau of Mines investigated the direct reduction of titanium dioxide to titanium metal using magnesium as the reductant. A product containing up to 89 percent titanium metal and about 4 percent oxygen was obtained. Direct reduction under a hydrogen atmosphere improved the product significantly, but oxygen content was about 2.4 percent.[31] Both products were amenable to electrorefining; however, the purity of the refined metal and current efficiency in electrorefining titanium-oxygen alloys containing more than 0.5 percent oxygen is very low.[32]

The engineering properties, forms, heat treatment, welding, and applications of various grades of titanium and its alloys were reviewed.[33] There are six grades of unalloyed titanium having a nominal composition of 98.9 to 99.5 percent titanium, plus small quantities of iron, carbon, hydrogen, nitrogen, and oxygen. One grade actually contains about 0.15 to 0.20 percent palladium to improve corrosion resistance in mildly reducing environments such as dilute hydrochloric or sulfuric acid. Alpha alloys normally have good weldability, strength, toughness, and high temperature stability. Alpha-beta alloys, which comprise the largest group of titanium alloys, are characterized by the alloy containing 6 percent aluminum and 4 percent vanadium. Mill products of this alloy equal the commercial production of all other alloys and that of the unalloyed grades. Currently, there are only two alloys which are called beta alloys. Beta alloys develop very high strength at moderately high temperatures.

Titanium Metals Corporation of America announced commercial availability of a new titanium alloy designed to raise the temperature limit of titanium in jet engines to 900° F. The alloy contains about 2.25 percent aluminum, 11 percent tin, 5 percent zirconium, and 1 percent molybdenum. The composition is unusual in that it relies on the formation of silicides for a portion of its strength. About 0.2 percent of silicon is in the alloy.

Laboratory tests indicated that titanium forms, such as sheet, can be produced by distilling the metal onto a form under a vacuum.[34]

For joining titanium to stainless steel, the National Aeronautics and Space Administration developed a brazing alloy containing 81.1 percent palladium, 14.3 percent silver, and 4.6 percent silicon. Brazed joints using the alloy were vacuum tight and corrosion resistant and also developed high strength levels.[35]

Joining of titanium and stainless steel also was accomplished by diffusion bonding or solid state welding. This method of joining metals is accomplished by applying heat and pressure simultaneously without melting the alloys being joined. In solid state welding of titanium and stainless steel, the eutectic alloy titanium nitride ($TiNi_3$) was believed to form at the interface of the two metals.[36] These metals also were joined by diffusion bonding using a gold filler material between the joints.[37]

Galling and sizing of titanium, rubbing against other metals or itself, was prevented by using a complex iodine lubricant developed by the General Electric Company.[38] A study of the effectiveness of a variety of surface treatments and lubricants in improving the deep-drawing and stretch-forming properties of a range of titanium sheet alloys indicated that a thin sheet of polythene or coating of polytetra-fluorethylene (PTFE) dispersed in resin and a methacrylic resin dissolved in trichlorethylene were the most efficient.[39] Although polythene was less expensive than other lubricants, its use was restricted to single-stage pressing.

In the early 1950's titanium was known as a hard-to-machine metal compared with common construction materials. However,

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[31] Dolezal, H., E. C. Perkins, D. E. Kirby, and R. S. Lang. Magnesium Reduction of Rutile. BuMines Rept. of Inv. 6599, 1965, 12 pp.

[32] Leone, Oliver Q., and F. S. Wartman. Electrorefining of Titanium-Oxygen Alloys. BuMines Rept. of Inv. 6588, 1965, 20 pp.

[33] Materials in Design Engineering. Titanium and its Alloys. V. 61, No. 234, October 1965, pp. 123–142.

[34] Bunshaha, R. F. Titanium Shapes Can Be Produced By Electron Beam Distillation. Am. Metal Market, v. 72, No. 142, July 27, 1965, p. 21.

[35] Light Metal Age. New Alloy Brazes Titanium to Stainless Steel. V. 23, Nos. 3 and 4, April 1965, p. 13.

[36] Albon, M. J. Solid State Welding of Reactive and Refractory Metals. Mat. in Design Eng., v. 61, No. 4, April 1965, pp. 106–109.

[37] Steel. Diffusion Bonding Reaches Production Stage. V. 175, No. 19, Nov. 8, 1965, pp. 60–61.

[38] Iron Age. Iodine Lubricants Smooth the Way for Broader Use of Titanium. V. 196, No. 22, Nov. 25, 1965, pp. 68–69.

[39] Mitchell, E., and P. J. Botherton. Surface Treatments and Lubricants for Improving the Press-Forming Properties of Titanium and Its Alloys. J. Inst. Metals (London), v. 93, pt. 8, April 1965, pp. 278–279.

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the usefulness of the metal led to considerable research on machining titanium by Government and industry, resulting in development of suitable methods. The status of machining titanium and its alloys was summarized.[40] Another article described methods for machining an alpha-beta titanium alloy containing 6 percent aluminum and 4 percent vanadium, and the beta titanium alloy containing 3 percent aluminum, 13 percent vanadium, and 11 percent chromium.[41]

Because titanium is recognized as a corrosion resistant metal of much promise, considerable test work has been conducted to determine its corrosion behavior in specific media. A review of data on the corrosion resistance of titanium, which outlined certain applications and discussed three prominent theories of inhibitor action, was published.[42] Titanium exhibited a high corrosion rate in saline waters at temperatures of 100° C. However, according to a paper by Bohlmann and Posey on aluminum and titanium corrosion in saline waters at elevated temperatures, which was presented at the First International Symposium on Water Desalination in Washington, D.C., Oct. 3–9, 1965, the initiation of the corrosion, the rate, and extent of the attack was not always reproducible.

Stress Corrosion cracking of titanium alloys on exposure to salt at elevated temperatures (above 315° C) can be caused by a gaseous intermediate product of the corrosion process, according to a report.[43] The intermediate product was chlorine which is regenerated in the corrosion process.

Coatings to protect titanium from the effects of high temperatures and wear were being studied. In one investigation a composite system of flame sprayed nickel-chromium and copper protected titanium tubes up to 1,370° C.[44] In another, tungsten carbide flame-plated on titanium improved its wear resistance.[45]

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[40] Olofson, C. T., A. F. Gerds, F. W. Boulger, and J. A. Gurklis. Machining of Titanium Alloys. Battelle Memorial Institute, Defense Metals Information Center, Feb. 2, 1965, 23 pp.

[41] Field, Michael, Normak Zlatin, and Robert T. Jameson. Machining Titanium Alloys. Metal Prog., February 1965, 8 pp.

[42] Materials Projection. Titanium: Its Corrosion and Behavior and Passivation. V. 4, No. 1, pp. 16–19, 21.

[43] Chemical & Engineering News. Cl_2 From Salt Corrosion Cracks Ti Alloys. V. 43, No. 46, Nov. 15, 1965, p. 42.

[44] Metal Progress. Protecting Titanium at High Temperatures. V. 87, No. 4, April 1965, pp. 182–190.

[45] Materials in Designing Engineering. Flame-Plated Titanium—New Qualities for an Exciting Metal. V. 62, No. 3, September 1965, pp. 81–82.

Tungsten

By Richard F. Stevens, Jr. [1]

While the tungsten ore and concentrate market continued to improve significantly in 1965, the domestic tungsten situation became one of relatively tight supply. As a result, tungsten imports increased, commercial stocks were drawn down to an abnormal low, and tungsten was released from the Government stockpile. Although the foreign price continued to increase and was four times the previous low of $7 per short-ton unit, estimated world production was slow to respond and decreased 7 percent. Few of the mines which had ceased to operate during the preceeding 3 years were reactivated during 1965, but plans to reopen several of these mines in 1966 were announced.

The two major factors influencing the improved tungsten market during the year continued to be the absence of mainland Chinese tungsten exports and the extremely high level of industrial activity in the United States, Europe, and Japan.

Legislation and Government Programs.—On September 23, 1965, the Office of Emergency Planning (OEP) released its findings regarding an application filed on January 2, 1964, by the Lamp Division, General Electric Co., requesting an investigation to determine the effects of imported tungsten mill products upon the national security. After a comprehensive survey of the industry was conducted, OEP stated that tungsten products were not being imported into the United States in such quantities or under such circumstances as to threaten to impair the national security.

On June 30, the General Services Administration (GSA) awarded a contract to the Molybdenum Corporation of Americt (Molycorp) for the conversion of Government-furnished tungsten concentrates from the national (strategic) stockpile to 148,300 pounds, tungsten content, of ferrotungsten. The fee for this upgrading will be reimbursed by payment-in-kind of pig tin from the Defense Production Act (DPA) inventory.

In February a long-range plan was announced to dispose of the approximately 77.9 million pounds of tungsten in con-

[1] Commodity specialist, Division of Minerals.

Table 1.—Salient tungsten statistics

(Thousand pounds of contained tungsten)

	1956–60 (average)	1961	1962	1963	1964	1965
United States:						
Mine production	[1] 9,820	8,188	8,280	W	W	W
Mine shipments	6,666	7,847	8,021	5,384	8,798	7,566
Releases from Government stocks	------	------	1,594	418	758	926
Imports, general	10,868	2,744	3,709	3,882	2,737	3,495
Imports for consumption	10,076	2,123	4,030	3,060	3,148	3,618
Consumption	8,873	11,128	13,691	11,061	12,311	13,868
Stocks:						
Producer	[1] 2,735	2,667	3,004	3,313	580	411
Consumer and dealer	3,618	3,212	3,054	2,934	2,090	1,434
World: Production	64,698	72,711	68,905	60,720	61,386	56,913

W Withheld to avoid disclosing individual company confidential data.
[1] 1958–59 not included to avoid disclosing individual company confidential data.

Table 2.—U.S. defense materials inventories and objectives

(Thousand pounds, tungsten content)

Material	Objective	Inventory by program, Dec. 31, 1965			Total
		National stockpile	DPA	Supplemental stockpile	
Tungsten ore and concentrate:					
Stockpile grade	35,785	35,445	50,595	3,352	89,39
Nonstockpile grade	-------	43,457	26,103	1,153	70,71
Ferrotungsten:					
Stockpile grade	1,800	1,352	--------	--------	1,35
Nonstockpile grade		638	--------	--------	63
Tungsten metal powder, hydrogen reduced:					
Stockpile grade	1,600	1,077	--------	--------	1,07
Nonstockpile grade		14	--------	--------	1
Tungsten metal powder, carbon reduced:					
Stockpile grade	500	499	--------	--------	49
Nonstockpile grade		171	--------	--------	17
Tungsten carbide powder:					
Stockpile grade	2,000	869	--------	1,080	1,94
Nonstockpile grade		63	--------	--------	6
Tungsten carbide, crystalline:					
Stockpile grade	1,100	--------	--------	--------	---------

centrate from the DPA inventory over a 25-year period, with 1 million pounds to be disposed of during the first year. In August, 203,157 pounds, tungsten content, were sold, 305,035 pounds were sold in October, and 398,288 pounds were sold in December. In addition, GSA committed approximately 104,000 pounds of tungsten content, of which only 19,574 pounds was released in 1965, as payment-in-kind for upgrading columbium concentrates from the Government stockpiles to ferrocolumbium.

In an attempt to meet increasing domestic demand for tungsten, 1,511,802 pounds of tungsten was sold from the the DPA inventory early in 1966 at an average price of $42.03 per short-ton unit. GSA subsequently announced that 6.1 million pounds of tungsten would be offered at $43 per short-ton unit on a "first-come, first-served" basis.

A Government survey was conducted to determine the views of the domestic tungsten industry regarding the establishment of new stockpile specifications for various forms of tungsten. As a result of this survey, several revised specifications were prepared which reflected the type of material currently needed by industry. Another result was the recommendation that in the future tungsten should be stockpiled in an intermediate form such as ammonium parratungstate (APT) which could readily be processed into any desired form of tungsten.

At the recommendation of the National Academy of Sciences, GSA initiated a program to evaluate the tungsten metal powder in the Government stockpiles to determine the extent of deterioration and suitability of this material, which was acquired 10 to 15 years ago, to the current requirements of industry.

To determine the potential demand for tungsten, GSA issued a contract to Stanford Research Institute for a market analysis report on tungsten for Government use only. GSA will also use this report as one basis for developing long-range tungsten disposal programs.

DOMESTIC PRODUCTION

During the year the domestic tungsten situation became one of relatively tight supply. Stimulated by the continued demand for tungsten as a replacement for molybdenum in steelmaking, the increased requirements for nonferrous tungsten-base alloys such as tungsten-rhenium for use in nuclear reactors, the increasing use of tungsten carbide in tire studs and other wear-resistant applications, and the absence of significant amounts of tungsten concentrates from mainland China from the world market, the price of tungsten concentrates reached $31.25 per short-ton unit in December. U.S. tungsten mine production increased 9 percent during the year while mine shipments decreased 14 percent. Of the eight mines in five States which reported production during the year, only the Pine Creek mine of the Mining and Metals Division of Union Carbide Corp., near Bishop, Calif., and the Climax mine of Climax Molybdenum Co., a division of American Metal Climax, Inc. (AMAX), at Climax, Colo., were operated continuously. Both of these mines obtained tungsten as a coproduct or byproduct. At the Pine Creek mine, tungsten was the main metal recovered, along with minor amounts of molybdenum, copper, and gold. At the Climax mine, molybdenum was the main metal recovered, while tungsten was recovered as a byproduct. Intermittent tungsten production was also reported from Pima County, Ariz., Pershing County, Nev., and Pend O'Reille County, Wash.

Union Carbide, the country's largest tungsten producer, has integrated its facilities at Pine Creek in order to process almost all its tungsten ore directly to ammonium paratungstate (APT).

During the year Union Carbide began driving a tunnel at the mill level of its Pine Creek mine. When completed this tunnel will extend for 11,000 to 12,000 feet into the mountain and will significantly improve ore haulage.

During 1965 the Molybdenum Corporation of America (Molycorp) formed a subsidiary group, Tumex Corp., to operate a tungsten processing plant at St. Thomas, Virgin Islands. Imports for consumption into the Virgin Islands and shipments of tungsten products from the Virgin Islands to the continental United States are reported in tables 7 and 8. The duty rate for imports of tungsten concentrate into the Virgin Islands is 6 percent ad valorem compared with a duty of $0.50 per pound of contained tungsten into the United States. Imports of tungsten products into the United States through the Virgin Islands are duty free when at least 50 percent of the declared value can be attributed to processing done in the Virgin Islands.

A report published by the Colorado School of Mines compiled information on known tungsten deposits in Colorado, the mineralogy of tungsten, the economic importance of tungsten minerals, general geologic occurrence, and the outlook for tungsten in that State.[2]

A comprehensive market report of the tungsten industry was published describing who sells tungsten, how to buy it, how it is used, price history, what effects the market, and the outlook for tungsten.[3]

[2] Sharps, Thomas I. Tungsten in Colorado. Colorado Sch. of Mines Res. Foundation, Inc., Mineral Industries Bull., v. 8, No. 5, September 1965, 16 pp.

[3] Pendergast, Russell A. (ed.). Market Guide —Tungsten. E&MJ Metal and Mineral Markets, Aug. 23, 1965, 24 pp.

Table 3.—Tungsten concentrate shipped from mines in the United States

Year	Quantity			Reported value, f.o.b. mines [1]		
	Short tons, 60 percent WO_3 basis	Short-ton units WO_3 [2]	Tungsten content (thousand pounds)	Total (thousands)	Average per unit of WO_3	Average per pound of tungsten
1956–60 (average)	7,004	420,249	6,666	$15,539	$36.98	$2.33
1961	8,245	494,741	7,847	10,565	21.36	1.35
1962	8,429	505,685	8,021	11,639	23.02	1.45
1963	5,657	339,402	5,384	7,202	21.22	1.34
1964	9,244	554,676	8,798	11,251	20.28	1.28
1965	7,949	476,979	7,566	13,028	27.32	1.72

[1] Values apply to finished concentrate and are in some instances f.o.b. custom mill.
[2] A short-ton unit equals 20 pounds of tungsten trioxide (WO_3) and contains 15.862 pounds of tungsten.

CONSUMPTION AND USES

Tungsten carbides continued to represent the major end use of tungsten, accounting for 45 percent of the total consumption; cemented carbides accounted for 37 percent; and other carbides (crystalline and cast) accounted for 8 percent. Some of this increase was due to the increased production of tungsten carbide tire studs.

In October, Cleveland Tungsten, Inc., a subsidiary of Molycorp., completed the transfer of its operations from Cleveland to Solon, Ohio, and began operating the new expanded $1 million plant at its rated capacity which was double that of the operation at Cleveland. On January 1, 1966, Chase Brass & Copper Co., Inc., a subsidiary of Kennecott Copper Corp., purchased Cleveland Tungsten for $1.75 million and announced plans to move the Rhenium Division from Waterbury, Conn., to the Ohio facility in 1966 following an additional expansion of the Solon plant.

Metco, Inc., Westbury, N.Y., developed a commercial plasma flame-spraying technique which greatly simplified the fabrication of tungsten parts. Tungsten was sprayed onto a removable configurated mandrel of graphite, brass, or steel. Using this process, stresses were reduced and wall thickness could be closely controlled.

Sylvania Electric Products, Inc., announced the availability of high-purity tungsten sheet coils for vacuum metalizing and plating and of a fine tungsten—1.5 percent rhenium (W–1.5 Re) alloy wire for use as flashbulb filaments.

Plasma-spray metal powders composed of tungsten carbide with a fused-cobalt binder were available from the Plasmadyne Division of Giannini Scientific Corp., Santa Ana, Calif. When sprayed onto a surface, this material, Plasmalloy 702, provides a wear resistant coating with a bond strength of 3,350 pounds per square inch (psi) and a microhardness of Rockwell C 38.

Early in 1966 Firth Sterling, Inc., McKeesport, Pa., announced plans to expand the tungsten carbide (WC) production facilities of its Tungsten Division to accommodate this rapidly growing industry. The tungsten carbide facility of Firth Sterling was operating at capacity.

Metal Carbides Corp., Youngstown, Ohio, had a major expansion program underway and planned to install more than $200,000 of new equipment to meet the domestic and foreign demand for tungsten carbides.

The Carmet Co., Detroit, Mich., announced plans to build a new tungsten carbide production plant in the Madison Heights suburb which would more than double the company's capacity at its present plant in Ferndale, Mich.

Johnson, Matthey & Co. Ltd., London, developed a small-diameter sintered copper-tungsten tube, designated Sparkonite 10, for use as an electrode material in spark-machining operations. Copper-tungsten has such a low rate of wear that shorter, more rigid electrodes may be used resulting in greater accuracy and higher concentricity.

Two reports were published on the use of tungsten as a catalyst in the hydrocracking, hydrotreating, dehydrogenation, isomerization, reforming, polymerization, hydration, dehydration, hydroxylation, and epoxidation of petroleum.[4]

A report describing the use of tungsten carbide in electromachining operations indicated that this new method of machining may account for 50 percent of all machining operations done within 10 years.[5]

Several reports on the production and use of tungsten carbide studs for snow tires appeared in the newspapers during the year, indicating the general public interest in this new form of tire. Approximately one-third of the States had sanctioned the use of these tires and another one-third of the States were considering and expected to approve their use. Almost all of these States were in areas which have severe winters. The use of studded tires were outlawed in Michigan, Illinois, and Iowa, however, because it was claimed that while these tires were effective on ice-covered highways they were ineffective in snow.

The Franklin Division of Studebaker Corp., Detroit, Mich., announced it had been licensed to make tungsten carbide studs by the Helsinki, Finland firm, Kova-

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[4] Kline, C. H., and V. Kollonitsch. Catalytic Activity of Tungsten. Part I. Ind. & Eng. Chem., v. 57, No. 7, July 1965, pp. 53–60.
Kline, C. H., and V. Kollonitsch. Catalytic Activity of Tungsten, Part II. Ind. & Eng. Chem., v. 57, No. 9, September 1965, pp. 53–60.

[5] Bonales, Anthonu.. The Spark That Carves. Product Eng., v. 36, No. 20, Sept. 27, 1965, pp. 53–57.

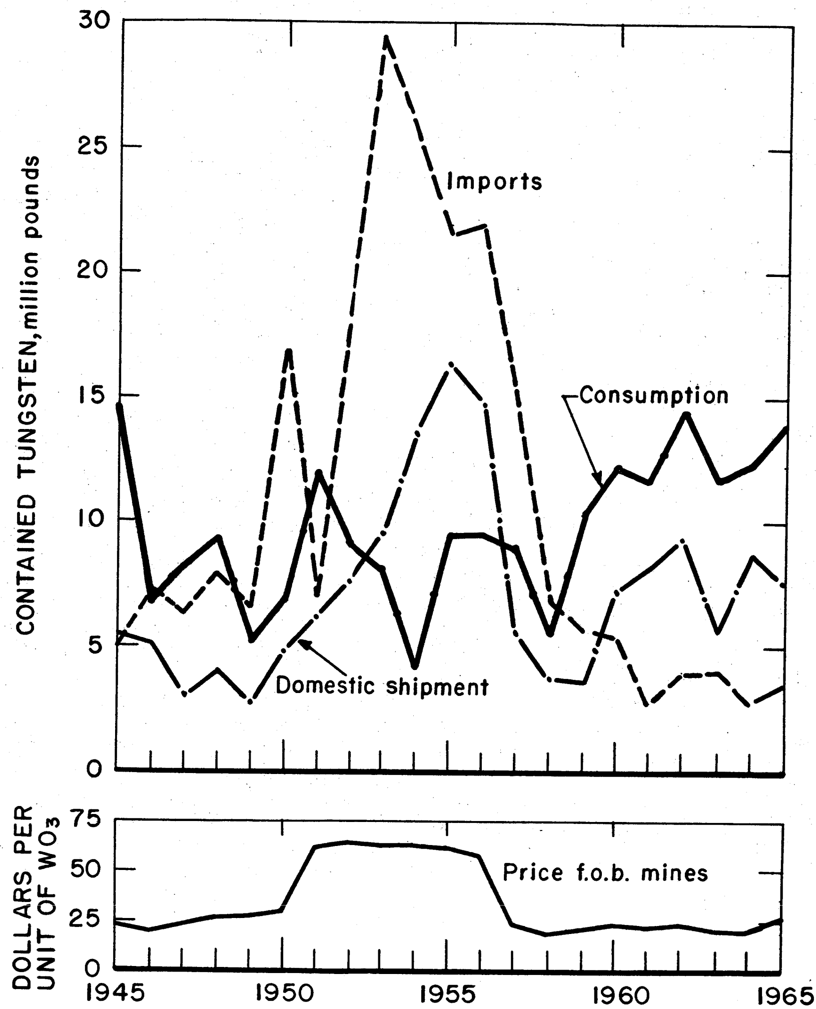

Figure 1.—Domestic shipments, imports, consumption, and average price of tungsten ore and concentrate.

metalli. Studebaker subsequently brought suit against Kennametal, Inc., Latrobe, Pa., charging patent infringement. Kennametal, which had designed, developed, and applied for a patent on its "Kengrip" tungsten carbide studs, stated that its product did not infringe upon the Kovametalli patent.

The General Electric Co. (GE) announced the commercial development of a new tungsten—2 percent thorium oxide (W–$2ThO_2$) dispersion alloy which retains the high temperature properties of tungsten while exhibiting twice the machinability of the pure metal. This alloy was produced in forms suitable for machining into finished shapes and was available in round bars up to 9 inches in diameter and 20 inches in length as well as in square bars and slabs measuring up to 9 inches across the corners and up to 29 inches in length.

A tungsten mesh heating element made by Sylvania had a significantly longer serv-

Table 4.—Production, shipments, and stocks of tungsten products in the United States

(Thousand pounds of contained tungsten)

	Hydrogen- and carbon-reduced metal powder	Tungsten carbide powder		Chemicals	Other [1]	Total
		Made from metal powder	Crushed cast			
1964:						
Received from other producers	3,790	3	9	4,297	1,147	9,246
Gross production during year	7,411	3,233	1,381	8,751	2,313	23,089
Used to make other products listed here	4,433	------	------	7,556	918	12,907
Net production	2,978	3,233	1,381	1,195	1,395	10,182
Shipments [2]	6,405	3,183	1,434	6,544	2,322	19,888
Producer stocks, December 31, 1964	2,271	148	128	1,658	957	5,162
1965:						
Received from other producers	5,152	17	1	4,846	1,516	11,532
Gross production during year	8,909	4,542	1,350	11,011	3,302	29,114
Used to make other products listed here	5,831	------	------	9,521	1,297	16,649
Net production	3,078	4,542	1,350	1,490	2,005	12,465
Shipments [2]	8,291	4,472	1,244	6,607	3,533	24,147
Producer stocks, December 31	2,210	235	235	1,387	945	5,012

[1] Includes ferrotungsten, tungsten carbide powder (crystalline), scheelite (produced from scrap), nickel-tungsten, self-reducing oxide, pellets, and scrap.
[2] Includes quantities consumed by producing firms for manufacture of products not listed here.

ice life than tungsten sheet elements at temperatures between 3,000° and 4,200° F. Because the mesh element consists of interlocked tungsten wires, it overcomes the distortion and cracking problems associated with the sheet elements. The mesh element has the added advantage of extreme flexibility, allowing it to be fabricated into a variety of complex shapes.

The Space Nuclear Propulsion Office (SNPO), a joint Atomic Energy Commission (AEC)—National Aeronautics and Space Administration (NASA) operation, sponsored feasibility studies of a tungsten reactor for use in a small space reactor system. The tungsten reactor incorporated a tungsten clad uranium dioxide (UO_2) fuel element. The high-temperature, high-strength of the tungsten and the low vapor pressure of UO_2 combine to produce a reactor which can be efficiently operated at extremely high temperatures. This work, which was conducted for SNPO at Argonne National Laboratory and Lewis Research Center for the past 3 years, is scheduled to be terminated in mid–1966.

Table 5.—Consumption of tungsten products by end uses

(Thousand pounds of contained tungsten)

End uses	Ferrotungsten melting base, self-reducing tungsten, tungsten sponge mix, etc.	Carbon-reduced tungsten powder [1]	Hydrogen-reduced tungsten powder [2]	Tungsten carbide powder: Made from metal powder	Tungsten carbide powder: Crystalline and crushed cast	Chemicals	Scheelite (natural or synthetic)	Scrap	Total
1964:									
Steel:									
High-speed	383	29	-----	-----	-----	-----	1,009	129	1,550
Hot-work and other tool	105	17	-----	-----	-----	-----	363	7	492
Alloy (other than tool)[3]	351	12	2	-----	-----	-----	141	139	645
High-temperature nonferrous alloys [4]	54	215	18	-----	-----	-----	174	180	641
Other nonferrous alloys [5]	16	5	136	4	240	65	3	101	570
Tungsten metal:									
Wire, rod, and sheet	-----	-----	1,455	-----	-----	7	-----	-----	1,462
Other [6]	-----	2	733	-----	1	-----	-----	-----	736
Carbides:									
Cemented or sintered	-----	-----	58	3,067	565	-----	-----	56	3,746
Other (including cast or fused)	4	66	74	18	870	-----	-----	27	1,059
Chemicals [7]	-----	-----	-----	-----	-----	151	-----	-----	151
Total	913	346	2,476	3,089	1,676	223	1,690	639	11,052
Stocks at consumer plants Dec. 31, 1964	365	59	883	141	11	41	-----	221	1,721
1965:									
Steel:									
High-speed	648	46	-----	-----	-----	-----	774	185	1,653
Hot-work and other tool	224	11	-----	-----	-----	-----	294	17	546
Alloy (other than tool)[3]	765	39	1	1	-----	-----	104	66	976
High-temperature nonferrous alloys [4]	45	357	28	-----	-----	-----	69	217	716
Other nonferrous alloys [5]	17	4	154	4	230	18	1	130	558
Tungsten metal:									
Wire, rod, and sheet	1	-----	2,044						2,045
Other [6]	1	2	696	-----	-----	-----	-----	-----	699
Carbides:									
Cemented or sintered	-----	-----	78	4,216	786	-----	-----	9	5,089
Other (including cast or fused)	4	84	87	18	870	-----	-----	86	1,149
Chemicals [7]	-----	-----	-----	-----	-----	147	-----	-----	147
Total	1,705	543	3,088	4,239	1,886	165	1,242	710	13,578
Stocks at consumer plants Dec. 31, 1965	305	63	508	259	54	28	-----	281	1,498

[1] Includes tungsten metal pellets that may be hydrogen or carbon reduced or scrap.
[2] Does not include quantities consumed in making tungsten carbide powder.
[3] Includes steel mill rolls, stainless and other alloys steels.
[4] Includes cutting and wear resistant alloys, high-temperature and other superalloys.
[5] Includes diamond drill bit matrices, electrical contact points, alloy welding rods, and resistance alloys.
[6] Includes wire, rod, and sheet produced from arc-welded material and various shaped parts produced by powder metallurgy techniques.
[7] Includes fluorescent powders, organic and inorganic pigments.

PRICE AND SPECIFICATIONS

Through May 10, the price of domestic tungsten concentrate, quoted in E&MJ Metal and Mineral Markets, ranged from \$17 to \$19 per short-ton unit of tungsten trioxide (WO_3), f.o.b. mine or mill. Subsequently quotations of domestic tungsten concentrates were discontinued when the major producer began to process all its material to ammonium paratungstate (APT). The average price of APT during 1965 increased to about \$26.50 per short-ton unit, delivered to contract customers. Effective January 1, 1966, Union Carbide announced a further price increase to \$30.

Carbon-reduced tungsten metal powder (99.8 percent in 1,000-pound lots) continued to be quoted at the 1962–64 price of \$2.75 per pound by E&MJ. The quoted price of hydrogen-reduced tungsten metal powder (99.99 percent) ranged from \$2.85 to \$3.63 per pound during the first part of the year. This quotation was increased and ranged from \$3.38 to \$4.19 per pound during the last half of the year as a result of the increasing prices of tungsten concentrate. During the first 2 months of the year the domestic price of ferrotungsten continued to be quoted at \$1.75 per pound of contained tungsten (in lots of 5,000 pounds or more, ¼-inch lump, packed, f.o.b. destination, continental United States, 70 to 80 percent tungsten), while imported ferrotungsten was quoted at \$1.50 per pound. In the latter part of February ferrotungsten was quoted at \$3 (nominal) and UCAR, Union Carbide's grade of ferrotungsten, was quoted at \$1.90 per pound of tungsten. On June 1 the quoted price of UCAR was increased to \$2.03 per pound where it remained for the balance of the year.

Several tungsten carbide manufacturers announced that effective October 2, the price of their tungsten carbide products would be increased by 5 to 13 percent. These increases reflected the rise in cost of tungsten metal powder starting material. During 1965 the price of tungsten rods was increased by 6.5 to 22 percent.

Table 6.—Monthly prices of tungsten concentrate in 1965

Month	Foreign ore per short-ton unit of WO_3, 65-percent basis, c.i.f. U.S. ports, duty extra — Wolfram and scheelite			London market, per long-ton unit of WO_3	
	Low	High	Average [1]	Low	High
January	\$21.00	\$22.00	\$21.50	200s	222½s
February	21.00	21.50	21.25	190s	205s
March	18.75	21.50	20.10	120s	200s
April	18.75	21.25	19.85	115s	180s
May	21.25	27.25	23.85	182½s	222½s
June	26.75	28.75	27.69	215s	237½s
July	27.50	28.75	28.19	220s	237½s
August	22.75	27.00	24.81	165s	215s
September	24.25	26.50	25.62	190s	225s
October	26.00	27.75	27.06	220s	238s
November	27.50	30.25	28.95	230s	257½s
December	29.75	31.25	30.38	247½s	265s
Average price	----------	----------	24.94	----------	----------
Duty	----------	----------	7.93	----------	----------
Average price, duty paid	----------	----------	32.87	----------	----------

[1] Arithmetic average of weekly quotations.

Source: E&MJ Metal and Mineral Markets.

FOREIGN TRADE

Exports.—Exports of tungsten concentrate during 1965, primarily to the Netherlands, decreased to 22,091 pounds, gross weight, valued at $17,936. Effective January 1, 1965, ferrotungsten exports were no longer separately classified.

Exports of tungsten metal and alloys in crude form and scrap, primarily to West Germany, were 303,594 pounds, gross weight, valued at $384,814. Tungsten and tungsten alloy powder totaling 106,114 pounds, gross weight, and valued at $365,359 was exported to West Germany (38 percent), the Netherlands (34 percent), Canada (20 percent), and Mexico, Belgium-Luxembourg, France, and Austria (1 percent each). Exports of tungsten and tungsten alloy wire, almost half of which went to Canada, totaled 29,336 pounds, gross weight, valued at $943,602.

Imports.—General imports of tungsten concentrate during 1965 increased 28 percent. Ninety percent of the total came from Canada (24 percent), Bolivia (19 percent), Peru (17 percent), South Korea (10 percent), Australia (8 percent), Mexico (5 percent), Argentina (4 percent), and the Congo (Léopoldville) (3 percent). Ten percent came from seven other countries. Imports for consumption of tungsten concentrate increased 15 percent. As in 1964, there were no duty-free imports of tungsten ore and concentrate for the U.S. Government.

Imports of ferrotungsten and ferrosilicon-tungsten increased to 385,514 pounds, tungsten content, valued at $403,963, from Austria (81 percent), Japan (6 percent), the United Kingdom (5 percent), France (4 percent), and West Germany (4 percent).

Imports of tungsten carbide, primarily from Sweden (44 percent) and the Republic of South Africa (30 percent), totaled 3,507 pounds, tungsten content, valued at $17,174.

Imports of fabricated and semifabricated tungsten forms contained 6,874 pounds of tungsten, valued at $102,010, of which the majority came from Austria (78 percent), the Netherlands (12 percent), and West Germany (8 percent).

Imports of unwrought tungsten in lumps, grains, and powder contained 39,243 pounds of tungsten valued at $97,874 from Sweden (43 percent), France (39 percent), and West Germany (15 percent).

Imports of tungsten waste and scrap containing more than 50 percent tungsten totaled 51,264 pounds tungsten content, valued at $80,067 from the United Kingdom (28 percent), West Germany (28 percent), the Netherlands (23 percent), and Switzerland (15 percent).

In 1965, 3,954 pounds, tungsten content, of calicum tungstate valued at $23,724 was imported from West Germany (96 percent) and the United Kingdom (4 percent).

During the year, 357,845 pounds, tungsten content, of synthetic scheelite valued at $275,148 was imported from South Korea under the classification "Materials in Chief Value Tungsten."

Table 7.—Tungsten ore and concentrate imported for consumption into the Virgin Islands in 1965, by country of origin

Country	Gross weight (pounds)	Contained tungsten (pounds)	Value
Korea, South	636,164	456,196	$382,901
Portugal	63,340	36,906	32,408
Total	699,504	493,102	415,309

Table 8.—Tungsten shipped from the Virgin Islands to the continental United States in 1965

Kinds	Gross weight (pounds)	Tungsten content (pounds)	Value
Unwrought:			
Containing by weight not more than 50 percent tungsten	615,213	345,032	$604,760
Containing by weight more than 50 percent tungsten	44,500	23,349	46,725
Tungstic acid	530,872	287,328	434,806
Total	1,190,585	655,709	1,086,291

Table 9.—U.S. imports for consumption of tungsten ore and concentrate, by countries

(Thousand pounds and thousand dollars)

Country	1964			1965		
	Gross weight	Tungsten content	Value	Gross weight	Tungsten content	Value
Argentina	327	165	$65	299	156	$73
Australia	198	115	53	592	336	396
Bolivia	2,132	1,173	751	2,151	1,014	1,066
Burundi and Rwanda	43	23	23	122	67	93
Canada	71	38	29	1,382	746	609
China [1]	--------	--------	--------	68	35	47
Colombia	62	36	60	--------	--------	--------
Congo (Léopoldville)	--------	--------	--------	211	114	155
Hong Kong	34	18	14	45	24	19
Korea, South	962	612	324	500	290	268
Mexico	--------	--------	--------	234	129	138
Peru	873	501	386	1,026	596	879
South Africa, Republic of	--------	--------	--------	102	53	71
Portugal	728	435	278	31	18	29
Thailand	--------	--------	--------	80	40	43
United Kingdom	56	32	25	--------	--------	--------
Total	5,486	3,148	2,008	6,843	3,618	3,886

[1] Importation permitted under Foreign Assets Control license issued in September 1965. This material was originally exported from mainland China to the United Kingdom in 1948–49 and stockpiled.

Table 10.—U.S. imports for consumption of ferrotungsten, by countries

(Thousand pounds and thousand dollars)

Country	1964			1965		
	Gross weight	Tungsten content	Value	Gross weight	Tungsten content	Value
Austria	111	89	$56	390	312	$305
Brazil	11	9	8	--------	--------	--------
France	60	48	35	22	18	37
Germany, West	33	27	16	18	15	17
Japan	--------	--------	--------	31	23	7
Portugal	22	18	17	--------	--------	--------
Sweden	5	4	4	--------	--------	--------
United Kingdom	--------	--------	--------	22	18	38
Total	242	195	136	483	386	404

Table 11.—U.S. imports for consumption of tungsten or tungsten carbide forms
(Thousand pounds and thousand dollars)

Year	Ingots, shot, bars, and scrap		Wire, sheets, or other forms, n.s.p.f.[1]		Total	
	Quantity	Value	Quantity	Value	Quantity	Value
1956–60 (average)	207	$287	185	$461	392	$748
1961	131	164	93	551	224	715
1962	194	189	73	384	267	573
1963	364	218	158	462	522	680
1964	323	181	75	213	398	394
1965	61	83	26	176	87	259

[1] Not specifically provided for.

WORLD REVIEW

A fifth meeting of the United Nations (U.N.) Ad Hoc Committee on Tungsten was held in New York City to review and evaluate the current tungsten market, to consider methods for improving statistics and the representativeness of price quotations, to discuss possible inter-Governmental arrangements, to consider the establishment of some form of International Tungsten Institute, and to review a producers' proposal for the establishment of maximum and minimum price levels.[6] The Committee deleted the term "Ad Hoc" from its name and became a regular standing committee under the framework of the Committee on Commodities of UNCTAD (United Nations Conference on Trade and Development).

The Committee's eight-member Working Group met twice during 1965. At its first meeting in January the newly expanded Working Group, consisting of representatives of Australia, Austria, Bolivia, Portugal, South Korea, Sweden, the United States, and West Germany, prepared a report on the status of the tungsten industry for the Committee's information. At its second meeting in June the Working Group discussed the possibility of having the U.N. Secretariat prepare a regular report covering published scientific, economic, and technical items on tungsten. The Working Group held a third meeting in January 1966 to prepare another report on the status of the tungsten industry for use by the U.N. Committee on Tungsten at its sixth meeting which was tentatively scheduled to be held in New York in May.

Australia.—Diamond drilling by King Island Scheelite (1947) Ltd., indicated that the orebody probably extends northeast of a fault previously considered as limiting the deposit. Increased production resulted from the larger tonnage milled and a small improvement in recovery. Plans for future operations included the reevaluation of the over-burden stripping rate and the purchase of additional equipment to enable mining to be conducted at a depth of 110 feet below sea level.

Spurred by the high price of tungsten, Aberfoyle Tin, N.L., increased production and announced plans to conduct a comprehensive program of underground and surface exploration to determine the limits of the company's ore deposit.

Storeys Creek Tin Mining Co. N.L., which was operating at one-shift capacity, expected to increase tungsten production in 1966 by operating on a partial two-shift schedule. Storeys also planned to extend development and surface exploration.

Metals Exploration, N.L., was evaluating the tungsten-molybdenum deposit at Wolfram Camp, Queensland, to determine the size and type of mill facility required to process this ore at the mine site.

Titan Manufacturing Co., Pty. Ltd., a subsidiary of Broken Hill Pty. Co. Ltd., announced the opening of a modern tungsten carbide plant in Newcastle, New South Wales. Scheelite concentrates from King Island will be used as the starting material.

Bolivia.—Tungsten production decreased as operation of the Unificanda, Caracoles and Kami tin-tungsten mines and the Bolsa

[6] United Nations Conference on Trade and Development. Report of the United Nations Ad Hoc Committee on Tungsten on its Fourth Session (11–14 May 1965). TD/TUNGSTEN/COM/13, 14 May, 1965, 79 pp.

Table 12.—World production of tungsten ore and concentrate, by countries

(Short tons, 60 percent WO_3 basis)

Country	1961	1962	1963	1964	1965 p [1]
North America:					
Canada	-------	3	--------	NA	NA
Mexico	193	88	36	9	202
United States (shipments)	8,245	8,429	5,657	9,244	7,949
South America:					
Argentina	892	r 619	r 184	r 13	NA
Bolivia (exports)	3,104	2,798	2,513	2,285	2,043
Brazil	1,361	1,368	612	r 421	[2] 563
Peru	428	435	572	r 731	730
Europe:					
Austria	317	320	246	116	215
Finland	58	--------	--------	--------	--------
France	806	r 772	--------	--------	--------
Italy	3	1	2	1	1
Portugal	3,274	2,754	1,784	1,948	1,830
Spain	1,192	777	162	r 41	77
Sweden	345	295	r 301	--------	--------
U.S.S.R.e	11,000	11,600	12,100	12,100	12,700
Yugoslavia	9	57	19	r 144	e 145
Africa:					
Congo, Republic of the (Kinshasa, formerly Léopoldville)[3]	595	406	223	r 258	237
Rhodesia, Southern	55	24	3	--------	15
Rwanda	734	165	14	r 165	[2] 196
South Africa, Republic of	30	28	9	4	4
South-West Africa [3]	190	171	239	216	187
Uganda	r 149	r 13	r 2	--------	54
United Arab Republic (Egypt)	91	--------	--------	--------	--------
Asia:					
Burma [3]	1,102	882	827	529	e 390
China, mainland e	24,900	24,900	24,900	22,500	18,700
Hong Kong	20	18	9	1	8
India	11	12	6	10	4
Japan	1,033	1,160	856	r 958	802
Korea:					
North e	5,500	4,400	4,400	4,400	4,900
South	r 7,354	r 7,456	6,092	r 5,988	4,935
Malaysia	41	11	8	6	11
Thailand	568	471	228	474	610
Oceania:					
Australia	2,866	1,946	1,793	1,860	2,197
New Zealand	6	10	6	6	--------
World total e	r 76,400	r 72,400	r 63,800	r 64,500	59,800

e Estimate. p Preliminary. r Revised. NA Not available.
[1] Compiled mostly from data available August 1966.
[2] Exports.
[3] Including WO_3 in tin-tungsten concentrates.

Negra tungsten mine was interrupted by labor problems.

Burma.—Although Burma is historically a significant source of tungsten, production there has recently declined as a result of the low prices paid mine owners by the Burmese Government who maintain a monopoly on tungsten sales. Because of this unprofitable situation, it is believed that significant tonnages are smuggled south into Thailand where exports were reported to be some 300 tons above production. In an attempt to discourage illicit trading and to revive the tungsten industry, the Burmese Government was revising its ore-buying program.

Canada.—Canada Tungsten Mining Corp. Ltd., (CTMC), commenced commercial scale open-pit production at its Flat River mine in the Northwest Territories and continued to be the only Canadian tungsten producer. Slightly less than 3 million pounds of tungsten was recovered from the rich (2.4 percent WO_3) scheelite ore and the company expected to produce 3.3 to 4 million pounds of tungsten in 1966.[7] In addition to tungsten, CTMC's ore was reported to contain 0.7 percent bismuth and 0.39 percent copper, and the company planned to install circuits to recover approximately 100 tons of combined byproduct concentrate per month. During 1965 tungsten recovery was increased from

[7] Department of Mines and Technical Surveys (Ottawa, Canada). The Cadadian Mineral Industry in 1965—Preliminary. Min. Inf. Bull. 81, February 1966, p. 54.

68 percent to the current rate of 77+ percent and the recovery was expected to reach a maximum of 85 percent in 1966 when the mill was expanded from its present 300-ton-per-day capacity to a 340-ton-per-day capacity.[8] It was reported that Canada Tungsten Mining Corp., Ltd., officially began its 3-year tax exemption period on June 1, 1965.

Torwest Resources was reactivating its tungsten-copper property at Swakum, near Merritt, British Columbia. Drillings have indicated that this deposit may contain 300,000 tons of ore averaging 0.298 percent WO_3.

The Macro Division of Kennametal Inc. continued to be the only manufacturer of tungsten carbide powder produced from imported tungsten concentrates.

Congo (Léopoldville).—One of the few remaining Congo tungsten producers, Cie. Miniere de Grands Lacs Africiains recovered tungsten concentrate from its Etaetu deposit.

France.—Near Carboire, a tungsten deposit containing almost 900,000 tons of ore was discovered by the Bureau de Recherches Géologiques et Minières in association with Cie. Minière et Métallurgique. Recent French tungsten requirements have been met almost entirely by purchases made by Société Commerciale de Tungstene et de Ferro-Tungstene from Brazil, South Korea, the U.S.S.R., and mainland China.

Korea, South.—The Korea Tungsten Mining Co., Ltd. (KTMC), discovered that large-scale pilfering of scheelite was taking place at its Sangdong mine. Since there was an embargo on exports of concentrate except by KTMC, it was believed that the scheelite concentrate was converted to tungstic acid by a simple treatment with hydrochloric acid. Production by KTMC decreased during the year as new construction in the mine was underway.

Peru.—In addition to the tungsten flotation section of the Morococha unit of the Cerro de Pasco Corp., which began operations in September 1964, the company planned to recover the tungsten contained in tailings from the San Cristobal ore milled at the Mahr concentrator. A tungsten recovery unit was also installed at the Sociedad Minera Puquio Cocha concentrator.[9]

Portugal.—Because of the combination of continued labor problems, rising operating costs, and a severe drought, the countries' tungsten production decreased during 1965. However, it was expected that production in 1966 would increase by 25 percent. A small ferrotungsten manufacturer suspended operations during the summer because of the lack of water power.

Rhodesia, Southern.—Filrho Mining & Exploration Co., (Pvt.) Ltd., announced plans to recover tungsten from the Killarney scheelite mine which was once a large gold producer. The tungsten reserve of this mine was believed to be small.

South-West Africa.—Open-pit production of tungsten from the tin-tungsten concentrates of the Brandberg West mine of the South West Africa Co. Ltd. continued to decrease in 1965. Ore reserves at the end of the year were reported at 1.5 million short tons containing a total of 0.23 percent tin and WO_3, of which about three-quarters was tin.

Spain.—The proposed reopening of the tungsten mines operated by Sociedad de Estanos de Silleda and Compania Minera Santa Comba in northwest Spain was contingent upon Government approval of legislation which would enable the companies to lay off workers without paying the compensation required under existing labor laws. In addition to these previously known sources, the Spanish Government found a new wolframite deposit in Saragossa Province.

Sweden.—To meet the increased demand for tungsten carbide, Sandvikens Jernverks AB increased the capacity of its cemented carbide manufacturing plants at Stockholm and Gimo.

TECHNOLOGY

Research on electrowon tungsten powder was described in a Bureau of Mines report which attracted much industrial interest.[10] This study demonstrated a procedure for producing high-density material, using a new method of hot-swaging sintered-tungsten compacts.

Deposits of cobalt-tungsten alloys were

[8] Northern Miner (Toronto, Canada). Canada Tungsten at High Peak to Up Production. No. 32, Oct. 28, 1965, pp. 1, 12.

[9] Bureau of Mines. Mineral Trade Notes. V. 61, No. 4, October 1965, p. 55.

[10] Keith, G. H., B. D. Jones, and E. A. Rowe. Evaluation of Electrowon Tungsten Powder. BuMines Rept. of Inv. 6578, 1965, 13 pp.

formed by codeposition of mixed vapors of cobaltous chloride and tungsten hexachloride.[11]

Chlorination studies were conducted to develop new methods for extracting tungsten from scheelite and mixed concentrates containing scheelite and wolframite.[12]

Using elemental chlorine and proper temperature controls, more than 90 percent extraction of tungsten was achieved. A study of the chlorination kinetics of tungsten were made to determine the effects of temperature, chlorine concentration, geometric surface area, and gamma radiation.[13] Because the reaction product was volatile at the temperatures used, the reaction rate was followed by measuring the weight loss of the solid.

Analytical studies were reported on direct spectrochemical methods for determining impurities in tungsten metal and oxides at the parts-per-million level.[14]

A report described methods of preparing ultrafine homogenous tungsten and tungsten-rhenium alloy powders by the hydrogen coreduction of their freeze-dried ammonium compounds.[15] Experiments on application of uniform coatings of tungsten and molybdenum to several types of ceramic powders having irregular shapes also were reported.[16]. Of the two processes evaluated, chloride and oxide, the oxide process was found to be more favorable.

The multiple-pass induction floating-zone melting process resulted in significant purification of tungsten.[17]

The effect of hydrostatic pressure on tensile properties of arc-cast tungsten and tungsten-4.5 percent tantalum alloy were evaluated.[18] The bend-ductility of tungsten increased linearly with increasing hydrostatic pressure. Arc-cast tengsten was found to be more ductile than that prepared from pressed-and-sinered tungsten powder.

Forging studies on W and W–15Mo alloys extruded from arc-melted and sintered compacts indicated that less forging pressure was required to upset billets consolidated by arc-melting than those consolidated by powder metallurgy.[19] Side forming at 2,050° to 2,250° F is used to commercially produce complex tungsten forgings with thin ribs and webs having very close tolerances.

Dense tungsten compacts were produced by isostatic pressing (solid state bonding) metal powder at 2,700° to 2,900° F and 10,000 to 20,000 psi for 1 to 5 hours.[20]

Satisfactory melting and extruding procedures were developed as the primary breakdown operations in the fabrication of W–3Mo–0.2Zr and W–0.6Cb alloys.[21] Extrusion ratios of at least 10:1 were required in order to produce uniform recrystallized structure of ASTM grain size 5 or smaller.

Hydrostatic extrusion of tungsten at low extrusion ratios on sintered, hot-swaged starting material produced induced stresses which caused cracking.[22]

Tungsten was formed by a high-pressure fluid-to-fluid extrusion process in which frictional resistance was eliminated.[23]

As-cast tungsten was successfully extruded and forged at room-temperature by the use of hydrostatic back pressure.[24]

High-deformation-rate extrusion of thin-walled tungsten conducted on a model 1210 Dunapak machine produced 4-inch-

[11] Donaldson, J. G. Vapor Deposition of Cobalt-Tungsten Alloys. BuMines Rept. of Inv. 6713, 1965, 15 pp.

[12] Henderson, A. W., S. C. Rhoads, and R. R. Brown. Extraction of Tungsten From Ore Concentrates by Chlorination. BuMines Rept. of Inv. 6612, 1965, 22 pp.

[13] Landsberg, Arne, and Frank E. Block. A Study of the Chlorination Kinetics of Germanium, Silicon, Iron, Tungsten, Molybdenum, Columbium and Tantalum. BuMines Rept. of Inv. 6649, 1965, 26 pp.

[14] Gabler, R. C., Jr., and M. J. Peterson. Spectrochemical Analysis of Tungsten. BuMines Rept. of Inv., 6632, 1965, 40 pp.

[15] Landsberg, A., and T. T. Campbell. Freeze-Dry Technique for Making Ultra-Fine Metal Powder. J. Metals, v. 17, No. 8, August 1965, pp. 856–860.

[16] Landsberg, A., T. T. Campbell, and F. E. Block. Tungsten and Molybdenum Coated Nonmetallic Powders. J. Metals, v. 17, No. 8, August 1965, pp. 850–855.

[17] Holden, F. C., and F. W. Boulger. Third Status Report of the U.S. Government Metalworking Processes and Equipment Program. Battelle Memorial Inst., Columbus, Ohio, DMIC Rept. 218, June 16, 1965, 66 pp.

[18] Pages 26–29 of work cited in footnote 17.

[19] Page 43 of work cited in footnote 17.

[20] Hodge, Edwin S. Hot Isostatic Pressing Improves Powder Metallurgy Parts. Materials in Design Eng., v. 61, No. 5, May 1965, pp. 92–97.

[21] Byrer, T. G., and F. W. Boulger. Metalworking. Defense Metals Inf. Center, Battelle Memorial Inst., Columbus, Ohio, DMIC Review of Recent Developments, July 30, 1965, 4 pp.

[22] Barth, V. B. Tungsten and Tungsten-Base Alloys. Defense Metals Inf. Center, Battelle Memorial Inst., Columbus, Ohio, DMIC Review of Recent Developments, May 28, 1965, 4 pp.

[23] Product Engineering. Hydroforming. V. 36, No. 25, Dec. 6, 1965, p. 53.

[24] Barth, V. D. Tungsten and Tungsten-Base Alloys. Defense Metals Inf. Center, Battelle Memorial Inst., Columbus, Ohio, DMIC Review of Recent Developments, Dec. 8, 1965, 4 pp.

diameter hemispheres with ¼-inch thick walls.[25]

Strengthened tungsten was developed by embedding oxides of zirconium, yttrium, hafnium, and thorium in a tungsten matrix and then extruding the tungsten to produce elongated internal fibers.[26]

Consolidation of spherical tungsten powders by hot isostatic pressure bonding has permitted the fabrication of final tungsten forms without recrystallization.[27]

Processing data on the W–5Re–2.2ThO_2 alloy indicate that better alloy ductility is achieved using thorium oxide obtained from a fluid colloidal solution instead of from thermally decomposed thorium nitrate.[28]

Because of its high-temperature, high-strength properties, which make it of interest as a structural and cladding material for nuclear reactors operating at elevated temperatures, investigations were continued on tungsten by AEC contractors.[29]

The influence of neutron irradiation on the creep-rupture, tensile, hardness, and resistivity properties of W, Mo, W–25Re, and Mo–TZM was evaluated.[30] Irradiation of tungsten by a fast neutron dose of 8 x 10^{19} NVT (neutrons per square centimeter) affected the creep-rupture properties by increasing the time-to-rupture by a factor of 5 and correspondingly decreasing the linear creep-rate.

The development of fabrication methods for the production of small diameter seamless tungsten and W–25Re tubing for use in high-temperature reactor applications was continued.[31] Tubing was successfully produced by extruding at 1,200° C and then drawing at 580° C, following an anneal at 1,450° C for 1 hour.

A new series of W–Re–Mo alloys were developed which offer a wide selection of elevated-temperature properties.[32] W–30-Re–30Mo an inherently fine-grained alloy which exhibits complete resistance to loss of room-temperature bend-ductility has been successfully fabricated and used as a prototype reactor component. The W–30Re and W–30Re–10Mo alloys can be age-hardened to develop high elevated-temperature creep-rupture strengths.

Tungsten, tantalum, and columbium which are soluble in liquid plutonium (Pu) but insoluble in solid plutonium are used as structural materials in fast reactors with solid Pu fuel elements and as liquid Pu alloys in molten reactor experiments.[33]

At the Oak Ridge National Laboratory (ORNL) studies were continued on the production of tungsten by vapor deposition.[34] This simplified one-step fabrication method, hydrogen reduction of WF_6, has the advantage of being able to produce complex shapes at low temperatures (600° C). A successful tungsten extrusion technique was developed by ORNL, using tungsten oxide which volatilizes in air at high temperatures as the lubricant.

In a compatibility study of tungsten as a structural material with high-temperature fuels for nuclear reactors, a pertectic reaction isotherm was found in the uranium carbide (UC)-tungsten system between 2,100° and 2,150° C.[35]

Tungsten and tantalum evaluated with uranium oxide (UO) fuel material were found to be compatable up to 2,760° C, the melting point of UO.[36]

The grain growth of arc-melted tungsten-boron alloys, studied as possible metallic nuclear poisons, was evaluated in the temperature range from 3,600° to 4,000° F.[37]

The primary objective of the AEC tungsten research program was to evaluate tungsten-core nuclear reactor concepts.[38] The Argonne National Laboratory continued to investigate a fast tungsten reactor concept and the National Aeronautics and Space Administration's (NASA) Lewis Research Center, Cleveland, Ohio, studied a thermal water-moderated tungsten reactor concept.

At the National Reactor Testing Station

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[25] U.S. Atomic Energy Commission. Reactor Materials. V. 8, Nos. 1–4, 1965, 249 pp.
[26] Chemical Engineering. Additives and Extrusion Add Strength to Tungsten. V. 72, No. 16, Aug. 2, 1965, p. 52.
[27] Page 226 of work cited in footnote 25.
[28] Page 47 of work cited in footnote 17.
[29] Rice, William L. R. Nuclear Fuels and Materials Development. U.S. Department of Commerce, Clearinghouse for Fed. Sci. and Tech. Inf., TID–11295, 4th ed., June 1965, 145 pp.
[30] Pages VIV.4 and VIV.5 of work cited in footnote 29.
[31] Pages XVIII.1 to XVIII.3 of work cited in footnote 29.
[32] Page XIV.4 of work cited in footnote 29.
[33] Miner, William N. Plutonium. U.S. Atomic Energy Commission, Div. of Tech. Inf., Oak Ridge, Tenn., November 1964, 52 pp.
[34] Pages XIX.9 of work cited in footnote 29.
[35] Page V.2 work cited in footnote 29.
[36] Page 189 of work cited in footnote 25.
[37] Page 204 of work cited in footnote 25.
[38] U.S. Atomic Energy Commission. Major Activities in the Atomic Energy Programs January–December 1965. January 1966, 442 pp.

in Idaho, the Fast Spectrum Refractory Metals Reactor is used to evaluate the high-temperature, high-strength properties of tungsten and tantalum under actual operating conditions.[39]

A detailed review of coatings for refractory metals indicated that although satisfactory methods exist to coat Cb and Mo for short times at elevated temperatures, coatings are not now available which will protect tungsten above 3,500° F.[40]

Pure, dense, coherent coatings of tungsten were electroplated from a fused salt bath over conventional metals to provide resistance to elevated temperatures and corrosion.[41] In addition tungsten was electroformed into parts which required no machining or additional forming.

Interest in the development of suitable coatings for tungsten to protect the metal from oxidation at high-temperatures was continued.[42]

Considerable simplification of a wolframite processing operation to yield ammonium paratungstate (APT) is possible by the application of a liquid-ion exchange process using a selective amine.[43]

The high-temperature tensile and creep strengths of arc- and electron beam (EB)-melted tungsten were significantly increased, by minor additions of boron, hafnium, tantalum, columbium, and rhenium.[44]

Porous tungsten ionizer emitter plates having pore diameters of 1.4±0.2 micron have been produced and suggested for use as diffusers for air or gas bearings, as high-temperature liquid bearings, and as hot filters.[45]

Methods of joining tungsten sheet were evaluated and tested to determine the properties of joints at temperatures up to 3,000° F.[46]

The excellent high-temperature, high-strength properties, and room temperature ductility of the tungsten-25 percent rhenium (W–25Re) alloy continued to be investigated for the AEC. These investigations are described in detail in the Rhenium chaper of this Yearbook.

Corrosion tests were conducted to determine the resistance of tungsten, tantalum, molybdenum, and some of their alloys to zinc and zinc-rich solutions containing magnesium and uranium in the presence of molten chloride salts.[47]

Because of its proposed use as a structural material in advance nuclear power plants, tungsten was evaluated to determine the effects of protracted vaporization

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[39] U.S. Atomic Energy Commission. Nuclear Reactor Testing Station. AEC Idaho Operations Office, Idaho Falls, Idaho, December 1965, 33 pp.

[40] National Research Council. Coated Refractory Metal Technology—1965. Nat. Ac. of Sci., Materials Advisory Board, Rept. MAB–210–M, November 1965, 123 pp.

[41] West, Philip. Refractory Metals Can Be Plated and Electroformed. Materials in Design Eng., v. 62, No. 1, July 1965, pp. 93–94.

[42] Air Force Systems Command, Research and Technology Division. Air Force Materials Symposium. USAF Wright Patterson Air Force Base, Ohio, Tech. Rept. AFML–TR–65–29, Defense Documentation Center, 463572, June 9–11, 1965, 895 pp.

Bartlett, R. W. Investigation of Mechanisms for Oxidation Protection and failure of Intermetallic Coatings for Refractory Metals. Aeronutronic Applied Res. Lab., Newport Beach, Calif., ASD–TDR–63–753, pt. III (U.S. Air Force Contract No. AF 33(657)–9170), September 1965, 104 pp.

Brett, J., L. L. Siegle, J. Berkowitz-Mattuck, B. Lement, D. I. Phalen, D. A. Vaughn, N. A. Richard, A. E. Austin, and C. M. Schwartz. Experimental Study of Factors Controlling the Effectiveness of High-Temperature Protective Coatings of Tungsten. Air Force Materials Lab., Res. and Tech. Div., Air Force Systems Command, USAF Wright-Patterson Air Force Base, Ohio, Tech. Rept. AFML–TR–64–392, August 1965, 282 pp.

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English, J. J. Oxidation-Resistant Coatings for Refractory Metals. Defense Metals Inf. Center, Battelle Memorial Inst., Columbus, Ohio, DMIC Review of Recent Developments, Dec. 4, 1964, 4 pp.

English, J. J. Oxidation-Resistant Coatings for Refractory Metals. Defense Metals Inf. Center, Battelle Memorial Inst., Columbus, Ohio, DMIC Review of Recent Developments, Mar. 19, 1965, 2 pp.

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———. Oxidation-Resistant Coatings for Refractory Metals. Defense Metals Inf. Center, Batelle Memorial Inst., Columbus, Ohio, DMIC Review of Recent Developments, Nov. 19, 1965, 4 pp.

Machonis, Alvin A. Protecting Refractory Metals From Oxidation at High-Temperatures. Metal Prog., v. 89, No. 1, January 1965, pp. 138–146.

U.S. Atomic Energy Commission. Fundamental Nuclear Energy Research—1965. December 1965, 338 pp.

Pages III.1–3, V.2, VIV.9 and XXIV.1–.2 of work cited in footnote 29.

[43] Page 1 of work cited in footnote 22.

[44] Page 2 of work cited in footnote 22.

[45] Barth, V. D. Tungsten and Tungsten-Base alloys. Defense Metals Inf. Center, Battelle Memorial Inst., Columbus, Ohio, DMIC Review of Recent Developments, Sept. 3, 1965, 4 pp.

[46] Evans, R. M. Metals Joining. Defense Metals Inf. Center, Battelle Memorial Inst., Columbus, Ohio, DMIC Review of Recent Developments, Dec. 10, 1965, 4 pp.

[47] Nelson, P. A., M. L. Kyle, G. A. Bennett, and L. Burris, Jr. Corrosion of Refractory Metals by Zinc-Magnesium-Uranium Halide Salt Systems. Electrochem Tech., v. 3, No. 9–10, September–October 1965, pp. 263–269.

(10,000 hours) under vacuum, forced convection of helium at one atmosphere (atm) total pressure, and free stream velocity of 100 feet per second.[48] Results indicated vaporization is not a problem with tungsten below 4,000° F.

An evaluation of the compatibility of materials with various rocket propellants and oxidizers indicated that tungsten had poor compatibility with liquid bromine trifluoride (BrF_3) but good compatibility with liquid hydrazine (N_2H_4).[49] Tungsten carbide had good compatibility with nitrogen tetroxide (N_2O_4).

The tungsten-hafnium system was examined in detail to evaluate substitutional strengthening mechanisms of solid solution and carbide strengthened alloys.[50]

Four electrochemical metal-removal (EC MR) processes were described in a recent report which indicated that when tungsten was processed by ECMR methods, much better tensile, ductility, fatigue, and impact properties were obtained than those obtained by conventional forming methods.[51] This improvement was the result of the ECMR method's ability to remove damaged tungsten surface layers while at the same time not introducing any new stresses or damage.

Recognizing the essential role that tungsten metal tubing will play in the development of future energy conversion and propulsion devices, a report was issued which indicated that the largest potential for use of this tubing will be in space power systems.[52]

Dilute additions of rhenium to tungsten caused significant improvement in low-temperature ductility, particularly in the worked condition.[53]

Tungsten and tungsten-base alloys were evaluated as structural materials for use in space-power liquid metals service.[54] Tungsten, W–0.9Cb, W–15Mo, W–10Re, and W–25Re were not attacked by molten lithium after 1,000 hours exposure at 2,500° F.

Tungsten, W–0.9Cb, W–15Mo, W–10Re, and W–25Re were not attacked by cesium vapor after 1,000 hours of exposure at 3,100° F.

Tungsten diselenide (WSe_2), a high-temperature, high-vacuum lubricant can be combined with metal composites, ceramics, and plastics to produce self-lubricating surfaces.[55]

During the year a comprehensive book was published which consolidated the more pertinent data on the seven refractory metals W, Cb, Ta, Re, Mo, Cr, and V.[56]

An extensive bibliography of W and Mo reports and patents was issued during the year.[57]

Interest in methods of extracting, consolidating, alloying, and utilizing tungsten continued to be reflected by some of the patents issued in 1965.[58]

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[48] U.S. Atomic Energy Commission. Vaporization of Advanced Powerplant Metals Under Vacuum and Force Convection Conditions. U.S. Department of Commerce, Clearinghouse for Fed. Sci. and Tech. Inf., UCRL–14274, June 1965, 25 pp.

[49] Boyd, W. K., W. E. Berry, and E. L. White. Compatibility of Materials With Rocket Propellants and Oxidizers. Battelle Memorial Inst., Columbus, Ohio DMIC Memorandum 201, Jan. 29, 1965, 40 pp.

[50] Raffo, Peter L., and William D. Klopp. Solid Solution and Carbide Strengthened Arc-Melted Tungsten Alloys. National Aeronautics and Space Administration, NASA TM X–52131, October 1965, 20 pp.

[51] Gurklis, John A. Metal Removal by Electrochemical Methods and Its Effects on Mechanical Properties of Metals. Battelle Memorial Inst., Columbus, Ohio, DMIC Rept. 213, Jan. 7, 1965, 34 pp.

[52] National Research Council. Status of Refractory Alloy Tubing—1964. Nat. Acad. of Sci., Materials Advisory Board, Rept. MAB–208–M, Aug. 16, 1965, 97 pp.

[53] Klopp, William D., Walter R. Witzke, and Peter L. Raffo. Ductility and Strength of Dilute Tungsten-Rhenium Alloys. National Aeronautics and Space Administration, NASA TM X–52131, October 1965, 20 pp.

[54] Stang, J. H., E. M. Simmons, and J. A. DeMastry. Materials for Liquid-Power Metals Service. Battelle Memorial Inst., DMIC Memorandum 209, Oct. 5, 1965, 9 pp.

[55] Chemical Engineering. Solid Lubricant. V. 72, No. 8, Apr. 12, 1965, p. 116.

[56] Tietz, T. E., and J. W. Wilson. Behavior and Properties of Refractory Metals. Stanford Univ. Press, Stanford, Calif., 1965, 419 pp.

[57] U.S. Department of Commerce. Molybdenum and Tungsten, Selected Bibliography of Government Research Reports and Translations. Clearing house for Fed. Sci. and Tech. Inf., SB–415, supp. 1, 1965, 48 pp.

[58] Andes, George M. (assigned to E. I. duPont de Nemours and Co., Inc., Wilmington, Del.). Tungsten Alloys. U.S. Pat. 3.184,304, May 18, 1965.

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Uranium

By Charles T. Baroch [1]

During 1965, private utility companies executed contracts for building seven large nuclear power stations aggregating over 4,000 megawatts (Mw) of electrical capacity. Completion of these plants, scheduled for 1969–71, would more than double the nuclear capacity now in operation or under construction. In addition, seven other utilities announced that they were evaluating the possibilities of nuclear power and desalination plants totaling 6,500 Mw. This accelerating interest in big nuclear plants was in sharp contrast to 1964, when no commercial nuclear plants were sold. These commitments were hailed by many power economists as the beginning of an accelerating trend in the construction of nuclear power plants which is necessary to the continued expansion of the country.

Mine production of uranium continued to drop as four mills closed and some contracts with the Atomic Energy Commission (AEC) were completed. Eleven milling contracts were stretched out and extended through 1970. About 650 mines produced 4.4 million tons of ore, yielding 10,442 tons of U_3O_8 concentrate valued at $167 million. Receipts from foreign countries dropped to just half of 1964 imports.

Table 1.—Salient uranium statistics

(Short tons)

	1961	1962	1963	1964	1965
United States:					
Production:					
Mine (ore shipments)	8,041,329	7,052,870	5,645,921	r 5,674,631	4,362,614
Mill (U_3O_8 content) [1]	17,399	17,010	14,218	11,847	10,442
Imports: Concentrate (U_3O_8)	12,915	11,720	8,802	5,297	2,650
Free world: Production (U_3O_8 content)	36,300	34,600	31,100	26,700	20,800

r Revised.
[1] Concentrate marketed.

Sales of uranium under the 1964 law permitting private ownership of special nuclear materials began to take place in significant quantities. The largest private contract was the result of a barter agreement whereby 475,000 pounds of U_3O_8 concentrate from Susquehanna-Western, Inc., Falls City, Tex., was to be shipped to the AEC. In return, an equal quantity of enriched uranium suitable for reactor elements would be shipped to Allgemeine Elektricitaets Gesellschaft in Frankfurt, West Germany.

Legislation and Government Regulations.—AEC began to devise procedures for its role in administering Public Law 88–489, the Private Ownership of Special Nuclear Materials Act of 1964. This act, among other things, authorized AEC to provide toll enrichment of uranium after December 31, 1968. For comments by industry, AEC published in the Federal Register a draft of proposed criteria under which this service would be offered. These criteria include provisions for 30-year contracts, establish that charges for enrichment services will be based on a published schedule equally applicable to all customers, prevent toll-enrichment of foreign-produced uranium for domestic use, and agree to terminate the services if and when suitable commercial services become available. Before adoption, the final criteria will have to be approved by Congress.

Pending the implementation of toll enrichment in 1969, the AEC is developing,

[1] Commodity specialist, Division of Minerals.

with several foreign users, arrangements for supplying enriched uranium for which natural uranium is accepted as partial payment.

A total of 15 regulations and amendments were put in effect by AEC, most of which were on the licensing of source and byproduct material and on standards for protection against radiation. Terms of these regulations are published in Title 10, Chapter I, Code of Federal Regulations (10 CFR 1) of the Federal Register.

Public Law 89–210, September 29, 1965, extended for 10 years to August 1, 1977, the Price-Anderson Indemnity Act. Power reactors of over 100-megawatt electrical capacity must provide the maximum financial indemnity available from private sources—$74 million beginning January 1, 1966—and the Government indemnity would be $486 million per nuclear incident. Previous private indemnity was $50 million, and Government indemnity was $500 million. Only three facilities of applicable size were operating at the end of 1965.

Oregon and Tennessee entered into agreements with AEC for the transfer of certain phases of regulatory authority over radioactive materials, making a total of 11 States formally participating in the program. Legislation has been adopted by 23 other States authorizing the negotiation of agreements with AEC, and several States began actively to develop programs for assuming regulatory authority.

Continental Uranium, Inc., Chicago, Ill., repaid to the Federal Government $25,821.48, the amount (75 percent) contributed by Defense Minerals Exploration Administration, predecessor of the Office of Minerals Exploration, under an exploration assistance contract for $34,428.46. Exploration work under the contract was done between July and December 1955, and a certification of discovery was issued in July 1956. The property is in San Juan County, Utah.

DOMESTIC PRODUCTION

Mine and Mill Production.—Approximately 650 operations in 12 States produced about 4.4 million tons of ore, about 23 percent less than in 1964. New Mexico produced about 46 percent of the total, followed by Wyoming with 24 percent. Next in order were Colorado, Utah, Arizona, Washington, North Dakota, Texas, South Dakota, Alaska, Nevada, and California.

Table 2.—Uranium mine and mill production in 1965, by State

State	Ore shipped				Concentrate purchased by AEC		
	Short tons	Value (thousands)	U_3O_8 content: Percent	U_3O_8 content: Pounds	Number of mills	Pounds U_3O_8	Cost (thousands)
Arizona	117,898	$3,918	0.38	900,776	----	--------	-----
Colorado	574,795	10,651	.23	2,641,785	4	2,579,235	$20,631
New Mexico	2,013,861	38,311	.23	9,406,073	4	9,182,949	73,464
South Dakota	44,738	303	.12	104,500	----	--------	-----
Utah	377,989	9,014	.29	2,159,625	2	3,020,541	24,164
Washington	73,495	1,871	.30	435,655	----	--------	-----
Wyoming	1,048,176	17,758	.22	4,560,625	5	4,194,388	33,551
Other States [1]	111,662	2,088	.24	538,300	4	1,907,487	15,258
Total	4,362,614	83,914	.24	20,747,339	19	20,884,600	167,068

[1] Ore shipments: Alaska, California, Nevada, North Dokota, and Texas. Concentrates: Arizona, South Dakota, Texas, and Washington.

Uranium ore was processed in 19 mills which delivered to AEC concentrates containing 10,442 tons of U_3O_8, compared with 11,847 tons in 1964. The mill of Vitro Corporation of America at Salt Lake City, Utah, did not reopen after a shutdown in January 1964 and was converted to vanadium production. The contract with AEC, which would have expired December 31, 1966, was terminated at Vitro's request because of declining ore production in the district. Three other mills discontinued operations during the year: Atlas Corp. at Mexican Hat, Utah, Cotter Corp. at Canon City, Colo., and Dawn Mining Co. at Ford, Wash. The Dawn mill will complete deliveries of 260 tons of U_3O_8 in concentrate by the end of 1966 from concentrates already produced. This quantity of undelivered U_3O_8 is in addition to the quantities shown in table 3. The Atlas Corp. mill at Moab, Utah, was permitted by AEC to

Table 3.—Uranium processing plants, December 31, 1965

State and company	Plant location	Contract expiration date, fiscal year	Tons U_3O_8 deliverable under contract from Jan. 1, 1966
Arizona:			
El Paso Natural Gas Co.	Tuba City	1967	230
Colorado:			
American Metal Climax, Inc.	Grand Junction	1967	460
Union Carbide Corp.	Rifle	1970	4,800
Do.	Uravan		
New Mexico:			
The Anaconda Company	Bluewater	1970	3,720
Homestake-Sapin Partners	Grants	1970	[1] 10,160
Kerr-McGee Corp.	do	1970	7,590
Vanadium Corporation of America	Shiprock	1970	1,560
South Dakota:			
Mines Development, Inc.	Edgemont	1967	310
Texas:			
Susquehanna-Western, Inc.	Falls City	1967	50
Utah:			
Atlas Corp.	Moab	1970	4,740
Wyoming:			
Federal-Radorock-Gas Hills Partners	Gas Hills	1970	1,810
Petrotomics Co.	Shirley Basin	1967	280
Union Carbide Corp.	Gas Hills	1970	1,000
Utah Construction & Mining Co.	do	1970	2,620
Western Nuclear, Inc.	Jeffrey City	1970	2,680

[1] Includes 4,770 tons under contract to United Nuclear Corp. which is treated in the Homestake-Sapin Partners mill under a tolling agreement.

process ores formerly processed at the Mexican Hat mill as well as ores of independent producers formerly shipped to the Vitro mill.

Ten companies with 11 contracts agreed to a modification of concentrate delivery proposed by AEC which, in total, deferred the delivery of about 15,300 tons of U_3O_8 to 1967 and 1968 with an equal amount to be delivered during 1969 and 1970. In addition, AEC will purchase up to 1 million pounds of U_3O_8 in concentrates per year from ore supplied from small mining properties. Subject to the million-pound ceiling, such a small property may produce up to 10,000 pounds in a 6-month period.

Susquehanna-Western, Inc., subsidiary of Susquehanna Corp., began to curtail operations at its Falls City, Tex., mill in April 1965 because production to fill its contract with AEC was practically complete. However, the company announced in September that it had contracted to supply 475,000 pounds of U_3O_8 concentrate to Allgemeine Elektricitaets Gesellschaft in Frankfurt, West Germany. AEC will enrich the uranium under the terms of a barter agreement. This was said to be the largest private contract signed through 1965 for U_3O_8 produced in the United States.

Refining and Enrichment.—During 1965, AEC production of enriched uranium decreased substantially to keep in step with national defense and civilian use needs. In February, a third reduction in the future production of enriched uranium was announced under which power usage at the three AEC gaseous diffusion plants will drop to 2,000 Mw by January 1, 1969. The first reduction was announced in the President's State of the Union Message on January 8, 1964, which reduced the level from 5,250 Mw to about 3,900 Mw in 1964. The second reduction announced in April 1964 scheduled a reduction to about 2,970 Mw by 1968. These planned reductions were the result of a continuous reassessment by Department of Defense and AEC of the production level necessary to meet projected military and civilian requirements.

Operations in the AEC feed materials plants at Weldon Spring, Mo., and Fernald, Ohio, operated by Mallinckrodt Chemical Works, and National Lead Co., respectively, continued to show a slight decline in output.

Table 4.—Enriched uranium furnished to industry, excluding the weapons production chain
(Pounds)

	Fiscal year				
	1961	1962	1963	1964	1965
Furnished as UF_6	261,025	276,900	221,070	256,620	336,835
Furnished in forms other than UF_6	15,210	6,610	8,630	4,490	3,180
Total	276,235	283,510	229,700	261,110	340,015

Source: AEC 1965 Report on the Nuclear Industry, p. 25.

CONSUMPTION AND USES

Weapon and Explosive Applications.—Production of plutonium decreased substantially, yet continued to meet military requirements. Six graphite-moderated reactors at Hanford, Wash., and four heavy-water reactors at Savannah River, S.C., were in operation, although full design power of 4,000 Mw (thermal) was not attained in the Hanford "N" reactor until December. This reactor, formerly called the New Production Reactor (NPR), was designed for the dual purpose of power production and plutonium production. Power-conversion equipment capable of generating 800 Mw was being installed by the Washington Public Power Supply System, and full generation of power was expected in 1966. Most of the thermal energy from previous production reactors was dissipated into cooling waters from the Columbia River.

Underground nuclear tests were continued in 1965 within the limitations of the nuclear test-ban treaty of August 5, 1963, between the United States, the United Kingdom, and the U.S.S.R. Of these, 1 was a Plowshare cratering experiment, 4 were made for the Department of Defense on improved detection methods, 1 was made jointly with the United Kingdom, and the other 21 were mainly weapons or device development events.[2]

The Plowshare Program, conducted by AEC to study the usefulness of nuclear engineering tools, in 7 years has made significant progress toward understanding the character of nuclear explosives and estimating their capabilities for excavation, mining, isotope production, and power generation. Rock breaking is technically feasible,[3] and this use may be expanded conceivably into such engineering problems as canal and harbor excavation.[4]

Civilian Reactors. — All the nuclear power plants planned and under construction will be either pressurized water or boiling water reactors, with the exception of the Colorado plant which will be a prototype nuclear power plant using an advanced converter type of high-temperature gas-cooled reactor fueled with a combination of uranium and thorium. The thorium will capture surplus neutrons from the fission of uranium-235 and will be transmuted into fissionable uranium-233, part of which will be available as fuel within the reactor and the rest will be recovered in fuel reprocessing. AEC will partly finance this plant because of its experimental nature, because it will contribute to the development of breeder-reactor technology, and is expected to result in more efficient use of fuel. These nine reactors will require nearly 5,000 tons of U_3O_8 for initial charges, based on present requirements of 0.7 to 1.0 tons per Mw of electrical capacity. After the initial charge, makeup requirements range from 0.13 to 0.16 ton of U_3O_8 per Mw-year of operation. Each of the reactors in this group will have a larger capacity than any operating in 1965.

In addition to those listed in table 5, five other utilities reached an advanced stage in considering nuclear-power generating units aggregating nearly 3,500 Mw. The largest to be considered is a 1,000 Mw plant by the Tennessee Valley Authority (TVA) the country's biggest user of coal and the operator of 15 hydroelectric plants in the Tennessee Valley. New York State Atomic Space and Development Authority

[2] U.S. Atomic Energy Commission. Major Activities in the Atomic Energy Programs. January-December 1965, pp. 97-100; 191-204.

[3] Hansen, Spenst M., and John Toman. Rock Breaking Takes a Giant Step Into the Space Age. Rock Products, v. 68, No. 6, June 1965, pp. 53-59.

[4] Johnson, Gerald W., and Gary H. Higgins. Useful Nuclear Explosives. Internat. Sci. and Technol., No. 38, February 1965, pp. 54-60.

Table 5.—Principal civilian nuclear power reactors

Reactor	Location	Electrical capacity, kilowatts	Initial criticality
Operable:			
Shippingport Atomic Power Station	Shippingport, Pa.	90,000	1957
Dresden Nuclear Power Station	Morris, Ill.	200,000	1959
Yankee Nuclear Power Station	Rowe, Mass.	175,000	1960
Big Rock Point Nuclear Power Plant	Big Rock Point, Mich.	70,400	1962
Elk River Reactor	Elk River, Minn.	22,000	1962
Indian Point Unit No. 1	Indian Point, N.Y.	270,000	1962
Humboldt Bay Power Plant	Humboldt Bay, Calif.	68,500	1963
Piqua Nuclear Power Facility	Piqua, Ohio	11,400	1963
Carolinas-Virginia Tube Reactor	Parr, S.C.	17,000	1963
Enrico Fermi Atomic Power Plant	Lagoona Beach, Mich.	60,900	1963
Boiling Nuclear Superheat Reactor	Puente Higuera, P.R.	16,500	1964
Pathfinder Atomic Power Plant	Sioux Falls, S. Dak.	58,500	1964
Total operable capacity		1,060,200	
Under construction:			
Peach Bottom Atomic Power Station	Peach Bottom, Pa.	40,000	1966
La Crosse Boiling Water Reactor	Genoa, Wis.	50,000	1966
San Onofre Nuclear Generating Station	San Clemente, Calif.	375,000	1966
Connecticut Yankee Atomic Power Station	Haddam Neck, Conn.	462,000	1967
Jersey Central Power & Light Co.	Toms River, N.J.	515,000	1967
Washington Public Power Supply System	Hanford, Wash.	800,000	1967
Nine Mile Point Plant	Oswego, N.Y.	500,000	1968
Total under construction		2,742,000	
Planned:			
Malibu Nuclear Plant	Corral Canyon, Calif.	462,000	1969
Dresden Nuclear Power Station No. 2	Morris, Ill.	715,000	1969
Brookwood, Rochester Gas & Electric Co.	Ontario, N.Y.	420,000	1969
Millstone Point Nuclear Plant	Waterford, Conn.	549,200	1969
Indian Point Unit No. 2	Indian Point, N.Y.	873,000	1969
Turkey Point Nos. 3 and 4	Turkey Point, Fla.	1,304,000	1971
Boston Edison Co.	Massachusetts	600,000	1971
Public Service Co. of Colo.	Platteville, Colo.	330,000	1972
Total planned		5,253,200	
Grand total		9,055,400	

Source: Adapted from "Nuclear Reactors Built, Being Built, or Planned in the United States," AEC Division of Technical Information, TID–8200 (13th Rev.).

also announced it was planning a dual plant to produce 2.5 Mw of electricity and desalt 1 million gallons of water per day.[5]

The Hallam Nuclear Power Facility was not included in table 5. After operating well for a time with only minor technical difficulties, seven of the stainless-steel cans, used for cladding the graphite moderator, failed by cracking caused by longtime stress rupture. The plant was being maintained in a standby condition at the end of the year. AEC is no longer pursuing this type of reactor concept, which uses sodium as a coolant and graphite as a moderator. Work on the Large Seed-Blanket Reactor, planned cooperatively between the Department of Water Resources of California and AEC, was discontinued because of technical problems encountered during research and development. Because of this, AEC planned to reorient the seed-blanket development work toward the design of thermal-breeder reactors.

Construction of the Southwest Experimental Fast Oxide Reactor (SEFOR) was started near Fayetteville, Ark., and was scheduled for completion in 1968. The reactor, with a thermal rating of 20 Mw, is being constructed for the Southwest Atomic Energy Associates, a group of 17 private power utilities associated with Gesellschaft für Kernforschung, a nonprofit corporation of the Federal Republic of Germany, which will make contributions to the project for itself and for Euratom. AEC will contribute, up to a specified ceiling, toward research and development needed in design, operating and maintaining the reactor after completion, and other experimental work in behalf of AEC research objectives. The project will study the nuclear characteristics of a fast-breeder reactor which uses a mixture of plutonium and uranium oxides for fuel and a sodium coolant.[6]

A breeder reactor and a nuclear-fuel reprocessing plant were dedicated at the AEC National Reactor Testing Station,

[5] Pages 113–129 of work cited in footnote 2.
[6] Pages 127–128 of work cited in footnote 2.

near Idaho Falls, Idaho. The Fuel Cycle Facility is attached to the Experimental Breeder Reactor No. 2 (EBR–2), and used fuel elements from the reactor can be reprocessed by remote control after only 15 days of "cooling" of the most intense short-lived fission product radioactivity. Reclaimed fuel can be refabricated into new uranium-alloy elements. EBR–2, designed to generate 20 Mw of electricity, produces more fissionable material than it consumes.

Nuclear energy received its share of consideration at the First International Symposium on Water Desalination, October 3–9, sponsored by the Department of the Interior in cooperation with the Department of State. The symposium was attended by delegates from 55 nations and 6 international organizations. The Office of Saline Water, Department of the Interior, and AEC cooperated in an accelerated program to develop and demonstrate suitable nuclear-energy sources for desalting sea water.

The nuclear ship, *Savannah,* the world's first nuclear-powered merchant ship, went into the regular commercial service of American Export-Isbrandtsen Lines in August. It is to operate as a cargo vessel only. The ship had completed 2 years of demonstration voyages and had traveled over 90,000 miles, during which only 33 pounds of enriched uranium fuel was consumed. About 17,000 tons of fossil fuel would have been required for a conventionally powered ship of equal size to travel the same distance.

The list of principal producers and fabricators of uranium fuels, table 6, was little changed during 1965. Minnesota Mining & Manufacturing Co. withdrew from the manufacture of coated uranium particles which are, as yet, used only in space propulsion experimental reactor systems. Nuclear Fuel Services, Inc. (NFS), a subsidiary of W. R. Grace & Co., began operations of its new sol-gel facility at Erwin, Tenn., and construction proceeded rapidly on its first fuel reprocessing plant at West Valley, N.Y. Spent fuel from Government and private sources was placed in storage there as early as June 5 and the plant was expected to start operations early in 1966. Heretofore, fuel processing was done only at AEC plants. AEC gave NFS a contract to recover plutonium from 1,820 pounds of uranium-plutonium scrap stored at Hanford, Wash. AEC also awarded 28 contracts for enriched uranium scrap reprocessing, totaling $831,500 to NFS, Nuclear Materials and Equipment Corp.; Kerr-McGee Corp., formerly Kerr-McGee Oil Industries, Inc.; and General Dynamics Corp.; as an incentive to encourage fuel processing by private industry.

Military Reactors.—The nuclear navy entered its second decade of growth and its future is assured, as the advantages of naval ship propulsion were thoroughly demonstrated. By the end of 1965, Congress had authorized 99 nuclear-powered submarines, of which 56 are in operation, including 34 that are capable of launching Polaris missiles. The first general overhaul of the ship and refueling of all eight reactors on the aircraft carrier *Enterprise* was completed in July 1965. The guided-missile destroyer leader *Bainbridge* and the guided-missile cruiser *Long Beach* were operational most of the year. A second guided-missile destroyer leader, the *Truxton,* was launched and a third was authorized by Congress.

Five Department of Defense reactors were operated. These were at Fort Belvoir, Va.; Fort Greeley, Alaska; McMurdo Station, Antarctica; Sundance, Wyo.; and National Reactor Testing Station, Idaho.

Test, Research, and University Reactors.—A total of 99 test, research, and teaching reactors were operable in 1965, consisting of 4 general irradiation, 5 for safety research and testing, 48 for general research, and 42 at universities used for teaching; 11 others were being built and 5 were planned.

Foreign Reactors.—Four operable central-station electric-power reactors built for export and subject to U.S. safeguards were located at Kahl-am-Main, West Germany (15.6 Mw); Punta Fiume (Garigliano), Italy (150 Mw); Tokai-Mura, Japan (12.5 Mw) and Trino (SELNI), Italy (240 Mw). Five reactors were being built at Chooz, France (210 Mw); Tarapur, India (380 Mw); Gundremmingen, West Germany (237 Mw); Zorita, Spain (153 Mw); and Beznau, Switzerland (350 Mw). Reactors were planned for Tsuruga, Japan (310 Mw); Roopur, Pakistan (70 Mw); and Santa Maria la Garona, Spain (440 Mw). A total of 50 test, general research, and teaching reactors were operable, 5 were being built, and 1 was planned. A pressurized-water propulsion reactor was

Table 6.—Principal producers of uranium materials and fabricators of uranium fuels

Company and principal location	Metal, oxides, and compounds	Coated particles	Fabricators of uranium fuels
Aerojet General Nucleonics, San Ramon, Calif.	----------	----------	X
Allis-Chalmers Manufacturing Co., Greendale, Wis.	----------	----------	X
Atomics International, Canoga Park, Calif.	----------	----------	X
The Babcock & Wilcox Co., Lynchburg, Va.	----------	----------	X
Battelle Memorial Institute, Columbus, Ohio	----------	----------	X
The Carborundum Co., Niagara Falls, N.Y.	----------	----------	X
Combustion Engineering, Windsor, Conn.	----------	----------	X
Coors Porcelain Co., Golden, Colo.	----------	----------	X
Diamond Alkali Co., Painesville, Ohio	----------	X	----------
General Dynamics Corp., San Diego, Calif.	----------	X	X
General Electric Co., San Jose, Calif.	X	----------	X
Kerr McGee Corp., Cushing, Okla.	X	----------	----------
Martin Marietta Corp., Baltimore, Md.	----------	----------	X
Metals & Controls Inc., Attleboro, Mass.	----------	----------	X
National Carbon Co., Lawrenceburg, Tenn.	----------	X	----------
National Lead Co., Albany, N.Y.	X	----------	X
Nuclear Fuel Services, Inc., Erwin, Tenn.	X	X	X
Nuclear Materials & Equipment Corp., Apollo, Pa.	X	X	X
Nuclear Metals, Inc., Concord, Mass.	----------	----------	X
Sylvania Electric Products, Inc., Hicksville, N.Y.	----------	----------	X
United Nuclear Corp., New Haven, Conn.	X	X	X
Westinghouse Electric Corp., Pittsburgh, Pa.	----------	----------	X

Source: AEC 1965 Report on the Nuclear Industry, pp. 24, 27.

operable in HMS *Dreadnought*.

Radioisotopes.—AEC continued to withdraw from isotope production in favor of private industry; nevertheless, AEC is still the principle domestic producer, and during the first 11 months of 1965 produced a total of 1.1 million curies of distributed radioisotopes from the Oak Ridge National Laboratory. This was a 95-percent increase over the same period in 1964. An additional shipment of 670,766 curies of Co^{60} was made from the Savannah River Laboratory to the Brookhaven National Laboratory for use in the High Intensity Radiation Development Laboratory. In 1965, AEC announced its withdrawal from the routine production and distribution of Sb^{125}, Ca^{45}, Fe^{59}, Se^{75}, Sn^{113}, Zn^{65}, and Sr^{85}.

Research was continued on the many applications of isotopes to process radiation.[7] Among these, the program on wood-plastic materials was significantly expanded. Wood is impregnated with a liquid monomer and then irradiated with Co^{60} gamma rays. This polymerizes the plastic molecules, producing a solid wood-plastic composite which is harder, stronger, and tougher than the original wood, yet retains its original beauty. Radiation preservation of food continued to show promise for ultimate commercialization. Four AEC research irradiators and the Marine Products Development Irradiator contributed to this program.

Development was continued on the applications of thermal energy from radioisotope decay as small power sources for space, terrestrial, and marine purposes. Pu^{238}, Po^{210}, Sr^{90}, Cm^{242}, Cm^{244}, Pm^{147}, and Ce^{144} were the leading isotopes in this field. AEC published a photograph of a 10-gram pellet of Cm^{242} which showed it to be incandescent while resting on a cool surface.[8] The Systems for Nuclear Auxiliary Power (SNAP) program continued to develop compact, lightweight nuclear devices utilizing both fission heat (reactors) and isotopic heat to produce electricity. SNAP–3, generating 2.7 watts, completed 4½ years in orbit aboard a navigational satellite, during which it traveled over 500 million miles and signaled clearly and regularly to tracking stations around the world. Four other SNAP projects on space power, generating from 20 to 50 watts, were under development.

Ten land and sea units operated in navigational buoys and weather station. Among these, the Navy Oceanographic and Meteorological Automatic Device (NOMAD) with a SNAP–7D, 60-watt unit, completed its second year of operation and still functioned well, despite an encounter with

[7] U.S. Atomic Energy Commission. Isotopes in Industry, Trends in the Industrial Use of Radioisotopes and Ionizing Radiation, September 1965. U.S. Dept. of Commerce, Clearinghouse for Federal Scientific and Technical Information, NYO–3337–16, September 1965, 134 pp.

[8] Page 230 of work cited in footnote 2.

Table 7.—Principal industrial producers of radioisotopes

	Method of production	
	Cyclotron	Reactor
Abbott Laboratories	X	X
The Babcock & Wilcox Co.	----------	X
Cambridge Nuclear Corp.	X	X
General Electric Co.	----------	X
New England Nuclear Corp.	X	X
Nuclear Science & Engineering Corp.	X	X
Union Carbide Corp.	----------	X
U.S. Nuclear Corp.	X	X
Western New York Nuclear Research Center, Inc.	----------	X

Source: AEC 1965 Report on the Nuclear Industry, p. 66.

Hurricane Hilda in October. Anchored in water 2 miles deep 300 miles south of New Orleans NOMAD transmitted meteorological data for forecasting weather changes in the Gulf of Mexico and was developed by the Navy as a forerunner of a worldwide network of unattended weather stations.

A 7.5 SNAP–7E thermoelectric generator has remained unattended since July 1964, and has faultlessly powered a sound transducer. It was implanted in water 3 miles deep about 750 miles east of Jacksonville, Fla., and was used as a navigational device. Other devices that continued in operation included a navigational buoy and a lighthouse in Chesapeake Bay. A navigational aid 80 miles southwest of Morgan City, La., using a SNAP–7F, 60-watt generator, was operated from June to October and was removed then for analytical testing. It operated two beacons and a foghorn.

A unique use for radioisotopes was described.[9] To study the transport and dispersion of bed-material in streams, sand labeled with radioactive Ir^{192} was released from a line source on the bed of the river. The movement of the tracer particles was measured by monitoring the streambed with a sled-mounted scintillation detector. Core samples were also monitored. It was concluded that the method was both experimentally feasible and safe.

Depleted Uranium.—Depleted uranium —that which contains less than the natural abundance (0.71 percent) of the U^{235} isotope—continued to accumulate, although a slightly rising trend was noted in 1965 in its use as counterweights in movable control surfaces of aircraft and as a shielding material against gamma and X-rays. From 2 to 500 pounds may be used in the wings of an aircraft, depending on its type. Gamma-ray projectors were used in making radiographic inspection of pipelines, using Ir^{192} as a 100-curie source. Shielding in some of these instruments was provided with about 30 pounds of depleted uranium. Depleted uranium, used in steel alloys, as coloring agents in ceramic glazes and glasses, and in a score of minor chemical and specialty uses, remained little changed and small in quantity.

PRICES AND SPECIFICATIONS

Uranium. Ore and Concentrate.—Uranium ore prices were based on contracts between mines and mills and were not generally disclosed. Most mills stated that prices for purchased ore were similar to the terms of AEC Circular 5 which expired in 1962. This stipulated a base price ranging from \$1.50 per pound of U_3O_8 on ore grade of 0.10 percent to \$3.50 per pound on ore containing 0.20 percent U_3O_8 or better; in addition, premiums were allowed for ores over 0.25 percent U_3O_8 and for quantity and development allowances. The average value of uranium ore, based on data supplied to the Bureau of Mines was about \$4.05 per pound of U_3O_8 on ore that averaged around 0.25 percent U_3O_8.

The domestic contract price for specification-grade concentrates continued to be \$8 per pound of contained U_3O_8, and this price was continued in the new stretchout contracts through the calendar year. For all U_3O_8 delivered in 1969–70, AEC expected to pay between \$5.50 and \$6.00 per pound. In the fiscal year ending June 30, 1965, AEC cost per pound of U_3O_8 from Canada was \$8.73 and from the Republic of South Africa it was \$11.08.

Uranium Metal.—Normal (natural) uranium metal was quoted at \$18 per pound periodically in American Metal Market, unchanged from 1964. Prices for 25 percent U^{235} were quoted nominally at \$9 to \$11 per gram. Prices for depleted ura-

[9] Sayre, W. W., and D. W. Hubbell. Transport and Dispersion of Labeled Bed Material, North Loup River, Nebraska. Geol. Survey Prof. Paper 433–C, 1965, 48 pp.

nium, delivered by AEC in the form of uranium hexafluoride (UF_6), were unchanged and ranged from $2.50 per kilogram (kg) of contained metal for material containing less than 0.38 percent U^{235} to $22.60 per kg for uranium containing 0.7 percent U^{235}. A new value for normal UF_6 was set by AEC at $23.46 per kg of uranium, based on the official change of the U^{235} assay assigned to normal uranium of 0.711 percent instead of the former assigned value of 0.7115 percent.

Special Nuclear Materials.—Base charges by AEC for enriched uranium as UF_6 remained unchanged since July 1962 and varied with the degree of enrichment from $4.77, $9.59, and $12.01 per gram of U^{235} content for 0.010, 0.050, and 0.90 weight-fraction material, respectively. New specifications were announced which increased the minimum weight percent of UF_6 from 99.0 to 99.5 and defined the maximum limits of other impurities.[10]

The AEC established new guaranteed purchase prices for privately owned plutonium and for uranium enriched in the isotope U^{233}. Whether nitrate, dioxide, or metal, the price was set at $10 per gram of the contained Pu^{239} and Pu^{241}. Similar forms for uranium enriched in U^{233} were priced at $14 per gram of the contained isotope U^{233}. These prices pertain only to Pu and U^{233} produced in a reactor licensed under the Atomic Energy Act and delivered to AEC before January 1, 1971.

FOREIGN TRADE

No uranium ores or concentrates were exported. Uranium and thorium compounds and alloys were classified into basket categories. Exports of compounds were made to 19 countries and totaled 132,665 pounds valued at $264,607; metal and alloys went to 13 countries and totaled 4,783 pounds valued at $230,405. In addition, under terms of the Atomic Energy Act, AEC distributed 19,470 pounds of U^{235}, 583 pounds of Pu, and 3.74 pounds of U^{233} to foreign nations having Agreements of Cooperation with the United States. The President had determined that 330,000 pounds of U^{235}, 1,195 pounds of Pu, and 99 pounds of U^{233} should be made available for international cooperation. AEC commitments have reached over two-thirds of this total availability.

Total value, as of mid-1965, of all special nuclear and other materials distributed by AEC through sale, lease, and deferred payment sales, increased to $141.7 million, and yielded $84.6 million in dollar revenues to the United States. A shipment of enriched uranium, a portion of the first fuel core of the SENA power reactor at Chooz, France, went by airfreight in November. The full core, valued at about $11.6 million, will consist of about 88,000 pounds of uranium varying from 2.95 to 3.90 percent U^{235}.

By the close of 1965, about 30 shipments of spent reactor fuel from abroad had been sent to the AEC Savannah River and Idaho chemical processing plants. During the year, 14 new ports were cleared for permitting shipments of irradiated fuels, raising to 35 the number of domestic ports allowing such shipments.

Domestic imports of uranium concentrate totaled 2,650 tons of contained U_3O_8 or 20.2 percent of total AEC procurement, compared with 31 percent in 1964; 1,930 tons came from Republic of South Africa, and 720 tons came from Canada. These imports were based on contracts made during the early stages of the procurement program. Uncompleted balances of about 1,330 and 720 tons, respectively, from South Africa and Canada, expire in 1966. No uranium ores or unwrought, wrought, waste, and scrap uranium were imported.

WORLD REVIEW

Australia.—An Australian mineral-exploration company, Mineral Resources Pty. Ltd., was acquired by Western Nuclear, Inc., along with exclusive exploration rights to about 5.5 million acres in Arnhem Land. The area lies between the McArthur River lead discovery of Mount Isa Mines and the Gove bauxite deposit and was an aborigine

[10] Federal Register. Uranium Hexafluoride Charges and Specifications. V. 30, No. 230, Nov. 30, 1965, p. 1482; V. 30, No. 232, Dec. 2, 1965, p. 14938.

Table 8.—Free world production of uranium oxide (U_3O_8) by countries [1]
(Short tons)

Country	1961	1962	1963	1964	1965 p 2
Argentina	e 6	4	r 9	r 37	40
Australia e	1,400	1,300	1,200	420	370
Canada	9,641	8,430	r 8,352	r 7,285	4,308
Finland e	20	----	----	----	----
France	1,619	1,978	1,987	1,833	1,800
Gabon	428	514	582	586	600
Malagasy	94	111	123	169	170
Portugal	132	24	----	----	----
South Africa, Republic of	5,468	5,024	4,532	4,445	2,942
Spain e	55	55	55	55	55
Sweden e	10	10	10	10	20
United States	17,399	17,010	14,218	11,847	10,442
Free world total e 3	r 36,300	34,600	r 31,100	r 26,700	20,800

e Estimate. p Preliminary. r Revised.
[1] Uranium is also believed to be produced in Czechoslovakia, East Germany, Hungary, U.S.S.R., and other Soviet-oriented countries, but production data are not available, and no estimates for these countries have been made. Estimates of production for these Soviet-oriented countries range from 10,000 to 20,000 tons per year.
[2] Compiled from data available April 1966.
[3] Uranium is also known to have been produced in Colombia, India, Italy, Japan, and West Germany, but production data are not available; no estimate for these countries has been included in the world total.

reserve which was opened for prospecting in 1963.[11]

Australian scientists have been deeply interested in Project Plowshare, the U.S. AEC program for developing nuclear explosives. A possible site for a new deepwater harbor, excavated with nuclear explosives is on the Robe River in northwestern Australia. The area contains valuable iron ore which is being developed for export, initially to Japan. As a large arid continent with a poorly indented coast line, the successful and practical development of harbor-building with nuclear explosives would be of great economic assistance to Australia.[12]

Canada.—The 1965 Annual Report of Eldorado Mining & Refining Ltd., which is a government-owned corporation responsible for the administration of government contracts for the sale of uranium, among other duties, stated that sales of uranium for export was 7,059,466 pounds valued at $55,128,622, a 37-percent drop in quantity and a 28-percent reduction in value from 1964. This quantity was only 23 percent and its value was only 17 percent of that for the peak year of 1959.

To ease unemployment and maintain a viable uranium industry, Eldorado, acting for the Canadian Government, entered into a stockpile agreement with three mines: Rio Algom Mines, Ltd., for 300 tons per year, and Denison Mines, Ltd., for 1,500 tons per year, both in the Elliot Lake area and whose contracts are to run for 5 years, and 900 tons per year with the Beaverlodge mine in Saskatchewan beginning January 1967 and extending through June 1970. All contracts specify a price of $4.90 per pound of U_3O_8. Stanrock Uranium Mines, Ltd., the third remaining producer in the Elliot Lake area, expected to complete its contract early in 1966. Stanrock recovers most of its uranium by a bacterial leaching method which is also used by the Rio Algom mine.[13] Eldorado continued a vigorous extensive exploration and development program at its Beaverlodge property and estimated its reserves at 1.5 million tons of ore grading 0.21 percent U_3O_8.[14]

French Government interests attempted to negotiate a purchase contract with Canadian uranium producers for 50,000 tons of U_3O_8 over a 25-year period. Negotiations failed when Canada insisted on satisfactory guarantees that the uranium would be used for peaceful purposes only. Several of the companies were not anxious to tie up a large part of their reserves at the currently depressed prices.

An engineering test reactor (WR–1) went into operation in November at the Whiteshell Nuclear Research Establishment

[11] Engineering and Mining Journal. Western Nuclear Goes to Australia. V. 166, No. 10, October 1965, pp. 131, 133.
[12] Mining Journal (London). Nuclear Blasting for W. Australian Port Development? V. 264, No. 6769, May 14, 1965, p. 373.
[13] Northern Miner (Toronto, Canada). Uranium Producers Commence Shipment for Stockpiling. No. 25, Sept. 9, 1965, p. 3.
[14] Northern Miner (Toronto, Canada). Eldorado Pursues Long Range Plans to Build Reserves. No. 15, sec. 1, July 1, 1965, pp. 1, 7.

of Atomic Energy of Canada Ltd. in Manitoba. It has a natural-uranium core moderated with heavy water and cooled by an organic fluid (hydrogenated terphenyl). Its thermal capacity is 40 Mw, but it will be used only as a research tool, and the U.S. AEC will rent half the facilities for engineering tests on heavy-water moderated and organic-cooled reactors.

China.—Uranium output was reported as being 2,500 tons of ore per day, part of which was partially processed in Hunan province. The concentrates then were sent to Czechoslovakia where half the uranium was retained as a processing charge. Uranium deposits were discovered north and south of Chiu Lien Shan in the Man Ling Mountains. Production was reported from the Mao Shan, Chu Shan, and Hsia Chuang mines, the first two in Kiangsi and the third in Kwangtung.[15]

Czechoslovakia.—The first Czech nuclear power station at Bohunice was started in 1958 and is expected to produce power by 1968. It will initially consist of one 150-Mw gas-cooled heavy-water moderated reactor, although provision was made for the future construction of a second unit. Except for some consultancy with U.S.S.R. experts, the project is being built entirely by Czech industry. Future stations, up to four in number, were being planned for completion in 1970.

Egypt.—After 7 years of nuclear development, the successful extraction of high-grade uranium from deposits in the eastern deserts was announced. Geologists have also discovered new radioactive deposits in an area 50 miles long between Damiette and Port Said bordering the Mediterranean.[16]

Finland.—Plans for a nuclear power plant at Kotka ranging between 300 and 500 Mw were announced.

France.—Electricité de France (EDF), the State-owned electric utility network, is finding it difficult to meet a rising demand for power. Paris officials are concerned about future uranium supplies in spite of France's known potential of about 50,000 tons. They have recommended long-term contracts with foreign producers in addition to increasing prospecting activity both home and abroad. By 1985, the annual nuclear installation rate was estimated to be 3,000 to 4,000 Mw. An attempt was made to negotiate a 25-year contract for the purchase of 50,000 tons of U_3O_8 with Canadian producers. However, French officials refused to agree to inspections that would guarantee that the uranium would be used for peaceful purposes only. Paris officials stated that such guarantees had not been demanded by Canada of the United States and Great Britain, and that inspection was valueless because of the relative abundance of uranium. Since France had ample supplies for its military needs, they stated, it was obvious that the Canadian supplies would be for peaceful purposes.[17] A report prepared by the consultative Commission on the Production of Nuclear Power concluded that French nuclear power should grow so that by 1975 about half of new power commissioned would be nuclear.[18] Near the end of 1965, both Australian and Republic of South Africa mining officials announced that French representatives had discussed the possibilities of uranium production contracts with them.

EDF adopted a new nomenclature for its nuclear power plants. EDF–1, 2, and 3 became Chinon–1, 2, and 3, respectively; and EDF–4 became St. Laurent–1. Chinon–1 (82 Mw) and Chinon–2 (250 Mw) operated throughout 1965. Chinon–3 (480 Mw), the Chooz (266 Mw) joint Franco-Belgian project Société d'Energie Nucléaire Franco-Belge, and EL–4 (80 Mw) were well underway for possible operation in 1966. St. Laurent–1 (480 Mw) was scheduled to go critical in 1967, and St. Laurent–2 (1,000 Mw) was scheduled for 1969. Plans were also announced for two new reactors: Bugey–1 (500 Mw), formerly called EDF–5, and Bugey–2 (1,000 Mw). Two additional units were allowed for under the Fifth National Plan and these could be at Bugey or in the Loire estuary.[19]

The EL–4 being built near Morlaix jointly by Commissariat à l'Energie Atomique (CEA, the French AEC) and EDF is

[15] Mining Journal (London). China's Uranium Ore. V. 265, No. 6802, Dec. 31, 1965, p. 481.

[16] EuroNuclear. Egypt-Uranium Success. V. 2, No. 2, February 1965, p. 68.

Mining Journal (London). Uranium Mines in Egypt. V. 24, No. 6762, Mar. 26, 1965, p. 231.

[17] EuroNuclear (London). Uranium Worry. V. 2, No. 1, January 1965, p. 9; A Leap Forward. V. 2, No. 2, February 1965, p. 62; No to Inspection. V. 2, No. 6, June 1965, p. 267.

[18] Nuclear Engineering (London). French Nuclear Energy Policy. V. 10, No. 106, March 1965, pp. 84, 90.

[19] Nucleonics. Vintage Year Forecast for French Nuclear Policy. V. 23, No. 10, October 1965, p. 25.

a prototype heavy-water-moderated gas-cooled power reactor which will operate on natural uranium.[20]

The first French atomic submarine had reached the planning state following development work by CEA at Cadarache and should be ready for launching in 1967 and for combat duty in 1969. CEA received a 220-pound shipment of plutonium from AEC, the largest sent abroad, for use in fast-reactor research at Cadarache. Fuel elements and control-rod followers fabricated from uranium enriched at Oak Ridge, Tenn., were shipped for the first core of the Euratom SENA power project at Chooz. This is the third large power reactor in Europe to be fueled by the United States and the second under the U.S.-Euratom joint program. Euratom purchased the fuel under a long-term supply contract. Deliveries will continue into 1966 and will aggregate almost 44 tons of uranium containing from 2.95 to 3.35 percent U^{235}.

Germany, West.—The 15-Mw boiling-water reactor at Kahl provided valuable operating experience and engineering data throughout 1965. A 250-Mw reactor at Gundremmingen, scheduled for operation in 1966, will be Germany's first full-scale nuclear station. Construction continued on a second 240-Mw reactor at Lingen, and site work for the third and largest (282 Mw) pressurized-water reactor at Obrigheim was started early in 1965.[21] Allgemeine Elektricitaets Gesellschaft of Frankfurt, the major German electrical equipment manufacturer active in reactor construction, contracted with Susquehanna-Western, Inc., Falls City, Tex., to supply 475,000 pounds of U_3O_8 in concentrates. The concentrate was to be shipped to AEC in exchange for an amount of enriched uranium suitable for fuel elements for the Lingen reactor.[22]

The Second Congress of Forum Atomique Europeen (FORATOM), an organization of the atomic industry associations of the six Euratom countries, was held in Frankfurt in September and was attended by 923 delegates from 22 countries. Much technology was discussed in papers, but it was also pointed out that nuclear nationalism and local patriotism prevented full cooperation in the scientific, economic, and other peaceful uses of nuclear energy in Europe. Several speakers referred to the waste of duplicated effort. Another preoccupation concerned the long-term requirements of uranium. The Federal Republic of Germany estimated that installed nuclear capacity for that country would be 1,500 Mw in 1970, 15,000 in 1980, and over 70,000 in 2000.[23]

The Karlsruhe Reactor Center worked on a high-temperature gas-cooled pebble-bed reactor in which the fuel is in the form of graphite-encased spheres. This included the construction of a 15-Mw prototype reactor (AVR) at Julich. The coating of fuel particles with pyrolytic carbon follows the patterns set at Peach Bottom (Pa.) and the Dragon project in England. The fuel spheres in AVR are 60 millimeters in diameter and the thorium-uranium ratio is 5:1. A further design study was in progress in cooperation with Euratom of a full scale (about 200 Mw) prototype of a thorium high-temperature reactor on the AVR principle.[24]

India.—The Trombay plant of the Indian Atomic Energy Establishment began extracting plutonium early in 1965, using spent fuel from the Canada-India 40-Mw reactor. India's intention to build three more of the Canadian Candu reactors was announced at the Japan Industrial Forum. One would be a 400-Mw twin reactor at Kalpakkam in Madras State and the other would be a 200-Mw station at Rajasthan. These are hopefully to be completed by 1971 and, with the 380-Mw American boiling-water reactor being built at Tarapur, north of Bombay, will give India over 1,000 Mw of installed nuclear-power capacity, the target for the first 5-year economic-development plan. The 1971–75 target was set at an additional 1,800 Mw of installed capacity.[25]

Israel.—A U.S.-Israeli joint effort to develop a large-scale sea water desalting plant may result in the use of a nuclear reactor, and a combination power and water-conversion plant was discussed, which would produce 200 Mw and 100 million

[20] Carle, R., and R. Gibrat. EL–4 and the French Heavy Water/Gas Line. Nuclear Eng. (London), v. 10, No. 108, May 1965, pp. 171–174.

[21] Nuclear Engineering (London). V. 10, No. 106, March 1965, p. 91.

[22] Engineering and Mining Journal. U.S.-West German Uranium Agreement. V. 166, No. 9, September 1965, p. 164.

[23] EuroNuclear (London). Second Foratom Kongress. V. 2, No. 10, October 1965, pp. 477–480.

[24] Nuclear Engineering (London). The Pebble-Bed Reactor. V. 10, No. 112, September 1965, pp. 317–360.

[25] Nucleonics Week. V. 6, No. 40, Oct. 7, 1965, p. 5.

gallons of desalted water per day. Estimates of the water cost range from 15 to 40 cents per thousand gallons. Israel would like the plant to be in operation in the early 1970's.[26]

Italy.—Italy was classed as an important market for nuclear power expansion. Water power has been the basis of her industrial development but additional hydroelectric power sites are scarce. Thermal power production is rising steeply but coal and oil must be imported. These economic facts led to the planning, as early as 1957, of the Latina 200-Mw, the SENN or Garigliano 160-Mw, and the Enrico Fermi 300-Mw nuclear stations. Garigliano was shut down most of 1965 for a scheduled maintenance program in which stainless-steel cladding was replaced with Zircaloy.[27]

Japan.—Uranium ore deposits containing from 0.1 to 0.2 percent U_3O_8 were discovered in Western Japan. The 150-Mw Tokai Mura power reactor of Japan Atomic Power Co. went critical in May 1965. It is of the Magnox type developed in England where the fuel elements were constructed and where they will be reprocessed. The company was considering a 300-Mw plant of the light-water type based on bids tendered by U.S. manufacturers.[28]

Pakistan.—Canadian General Electric Co., Ltd., Toronto, Canada, signed an agreement to build a 137-Mw heavy-water plant of the Candu type.[29]

Spain.—Geological formations that may yield uranium have been found in several provinces and prospecting in these areas may begin in the near future. The Spanish Atomic Energy Commission planned another milling plant, possibly in Ciudad Rodrigo, in addition to the plant in Andujar. Spain ranks sixth among the world's uranium producing countries and is second after France in West Europe with respect to uranium resources. A contract was concluded between Union Electrica Madrileña and Westinghouse Electric Corp. for the construction of Spain's first nuclear power plant at Zorita de los Canes. The 150-Mw plant is scheduled to begin operating in late 1967.[30] The reactor will be fueled with uranium produced in Spain and enriched in the United States under a special barter agreement.[31] Other reactors planned include a 300-Mw unit at Santa Maria de Garona for completion in 1969, a 350-Mw unit at Castillon for 1971–72, and a 500-Mw unit in Catalonia for completion by 1972. The Catalonia plant will be jointly owned by three Spanish utilities and the French EDF. Spain will use 75 percent of the power, and the remainder will go to France along a 380-kilovolt power line.[32]

Sweden.—Production started at the Ranstad uranium mill which has a planned capacity of about 135 tons of U_3O_8 per year. Raw material is uranium-bearing oil shale, and reserves have a total uranium content of about 1 million tons. By United States and Canadian standards the ore is low grade, assaying only 300 grams—about two-thirds pound—of uranium per ton. The 12-foot bed of shale is covered with 40 feet of overburden, which is stripped with a dragline.[33]

The Central Operating Management, the joint organization for the Swedish State Power Board and private and municipal electricity generator groups, expected that nuclear power would become competitive in Sweden after 1970 and that two commercial installations would be started before 1975. Sweden's first nuclear-power station, the Agesta reactor, in a suburb of Stockholm, went critical in 1963. It is a pressurized, heavy-water-moderated reactor of 65 Mw of thermal power and is used for both electric power and space heating. The second reactor, a boiling heavy-water type being built near Marviken as a development project, is expected to have a capacity of about 200 Mw. The private power producers Atomkraftkonsortiet (AKK) was considering a 400-Mw plant in Simpevarp.[34]

Switzerland.—At the end of 1965, four nuclear-power projects were in an ad-

[26] Engineering News-Record. U.S., Israel Study 100 mgd Desalter. V. 174, No. 7, Feb. 18, 1965, p. 50.

[27] Cassuto, Aldo. Special Report from Southern Europe. Nuclear Eng., v. 10, No. 110, July 1965, pp. 262–263.

[28] Ipponmatsu, Tatmaki. Japan's Nuclear Future. Nuclear Eng., v. 10, No. 111, August 1965, pp. 288–289.

[29] EuroNuclear. Canadian Reactor for Karachi. V. 3, No. 1, January 1966, p. 12.

[30] Bureau of Mines. Mineral Trade Notes. V. 60, No. 6, June 1965, pp. 43–44.

[31] Bureau of Mines. Mineral Trade Notes. V. 61, No. 3, September 1965, p. 59.

[32] Engineering News Record. Spain Launches A-Plant Program. V. 174, No. 7, Feb. 18, 1965, p. 52.

[33] World Mining. Uranium Ore Production Has Started at Ranstad Open Pit. V. 18, No. 11, October 1965, p. 87.

[34] Nuclear Engineering (London). Swedish Nuclear Activities. V. 10, No. 106, March 1965, p. 85.

vanced stage of consideration. The Lucens plant, a federally subsidized experimental plant with a Swiss reactor having a capacity of 7 Mw, was under construction and was expected to be completed in 1966. Construction was started in 1965 on a 350-Mw power reactor for Northeast Swiss Co. at Beznau and was scheduled for completion by 1969. A 300-Mw plant, Muhleberg I on the Aare River, and a 600-Mw plant, Liebstadt on the Rhein River, were in the planning stages, to begin construction either in 1966 or 1967. Three other projects were under consideration—Beznau II, Muhleberg II, and one at Geneva.

U.S.S.R.—Soviet scientists continued to argue the relative merits of big boiling-water reactors and fast-breeders. It would not appear that a country rich in coal and oil reserves, as well as a huge hydropower potential, would find nuclear energy attractive. However, the hydropower is mainly in Siberia and most of the population is in European Russia and the Ukraine. Furthermore, coal is also distant from the population centers and oil reserves are widely scattered and often in inhospitable marshlands. Beloyarsk, 100-Mw superheat reactor with some breeding capability, was in operation, and a second 200-Mw unit was being built. Novovoronezh, a 210-Mw nonsuperheating pressurized-water reactor went into operation in 1964, and work was underway on a second 365-Mw unit. Work proceeded on a 300-Mw fast breeder reactor on the eastern coast of the Caspian sea. It was to be a dual-purpose plant for power production and water desalination. All these when completed will give the Soviet Union a little over 1,000 Mw of nuclear power capacity.[35]

United Kingdom.—Britain had 10 nuclear-powered generation stations with 22 reactors in operation, having a generating capacity of 3,400 Mw, the greatest of any country in the world and over three times that of the United States. Three others, Sizewell (580 Mw), Oldburg (600 Mw) and Wylfa (1,180 Mw) were in various stages of completion. Of the 10 stations, 6 were considered as commercial plants, and each had 2 reactors. The other 4 were prototype and developmental units, and 1, Dounreay has become an irradiation facility principally.[36]

Britain has spent much time and money on reactor development, and most of both have been in developing gas-cooled, graphite-moderated (GCGR) reactors. The latest development of these is known as the Advanced Gas-Cooled Reactor (AGR), the first unit of which will be known as Dungeness B with a net output of 1,200 Mw. A 30-Mw prototype AGR has been operating at Windscale since 1962. According to the United Kingdom Atomic Energy Authority (AEA), the competitive ability of AGR over alternative systems has been confirmed. Gas-cooled reactors have been demonstrated by eight GCGR at Calder Hall and Chapelcross aggregating 450 Mw and which have produced over 22 million Mw-hours of electricity in 8 years of operation through 1965. These use natural-uranium fuel elements sealed in cans of magnesium alloy—Magnox—hence, they are known as Magnox reactors. Important engineering improvements and reduced costs have resulted from the building of 28 Magnox reactors ranging from 138 Mw to 590 Mw. Two were built abroad—Latina in Italy and Tokai Mura in Japan. In AGR the metallic uranium fuel was replaced by ceramic uranium oxide which permits higher operating temperature and a higher fuel burnup. The canning material selected was stainless steel which permits a surface temperature up to 750° C. Since stainless steel absorbs more neutrons than Magnox, it has been necessary to enrich the initial fuel slightly to 1.46 in the inner region and 1.76 percent U^{235} in the outer region. In the Windscale reactor the fuel elements operate at red heat and the CO_2 gas coolant is heated to 600° C, permitting steam to be produced at 565° C and 2,300 pounds pressure.[37]

WORLD RESERVES

AEC estimated uranium reserves minable at $8 per pound of U_3O_8 on January 1, 1966, as 61.6 million tons of ore with an average grade of 0.235 percent or 145,000 tons of U_3O_8. This was a decrease from the previous year of 1.4 million tons of ore and 7,000 tons of U_3O_8.

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[35] Winston, Don. Letter From the Soviet Union. Nucleonics, v. 23, No. 7, July 1965, p. 33.

[36] Edwards, A. G. DFR as an Irradiation Facility Nuclear Eng., v. 10, No. 113, October 1965, pp. 383–387.

[37] EuroNuclear (London). AGR Success in the U.K. V. 2, No. 8, August 1965, pp. 371a–371d.
Moore, R. V. Gas-Cooled Reactor Development

Table 9.—Free-world estimated resources of uranium

(Thousand short tons)

Price range per pound of U_3O_8	$5 to $10		$10 to $15		$15 to $30	
Country	Reasonably assured resources	Possible additional resources	Reasonably assured resources	Possible additional resources	Reasonably assured resources	Possible additional resources
United States:						
Conventional deposits	175	325	100	200	100	140
Byproduct of phosphate operations	20	----	50	----	70	300
Total	195	325	150	200	170	440
Canada	210	290	130	170	100	200
Argentina	5	15	5	12	----	NA
Europe:						
Denmark (Greenland)	NA	NA	5	NA	NA	NA
France	37	28	5	10	NA	NA
Portugal	7	3	NA	6	NA	10
Spain	11	NA	NA	40	NA	250
Sweden	NA	NA	350	50	150	200
Other [1]	5	20	6	NA	NA	NA
Total	60	NA	366	NA	NA	NA
Africa:						
Angola (Portugal)	NA	NA	NA	15	NA	NA
Gabon	5	NA	NA	NA	NA	NA
Morocco	6	NA	11	NA	8	NA
Republic of the Congo (Léopoldville)	6	NA	NA	NA	NA	NA
Republic of South Africa	140	NA	NA	NA	NA	NA
Total	157	NA	11	NA	NA	NA
India	NA	NA	16	NA	NA	NA
Japan	NA	NA	3	NA	NA	NA
Australia	15	NA	3	NA	1	NA
Total	642	NA	684	NA	NA	NA

NA Not available.
[1] Italy, Spain, Turkey, West Germany, and Yugoslavia.

Source: European Nuclear Energy Agency "World Uranium and Thorium Resources." Organization for Economic Co-Operation and Development, Paris, France, August 1965, 22 pp.

Early in 1965, the Steering Committee of the European Nuclear Energy Agency (ENEA) set up a study group of 11 experts from 6 countries and the ENEA staff, to establish world estimates of uranium and thorium resources which are known to exist or which can be estimated or inferred. These were tabulated as in table 9 for each of a series of price ranges and for two degrees of accuracy in each range. "Reasonably assured resources" was defined as material in known deposits of such grade, quantity, and configuration that it can be profitably mined and processed under present technology within the given price range. "Possible additional resources" refers to material surmised to occur in unexplored extensions of known deposits, in undiscovered deposits, known or postulated uranium districts, and which is expected to be economically exploitable in the given price range. The general tendency was to underestimate resources when available data were meager.

AEC supplied the estimates shown in table 9 for the United States. Uranium in Morocco is largely in phosphate rock. For India and Japan, costs are not sufficiently known to determine whether these resources should be where shown or in the first column. Similarly, the Angola resources may properly belong in either the second or sixth columns. Totals, except for columns 1 and 3, were considered to be meaningless because of the lack of information for many countries.

Resources for U.S.S.R., China, and Eastern Europe were not considered by the study group.

TECHNOLOGY

Nuclear Science Abstracts,[38] which may be considered to be a complete index of international nuclear-research reporting, contained 48,118 items in 1965, compared with 45,203 in 1964 and 42,247 in 1963. AEC also reported the scope of its fundamental and basic research programs.[39] Concise summaries of current atomic-energy developments continued to be issued in a series of quarterly Technical Progress Reviews which evaluated the latest findings in five specific areas of nuclear technology and science.[40]

The geology of uranium deposits in and around San Juan County, Utah, were described in three publications of the Geological Survey. The first described a 1,000-square-mile area around Elk Ridge in the canyon country of southeastern Utah where exposed sedimentary rocks range in age from Pennsylvanian to Jurassic and total about 6,000 feet in thickness. Uranium ore has been produced from two parts of the area which lies across the north end of the Monument upwarp.[41] The area on the gently dipping west flank of the Monument upwarp, where buried sandstone channel fillings in Triassic rocks are the sites of copper-uranium deposits, some containing over a million tons of ore, was described in the second publication.[42] The third publication described massive sandstone beds within the Salt Wash Member of the Morrison formation which contain many scattered, small uranium-vanadium deposits, only a few of which have produced more than 1,000 tons of ore.[43]

Wyoming, already extensively covered by geological surveys of uranium deposits in previous years, was the subject of additional

in the U.K. Nuclear Eng., v. 10, No. 113, October 1965, p. 367.

[38] U.S. Atomic Energy Commission, Division of Technical Information. Nuclear Science Abstracts. V. 19, Nos. 1–24, issued semimonthly, 1965, 6,040 pp.

[39] U.S. Atomic Energy Commission. Fundamental Nuclear Research. December 1965, 388 pp.

———. Summaries of the USAEC Basic Research Programs in Metallurgy, Solid State Physics, and Ceramics (Fiscal Year 1965). U.S. Dept. of Commerce, Clearinghouse for Federal Scientific and Technical Information, January 1966, 464 pp.

[40] Baker, P. S., A. F. Rupp, and Associates (Oak Ridge National Laboratory). Isotopes and Radiation Technology. V. 2, Nos. 1–4, 1965, 364 pp.

Cottrell, W. B., W. H. Jordan, and Associates (Oak Ridge National Laboratory). Nuclear Safety. V. 6, Nos. 1–4, 1965, 477 pp.

Dayton, R. W., E. M. Simons, and Associates (Battelle Memorial Institute). Reactor Materials. V. 8, Nos. 1–4, 1965, 249 pp.

Lawroski, Stephen, and Associates (Argonne National Laboratory). Reactor Fuel Processing. V. 8, Nos. 1–4, 1965, 250 pp.

Zinn, W. H., and J. R. Dietrich (Combustion Engineering, Inc.). Power Reactor Technology. V. 8, Nos. 1–3, 1965, 198 pp.

[41] Lewis, R. Q., Sr., and R. H. Campbell. Geology and Uranium Deposits of Elk Ridge and Vicinity, San Juan County, Utah. Geol. Survey Prof. Paper 474–B, 1965, 69 pp.

[42] Thaden, R. E., A. F. Trites, Jr., and T. L. Finnell. Geology and Ore Deposits of the White Canyon Area, San Juan and Garfield Counties, Utah. Geol. Survey Bull. 1125, 1965, 166 pp.

[43] Huff, L. C., and F. G. Lesure. Geology and Uranium Deposits of Montezuma Canyon Area, San Juan County, Utah. Geol. Survey Bull. 1190, 1965, 102 pp.

detailed studies. The rocks of the Wind River basin, which contain commercial concentrations of uranium, notably the Gas Hills uranium district, were described and mapped in detail.[44] A similar study was made of nine different areas in the Williston Basin which covers an area about 280 miles long and 195 miles wide extending between the 49th and 45th parallels and the 102d and 107th meridians in North Dakota, South Dakota, and Montana. All the uranium-rich deposits studied are in the unglaciated part of the Missouri River Plateau, and the uranium occurs principally in carbonaceous shale and lignite although a few uranium-bearing sandstone deposits are known.[45] The Cave Hills area of Harding County, S. Dak., covering about 215 square miles, although included in the Williston Basin paper, was given a still more detailed study, which included sampling by surface sections and auger cuttings in five selected areas. The samples were analyzed by chemical, radioactivity measurement, X-ray, and spectographic analyses, and microscopic examination.[46]

The seventh chapter of a series on the geology of uranium-bearing veins was published. A review of the literature shows that uranium vein deposits occur in many structural environments which are similar to those for other mineral deposits and that in many districts the veins have characteristic structural patterns that might aid in prospecting for unknown districts.[47] Three other papers, particularly useful in interpreting uranium deposits in sandstone, were published.[48]

New minerals described included hallimondite, a lead uranyl arsenate found in the Black Forest, West Germany,[49] and moctezumite, found at Moctezuma, Sonora, Mexico.[50] Several unusual uranium deposits were described, in which the ore occurred as yellow boulders weighing up to 143 pounds and in which about 11 uranium minerals were identified.[51]

The geology of two important Canadian uranium mines was described in detail. The Metal Mines Ltd. mined 2.8 million tons of ore in Faraday township, Hastings County, Ontario, containing over 6 million pounds U_3O_8 from April 1957 to May 1964. The deposits are in a pegmatite zone in which most of the pegmatite contains 0.01 to 0.04 percent U_3O_8, and enriched portions may contain 3 to 4 percent U_3O_8. Mined ore averaged about 0.11 percent U_3O_8 and the proved and probable reserve at July 1964 was estimated to be nearly 500,000 tons containing 1.3 million pounds of U_3O_8.[52] Production began at the Lake Cinch deposit in the Beaverlodge Camp, Saskatchewan, in 1957 and ceased in 1960, when the contract terminated. This was the highest-grade ore producer in the area. Uranium mineralization was in pegmatites and veins in faults, shears, and fracture zones containing pitchblende.[53]

Another publication in the series on uranium mining was issued by the Bureau of Mines. Operation and costs at the Section 23 mine of Homestake Sapin Partners, Ambrosia Lake district, N. Mex., were described. This operation was considered to be typical of other mines in the highly productive Morrison formation in New Mexico. Ore bodies are irregularly shaped and vary in size and rock strength. Four

[44] Keefer, William R. Stratigraphy and Geologic History of the Uppermost Cretaceous, Paleocene, and Lower Eocene Rocks in the Wind River Basin, Wyoming. Geol. Survey Prof. Paper 495–A, 1965, 77 pp.
Van Houten, Franklyn B. Tertiary Geology of the Beaver Rim Area, Fremont and Natrona Counties, Wyoming. Geol. Survey Bull. 1164, 1965, 99 pp.

[45] Denson, N. M., and J. R. Gill. Uranium-Bearing Lignite and Carbonaceous Shale in the Southwestern Part of the Williston Basin. Geol. Survey Prof. Paper 463, 1965, 75 pp.

[46] Pipiringos, G. N., W. A. Chisholm, and R. C. Kepferle. Geology and Uranium Deposits in the Cave Hills Area, Harding County, South Dakota. Geol. Survey Prof. Paper 476–A, 1965, 64 pp.

[47] Osterwald, Frank W. Structural Control of Uranium-Bearing Vein Deposits and Districts in the Conterminous United States. Geol. Survey Prof. Paper 455–G, 1965, pp. 121–146.

[48] Rosholt, J. N., A. P. Butler, E. L. Garner, and W. R. Shields. Isotopic Fractionation of Uranium in Sandstone, Powder River Basin, Wyoming, and Slick Rock District, Colorado. Econ. Geol., v. 60, No. 2, March-April 1965, pp. 199–213.
Rosholt, J. N., M. Tatsumoto, and J. R. Dooley, Jr. Radioactive Disequilibrium Studies in Sandstone, Powder River Basin, Wyoming, and Slick Rock District, Colorado. Econ. Geol., v. 60, No. 3, May 1965, pp. 477–484.
Shawe, D. C., and H. C. Granger. Uranium Ore Rolls—An Analysis. Econ. Geol., v. 60, No. 2, March-April 1965, pp. 240–250.

[49] Walenta, Kurt. Hallimondite, a New Uranium Mineral From the Michael Mine Near Reichenbach. Am. Mineralogist, v. 50, No. 9, September 1965, pp. 1143–1157.

[50] Gaines, Richard V. Moctezumite, a New Lead Uranyl Tellurite. Am. Mineralogist, v. 50, No. 9, September 1965, pp. 1158–1163.

[51] Gross, Eugene B. A Unique Occurrence of Uranium Minerals, Marshall Pass, Saguache County, Colorado. Am. Mineralogist, v. 50, Nos. 7–8, July-August 1965, pp. 909–923.

[52] Bullis, A. R. Geology of Metal Mines Ltd. (Bancroft Division). Canadian Min. and Met. Bull. V. 58, No. 639, July 1965, pp. 713–721.

[53] Turek, A. Geology of Lake Cinch Mines, Uranium City, Saskatchewan. Canadian Min. and Met. Bull. V. 58, No. 634, February 1965, pp. 183–192.

different mining methods are required: Retreating room-and-pillar, sublevel slicing (top slicing), horizontal cut-and-fill, and modified ring-drill method. Mining costs in 1962 averaged about $6.80 per ton of ore, not including amortization, depreciation, or Federal taxes.[54]

Uranium assays from gamma-ray logs of exploratory drill holes were used to compute grade and tonnage of ore using both a polygonal method and statistical analysis. Statistical analysis of assay data can provide much more information for mineral-deposit evaluation than can conventional methods of estimating ore reserves from the same data, providing certain requirements are met. The effects of stratified sampling, required minimum mining thickness, and increased assay-interval length were investigated.[55]

Union Carbide Corp. utilized big-hole rotary drilling to develop two small underground mines in the Gas Hills district, Wyo. A service shaft on the Thunderbird property was drilled as a 60-inch hole 377 feet deep, and it was fitted with a 48-inch steel casing with a ½-inch wall. A second service shaft nearby was drilled 48 inches in diameter and cased with a 36-inch pipe, and was fitted with ladders, landings, and service lines. A similar pair of shafts 435 feet deep was drilled on the Rox property about 1,100 feet from the Thunderbird. All shafts were cemented between casing and ground, using a 50-50 mix of pozzolana and cement. The Rox shaft was drilled in 210 hours and completed in 13 days. It cost $178 per foot for the main shaft and about $122 per foot for the service shaft.[56]

A study was made in which the historical, technical, and economic data on most of the world's big holes drilled from 1927 through 1965 were tabulated. This included about 170 commercially drilled holes, 50 access shafts for gas-storage caverns, and over 150 holes drilled by AEC for testing nuclear detonations. These holes have ranged from up to 300 inches in diameter and 1,600 feet deep to 72 inches in diameter and 4,000 feet deep. Included is an excellent list of references on the drilling of big holes.[57]

Uranium metal of improved purity was prepared on a laboratory scale by electrorefining commercial magnesium-reduced uranium in a molten (860° C) sodium chloride electrolyte containing uranium trichloride of 8.7 to 13.3 weight-percent uranium. Initial cathode current densities ranged from 300 to 1,500 amperes per square foot. The current density dropped from the initial value, as the uranium deposited in dendritic masses with a large surface area. Electrolysis had to be conducted in an inert (helium) atmosphere, and consolidation of the crystals, after thoroughly washing in dilute acid, was accomplished by arc-melting in an inert atmosphere.[58]

The oxidation behavior of uranium in carbon dioxide is important in the current types of British and French gas-cooled nuclear power reactors. Although the uranium in these reactors is encased in stainless steel, occasional leaks permit carbon dioxide to contact the uranium inside. Tests showed that the oxide formed by interaction of uranium and carbon dioxide between 350° and 650° C was protective initially but then nonuniform oxidation and cracking occur, leading to a gradual acceleration of the oxidation rate. Carbon monoxide produced in an initial stage reacts to form UO_2 and C or UC_2.[59] In investigations aimed at selecting oxidation-resistant uranium-alloy coatings for fuel elements in gas-cooled reactors, it was found that UCu_5 had good possibilities. In the temperature range 350° to 850° C, UCu_5 in a CO_2 atmosphere first forms a UO_2–Cu mixture followed by migration of the copper to the outer surface.[60]

Nuclear energy is expected to play an important part in water desalination, particularly where the relatively low-cost heat from large reactor installations can be util-

[54] Young, W. E., and D. T. Delicate. Mining Methods and Costs at Section 23 Uranium Mine, Homestake-Sapin Partners, McKinley County, N. Mex. BuMines Inf. Circ. 8280, 1965, 48 pp.

[55] Schottler, George R. Statistical Analysis of Gamma-Ray Log Sample Data From a Uranium Deposit, Ambrosia Lake Area, McKinley County, N. Mex. BuMines Rept. of Inv. 6645, 1965, 49 pp.

[56] Taylor, I. R., and J. A. Tavelli. Mining Through 48-in. Circular Shafts. Min. Cong. J., v. 50, No. 12, December 1965, pp. 37–41.

[57] Dellinger, Thomas B. Big Hole Drilling, A Study in Depth. Min. Eng., v. 17, No. 12, December 1965, pp. 71–75.

[58] Campbell, R. E., and T. A. Sullivan. Electrorefining Uranium in a Chloride Electrolyte. BuMines Dep. of Inv. 6624, 1965, 14 pp.

[59] Stobbs, J. J. The Oxidation Mechanism of Pure Uranium in Carbon Dioxide Between 350° and 650° C. J. Electrochem. Soc., v. 112, No. 9, September 1965, pp. 916–921.

[60] Stobbs, J. J., R. J. Pearce, and I. Whittle. Oxidation of the Uranium-Copper Intermetallic Compound UCu_5 in Carbon Dioxide Between 350° and 850° C. Trans. Met. Soc. AIME, v. 233, No. 9, September 1965, pp. 1676–1682.

ized, either in single-purpose or dual-purpose (desalination with power production) plants. At the First International Symposium on Water Desalination in Washington, D.C., October 3–9, 97 papers were delivered while another 28 were submitted for publication. U.S.S.R. representatives presented four papers on a low-capacity and a large-scale reactor concept, a paper from Britain discussed a dual-purpose unit employing the Advanced Gas-Cooled reactor; and two United States papers discussed the potential of nuclear energy for desalting and described a dual-purpose 1,800 megawatt electrical, 150 million gallons-per-day plant being studied for Southern California.[61]

A single-purpose desalting plant, based on a new concept by AEC, was the subject of a design study by Bechtel Corp. The nuclear unit consists of a conventional water-reactor core at the bottom of a water-filled tank 150 feet deep, encased in a steel-lined concrete cylinder extending 100 feet underground and 50 feet above ground. The water depth provides sufficient static head to prevent boiling in the core at a reactor-coolant outlet temperature of 270° F. Reactor coolant flows through three stages of brine heaters in series which are located at the bottom of the reactor structure. The plant will be designed to produce 50 million gallons of desalted water per day.[62] Single-purpose and dual-purpose reactors and the use of large-scale nuclear desalting plants for agricultural water were discussed.[63]

The status of controlled thermonuclear fusion was discussed at the Second International Atomic Energy Agency (IAEA) Conference on Plasma Physics and Controlled Nuclear Fusion Research held at Culham, England, on September 6–10, 1965, at which about 250 papers were presented. The central problem of fusion research is to excite a deuterium-tritium mixture to an energy equivalent to well over 100 million degrees K, and contain it in a highly evacuated vessel without touching any walls which would cool it. Under these conditions, matter exists in the plasma state, and deuterium and tritium will react together to produce helium-4 with the release per unit of mass of more energy than that obtained in the fission of uranium. The only feasible way devised to insulate a plasma is in a magnetic trap. Methods of producing plasmas were discussed, but many details must be resolved before fusion power becomes feasible.[64] A review of progress and problems of thermonuclear power was published.[65] Scientists of General Dynamics Corp. who had toured all the Russian fusion research centers, stated that the U.S.S.R. was ahead of and was spending about five times as much as the United States on research in this field. They estimated that technology permitting controlled nuclear fusion for power generation probably lies 20 years ahead.[66]

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[61] Hitchcock, A. Nuclear Desalination Prospects. EuroNuclear (London), v. 2, No. 11, November 1965, pp. 533–536.
Nucleonics. Desalting Symposium Report. V. 23, No. 11, November 1965, pp. 17–20.

[62] Nucleonics Week. A Single-Purpose Desalting Plant. V. 6, No. 34, Aug. 26, 1965, pp. 3–4.

[63] Nucleonics. Desalting Technology—1965. V. 23, No. 9, September 1965, pp. 43–55.

[64] Furth, Harold P. The Status of World Fusion. Nucleonics, v. 23, No. 12, December 1965, pp. 64–69.
Jukes, J. W. A New Look at Plasma Physics. EuroNuclear (London), v. 2, No. 11, November 1965, pp. 548–549.

[65] Roderick, Hiliard, and Arthur E. Ruark. Thermonuclear Power. Internat. Sci. and Technol., No. 45, September 1965, pp. 18–29.

[66] Burkett, Warren. Soviets Leading in Fusion Research. Missiles and Rockets, v. 16, No. 4, Jan. 25, 1965, p. 3.

Vanadium

By Gilbert L. DeHuff [1]

Vanadium consumption in the United States continued to increase rapidly in 1965; a 33-percent increase was registered over that of 1964. Domestic production also increased and again exceeded consumption. The processing of vanadium-bearing intermediate sludges, set aside previously in the course of obtaining uranium, contributed to the high output of 1965. However, the emphasis was otherwise on vanadium rather than uranium recovery from Colorado plateau ores, which remains the principal source of supply. In addition to production, domestic supply was augmented by 1,282 tons of vanadium contained in Atomic Energy Commission (AEC) stocks of vanadium pentoxide offered for sale on a sealed-bid basis. Development of an entirely new and important domestic source of vanadium in Arkansas was announced.

Table 1.—Salient vanadium statistics

(Short tons of contained vanadium)

	1956–60 (average)	1961	1962	1963	1964	1965
United States:						
Production:						
Ore and concentrate:						
Recoverable vanadium [1]	3,856	5,343	5,211	r 3,862	4,362	5,226
Value ... thousands	W	$19,076	$18,605	r $13,788	$13,061	$18,284
Vanadium pentoxide recovered	3,985	5,817	4,750	3,897	5,049	6,160
Consumption		2,015	2,314	2,906	3,550	4,708
Imports:						
Ferrovanadium (gross weight)	6	----	88	442	466	51
Ore and concentrate	1	----	----	----	111	----
Exports:						
Ferrovanadium and other vanadium alloying materials (gross weight)	133	120	201	183	103	220
Vanadium ores, concentrates, oxides, and vanadates	1,398	2,081	1,021	536	1,231	928
World: Production	5,059	r 8,722	8,264	r 7,161	r 7,841	9,150

r Revised.
W Withheld to avoid disclosing individual company confidential data.
[1] Measured by receipts of uranium and vanadium ores and concentrates at mills plus vanadium recovered from ferrophosphorus derived from domestic phosphate rock.

Legislation and Government Programs.—As the beginning of a long-range program for disposal of excess Government stocks of vanadium, General Services Administration (GSA) opened bids in September for the sale of 250 short tons of vanadium contained in fused pentoxide, which had been acquired by AEC during its uranium purchase program. An award of approximately 100 tons was made from this offering, and 1,182 tons were awarded late in December from a second offering from AEC stocks.

In May, after negotiation with four firms responding to invitation for offers, GSA awarded a contract to Vanadium Corporation of America for conversion of vanadium pentoxide from Government stocks to 200 tons of vanadium contained in three grades of ferrovanadium. The contract called for payment to be made with other Government-owned materials. These con-

[1] Commodity specialist, Division of Minerals.

version services had been advertised earlier in the year by GSA on a sealed-bid basis, but no acceptable bids were received.

As of December 31, 1965, the national stockpile inventory was 7,865 tons of vanadium, consisting of 1,001 tons contained in ferrovanadium plus 6,864 tons contained in vanadium pentoxide. In addition, AEC held 1,104 tons of vanadium contained in vanadium pentoxide compared with 2,386 tons held at the beginning of the year.

DOMESTIC PRODUCTION

Vanadium recovery from ferrophosphorus increased in importance, but the greater part of domestic production continued to come from western ores containing vanadium and uranium. The Rifle mine of Union Carbide Corp. started production in February with vanadium as its principal product.

The same four mills that recovered vanadium from uranium-vanadium and vanadium-uranium ores in 1964 continued as the producers from these sources in 1965: American Metal Climax, Inc., Grand Junction, Colo.; Mines Development, Inc., Edgemont, S. Dak.; Union Carbide Corp., Rifle, Colo.; and Vanadium Corporation of America, Shiprock, N. Mex. Both purchased ores and ores from company-owned mines were processed. Intermediate products — vanadium-bearing sludges, liquors, or tailings — from other uranium mills, or from previously accumulated stocks, contributed appreciably to 1965 production, and there was some recovery from lignite. Kerr-McGee Corp., Soda Springs, Idaho, and Vitro Chemical Co., Salt Lake City, Utah, recovered vanadium from ferrophosphorus, a byproduct of the production of elemental phosphorus from Idaho phosphate rock.

Table 2.—Recoverable vanadium of domestic origin produced in the United States, by States

(Short tons of contained vanadium)

State	1956–60 (average)	1961	1962	1963	1964	1965
Colorado	3,059	4,149	3,742	3,047	3,312	4,017
Utah	486	514	525	382	405	387
Arizona and other States [1]	311	680	944	r 433	645	822
Total	3,856	5,343	5,211	r 3,862	4,362	5,226

r Revised.

[1] Includes Idaho, 1961–65; Montana, 1957; New Mexico, 1956–65; North Dakota, 1965; South Dakota, 1960–65; Wyoming, 1956–58, 1960–65; Oregon, 1964.

Table 3.—Mine production and recoverable vanadium of domestic origin produced in the United States

(Short tons)

Year	Mine production [1]	Recoverable vanadium [2]
1956–60 (average)	7,127	3,856
1961	6,359	5,343
1962	7,647	5,211
1963	6,047	r 3,862
1964	5,184	4,362
1965	5,641	5,226

r Revised.

[1] Measured by receipts of uranium and vanadium ores and concentrates at mills, vanadium content.

[2] Recoverable vanadium contained in uranium and vanadium ores and concentrates received at mills, plus vanadium recovered from ferrophosphorus derived from domestic phosphate rock.

Table 4.—Production of vanadium pentoxide in the United States

(Short tons)

Year	Gross weight	V_2O_5 content
1956–60 (average)	7,866	7,116
1961	10,796	10,387
1962	8,955	8,483
1963	7,347	6,959
1964	9,775	9,013
1965	11,498	10,996

Data in table 4 include the vanadium pentoxide and metavanadate produced from all the above sources plus small quantities obtained from oil residues, boiler scrapings, spent catalysts, and other miscellaneous sources including that from imported chromium ores as a byproduct of chromium chemical production.

Vanadium Ferroalloys.—Ferrovanadium was produced in the United States principally by Reading Alloys Co., Inc., Shieldalloy Corp., Union Carbide Corp., and Vanadium Corporation of America. Production increases over those of 1964 were registered for ferrovanadium alone, and for the total of ferrovanadium and other vanadium-carbon-iron alloys as well.

Vanadium Metal.—Oregon Metallurgical Corp. and Vanadium Corporation of America reported production of vanadium metal. Both high-purity metal and the alloying grade of 90-percent vanadium content were produced.

CONSUMPTION AND USES

Domestic consumption of vanadium contained in ferrovanadium, other vanadium alloys, metal, and chemicals increased 33 percent from 1964 for all uses, and increased 36 percent for the manufacture of steel. The increase in the use of ferrovanadium (including other vanadium-carbon-iron alloys) for all uses was 41 percent. Consumption of vanadium in the production of both nonferrous alloys and chemicals continued to climb, but at a slower rate than was the case in 1964. Increased use of vanadium by the steel industry has been primarily for use in high-strength low-alloy steels, line and oil-drill pipe, heavy forgings, and in the production of deep-drawing steels by the continuous casting process.

The new plant of Vanadium Corporation of America at Cambridge, Ohio, was completed in January, and began to produce vanadium oxytrichloride for use as a catalyst in producing ethylene-propylene synthetic rubbers.

Table 6.—Vanadium consumed in the United States in 1965, by uses

Use	Short tons
Steel:	
High-speed	304
Hot-work tool	115
Other tool	116
Stainless	32
Other alloy [1]	2,830
Carbon	656
Total steel	4,053
Gray and malleable castings	35
Nonferrous alloys [2]	351
Chemicals	197
Other [3]	72
Grand total	4,708

[1] Includes some vanadium used in high-speed or other tool steels not specified by reporting firms.

[2] Principally titanium-base alloys.

[3] Principally high-temperature alloys, welding rods, cutting and wear-resistant materials.

Table 5.—Vanadium consumed and in stock in the United States in 1965, by type of material

(Short tons of vanadium)

Type of material	Stocks at consumer plants, Dec. 31, 1964	Consumption	Stocks at consumer plants, Dec. 31, 1965
Ferrovanadium [1]	603	4,042	608
Oxide	12	127	37
Ammonium metavanadate	28	175	26
Other [2]	100	364	157
Total	743	4,708	828

[1] Includes other vanadium-carbon-iron alloys.

[2] Consists principally of vanadium-aluminum alloy and relatively small quantities of other vanadium alloys and vanadium metal.

STOCKS

Stocks of vanadium as fused oxide, precipitated oxide, metavanadate, metal, alloys, and chemicals, held by producers of these items, totaled 1,186 tons at yearend. This is in addition to the consumers' inventory reported in table 5, and is to be compared with the revised figure of approximately 2,250 tons at the end of 1964. Vanadium contained in stocks of intermediates, sludges, and tailings held by oxide producers is not included in any of these figures.

PRICES

Domestic ore continued to be quoted at 31 cents per pound of contained vanadium pentoxide, nominal. This reflected actual prices paid with some upward adjustments reported for certain ores of relatively high vanadium content. Prices for technical-grade vanadium pentoxide were quoted throughout the year at $1.15 per pound of contained vanadium pentoxide. Actual prices for large lots of fused vanadium pentoxide, a technical grade, rose gradually during the year from approximately 95 cents at the beginning of the year to $1.15 and higher at yearend. Government sales of fused oxide from AEC stocks on competitive bidding brought an average price of $1.128 for 177 tons (100 tons vanadium content) sold in September, and an average price of $1.245 for 2,110 tons (1,182 tons vanadium content) sold late in December. Approximately 80 tons in the last sale brought $1.375 per pound. These sales had certain restrictions regarding exports. European prices for fused oxide were higher than the domestic price in 1965.

The price of ferrovanadium containing 50 to 55 percent vanadium remained at $2.50 per pound of contained vanadium, delivered, until June 1. At that time, a previously announced price increase by Vanadium Corporation of America became effective to $2.65, f.o.b. plant, freight allowed for 100 pounds or more; Union Carbide's price went to $2.62, f.o.b. producing plant. In October, Vanadium Corporation raised its price to $2.88, basis unchanged, while Shieldalloy and Reading Alloys increased their prices to $2.95, delivered. The basis for pricing Carvan was changed by Union Carbide Corp., effective June 1, from $2.17 delivered to $2.15 f.o.b. plant, both prices per pound of contained vanadium.

The nonductile, 90-percent grade of vanadium metal, used mainly for alloy additions, continued to be quoted throughout the year at $3.45 per pound in 100-pound lots. High-purity ductile metal was priced at $30 to $50 a pound.

FOREIGN TRADE

Beginning January 1, 1965, exports of flue dust and other vanadium waste materials were no longer reported separately.

There were no imports of ore or concentrate in 1965, and imports of ferrovanadium were greatly reduced from the levels of the two preceding years. Vanadium carbide imports consisted of 690 pounds from West Germany, valued at $2,301; less than 1 pound of anhydride vanadium pentoxide, valued at $119, came from the United Kingdom; and imports of other vanadium compounds totaled 194 pounds from the United Kingdom with a valuation of $816.

Table 7.—U.S. imports of ferrovanadium, by countries

Country	General imports [1]				Imports for consumption [2]			
	1964		1965		1964		1965	
	Gross weight (pounds)	Value	Gross weight (pounds)	Value	Gross weight (pounds)	Value	Gross weight (pounds)	Value
Austria	583,497	$731,655	88,184	$99,875	413,573	$491,058	39,566	$53,468
Belgium-Luxembourg [3]	249,798	191,883	13,448	21,065	244,457	183,164	12,350	19,715
Germany, West	44,092	59,353	----	----	66,113	93,769	----	----
Italy	11,023	11,481	----	----	----	----	----	----
Japan	44,092	50,507	----	----	65,134	72,660	----	----
Total	932,502	1,044,879	101,632	120,940	789,277	840,651	51,916	73,183

[1] Comprises ferrovanadium received in United States; part for immediate consumption and remainder entering bonded warehouses.

[2] Comprises ferrovanadium received for immediate consumption plus material withdrawn from bonded warehouses.

[3] Reported figures for both general imports (110,950 pounds at $4,380) and imports for consumption for Belgium-Luxembourg for June 1964 are being questioned.

Table 8.—U.S. exports of vanadium, by countries
(Pounds)

Destination	Ferrovanadium and other vanadium alloying materials containing over 6 percent vanadium (gross weight)		Vanadium ore, concentrates, pentoxide, vanadic acid, vanadium oxide, and vanadates (except chemically pure grade) (vanadium content)	
	1964	1965	1964	1965
North America:				
Canada	133,189	385,625	44,235	50,863
Honduras	683	----	----	----
Mexico	44,624	38,604	1,232	----
Total	178,496	424,229	45,467	50,863
South America:				
Argentina	----	----	280	----
Brazil	----	2,441	----	----
Colombia	----	----	145	5,541
Total	----	2,441	425	5,541
Europe:				
Austria	----	----	313,689	495,790
Belgium-Luxembourg	----	----	1,379,925	106,517
Czechoslovakia	----	----	----	144,529
Denmark	----	----	2,680	----
France	----	----	----	217,946
Germany, West	7,354	10,457	30,296	190,028
Ireland	5,070	----	----	----
Italy	----	----	----	370
Netherlands	7,988	----	----	45,272
Spain	----	----	63,840	5,981
Sweden	----	----	----	117,827
United Kingdom	6,149	451	86,634	59,543
Total	26,561	10,908	1,877,064	1,383,803
Africa: South Africa, Republic of	----	----	----	148
Asia:				
India	----	2,000	2,470	220
Japan	601	----	418,264	412,018
Korea, South	----	----	----	791
Pakistan	----	----	----	448
Philippines	----	----	115,248	----
Taiwan	----	----	2,031	1,761
Total	601	2,000	538,013	415,238
Oceania: Australia	585	600	224	503
Grand total:				
Quantity	206,243	440,178	2,461,193	1,856,096
Value	$308,880	$747,399	$3,619,654	$3,540,434

WORLD REVIEW

In addition to the production reported in table 9, there was some relatively small production of vanadium in 1965, such as that described herein for Canada from oil residues and for Japan from waste acids, for which data are lacking. It is believed

Table 9.—World production of vanadium in ores and concentrates, by countries
(Short tons)

Country	1961	1962	1963	1964	1965 p
Argentina	e 4	9	r 2	r 2	NA
Finland	701	629	771	r 1,084	e 1,100
South Africa, Republic of	1,422	1,393	r 1,392	1,282	1,519
South-West Africa (recoverable vanadium)	1,145	1,019	1,134	r 1,111	1,275
United States (recoverable vanadium)	5,343	5,211	r 3,862	4,362	5,226
Zambia	r 107	3	----	----	----
World total e	r 8,722	8,264	r 7,161	r 7,841	9,150

e Estimate. p Preliminary. r Revised. NA Not available.

that there was some recovery of a byproduct or secondary nature in West Germany, and possibly in Sweden and Norway as well. The U.S.S.R. is believed to have recovered enough vanadium for its own needs, probably from titaniferous magnetites for the most part.

Canada.—Canada's potential as a vanadium source began to materialize in January 1965 with the start of vanadium oxide recovery from oil residues at the Montreal East Refinery of Canadian Petrofina Ltd. at a rate of approximately 800 pounds of vanadium pentoxide per day. This was Canada's first commercial vanadium production, expected to be increased to 1,500 pounds per day in 1966. Vanadium content of the Venezuelan crude oil being processed was 130 parts per million.

Iron-blast-furnace slags, containing 0.075 to 1 percent vanadium pentoxide, produced at Sydney, Nova Scotia, from Wabana iron ore was a potential vanadium source, as was the Athabaska tar sands near Fort McMurray, Alberta. These tar sands were the subject of a $220 million development to produce 45,000 barrels of oil per day starting in September 1967. Coke will be one of the products, to be burned as fuel to supply steam requirements. The resulting ash will have a vanadium content of approximately 4 percent, the equivalent of 240 parts per million in the bitumen.

Ferrovanadium was produced for export and domestic consumption by Masterloy Products Ltd., Ottawa, Ontario. The largest use for vanadium in Canada in 1964 was by the iron and steel industry in the form of ferrovanadium; 204 tons was consumed with an average vanadium content of 56 percent. The second largest use was as a catalyst in the manufacture of sulfuric acid by the contact process.[2]

Finland.—The U.S.S.R., West Germany, and Sweden were the principal recipients of Finnish vanadium in 1964. There was no domestic consumption. Expansion of production of iron concentrates in 1966–67 at Otanmäki Oy, the country's only vanadium producer, will result in a 20-percent increase in vanadium output.

Japan.—Ishihara Sangyo Kaisha, Ltd., recovered vanadium as ammonium metavanadate from waste sulfuric acid obtained in the manufacture of titanium dioxide. The waste acid had a vanadium content of 0.2 gram per liter. Principal product of the waste treatment process was ammonium sulfate for fertilizer.

South Africa, Republic of.—In 1965, there were exported 2,369 tons of fused pentoxide and 51 tons of ammonium metavanadate, compared with 3,575 and 67 tons, respectively, in 1964. Anglo-American Corporation of South Africa Ltd. subsidiary, Transvaal Vanadium Co. (Pty) Ltd., was the only producer. The abnormally high 1964 exports reflected shipments from its previously accumulated stocks. Ruigheek Chrome Mines, a subsidiary of Union Carbide Corp., acquired the assets of the inactive Federale Vanadium Mining Co., and planned to produce vanadium oxide by mid-1966.[3]

Anglo-American Corporation of South Africa, Ltd., signed a contract with a member of the Davy Ashmore group, a British firm, for construction of the new steel and vanadium plant to be built at Witbank for Highveld Steel and Vanadium Corp. Ltd. (formerly Highveld Development Co., Ltd.). Substantial loan funds were to be provided by a consortium of European banks. Vanadium-bearing titaniferous magnetite from the Bushveld complex will be prereduced in coal-fired kilns which will feed 50-foot-diameter electric furnaces in which titanium will be slagged off. The vanadium will then be slagged off in special vessels using oxygen and silica. The resulting hot metal will be blown to steel by the basic oxygen process. Trial mining started late in 1965 at the new Mapoch's mine at Roosenekal, Transvaal, 40 miles west of Lydenburg. This mine will supply ore to the project at the rate of 1 million tons per year by October 1967.

South-West Africa.—The Berg Aukas mine of South West Africa Co., Ltd., produced 10,930 tons of lead-vanadium concentrate in 1964 compared with 11,250 tons in 1963. It continued to be the only vanadium producer. Assured ore reserves at the beginning of 1965 were 305,000 tons analyzing 1.56 percent vanadium pentoxide, 7.4 percent lead, and 33.1 percent zinc.

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[2] Schneider, V. B. Vanadium—1964. Mineral Resources Division, Department of Mines and Technical Surveys, Ottawa, 1965, 5 pp.

[3] Bureau of Mines. Mineral Trade Notes. V. 62, No. 3, March 1966, pp. 32–33.

TECHNOLOGY

Studies of the solubility of carbon in electrorefined vanadium by the Bureau of Mines determined an approximate weight-percent of 0.27 at the eutectic temperature 1,650° C. and 0.03 at 700° C. With increase of carbon content to the solubility limit there was a small increase in tensile strength, hardness, and coefficient of thermal expansion. Room temperature electrical resistivity did not vary. The carbon content of commercial calcium-reduced metal usually falls between 0.05 and 0.3 weight-percent.[4]

Electrorefined vanadium in the temperature range of 77° to 273° K was evaluated as to tensile properties and the effects of interstitial impurities.[5] In this range of low temperatures, electrorefined vanadium possesses low strength and high ductility.[6]

High-purity vanadium metal of 99.95-percent purity was prepared by electrorefining commercial vanadium metal in a molten sodium bromide, potassium bromide, and vanadium bromide electrolyte. The commercial metal used for feed was produced by calcium reduction and had a vanadium content of approximately 99.6 percent. Only iron and oxygen were transferred to the product in quantities exceeding 50 parts per million. Very ductile arc-melted ingots, which could be cold-rolled into foil without annealing, were prepared from the refined product.[7] Using a variety of chloride electrolytes, high-purity ductile metal of somewhat lower purity was obtained from feed materials of lower vanadium contents ranging from 80 to 95 percent vanadium.[8]

Commercial high-purity vanadium metal was evaluated for susceptibility to stress corrosion cracking in different acids and corrosive salts.[9] The hafnium-vanadium system was the subject of study by the Bureau of Mines because of the possibility of using hafnium-vanadium alloys advantageously in atomic reactors.[10] Heats of formation of ferrous vanadate from the elements and from the oxides were determined in another investigation.[11]

Studies, at the Argonne National Laboratory of AEC, of a lithium hydride fuel cell for use with a reactor suggested that high-purity vanadium metal would be the best diaphragm material. Because the rate of hydrogen diffusion through the diaphragm governs the power output, the diaphragm is the key to the system.[12] The vanadium metal used analyzed 99.81 percent vanadium, 0.019 percent iron, 0.037 percent carbon, 0.028 percent nitrogen, and 0.086 percent oxygen.[13]

Investigations at Oregon State University, Corvallis, Oreg., showed that vanadium pentoxide behaves in a manner similar to manganese dioxide as a cathode in electrochemical cells. It was found that moderate polarization occurred during cathodic discharge. After partial discharge a gradual recuperation occurred to a potential that nearly equalled the previous potential.[14]

In studying the low-temperature embrittlement of high-purity vanadium metal at the Ames Laboratory of AEC it was found that a hydrogen concentration of 6 parts per million in the temperature range from 77° to 298° K gave a hydrogen "embrittlement surface" with characteristics similar to those exhibited by hydrogen embrittlement of steel.[15] The same labora-

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[4] Mathews, D. R., and E. A. Rowe. Properties of Vanadium-Carbon Alloys. BuMines Rept. of Inv. 6628, 1965, 14 pp.

[5] Mathews, D. R., G. H. Keith, and E. A. Loria. Effects of Interstitial Impurities on the Mechanical Properties of Electrorefined Vanadium at Low Temperatures. BuMines Rept. of Inv. 6637, 1965, 23 pp.

[6] Loria, E. A., G. H. Keith, and E. A. Rowe. Correlation of Yield Behavior in Electrorefined Vanadium with Interstitial Impurities. BuMines Rept. of Inv. 6716, 1965, 31 pp.

[7] Sullivan, T. A., and F. R. Cattoir. Electrorefining Vanadium in a Molten Bromide Electrolyte. BuMines Rept. of Inv. 6631, 1965, 12 pp.

[8] Sullivan, T. A. Electrorefining Vanadium. J. Metals, v. 17, No. 1, January 1965, pp. 45–48.

[9] Carter, J. P., C. B. Kenahan, and David Schlain. Stress Corrosion Cracking of Vanadium, Molybdenum, and a Titanium-Vanadium Alloy. BuMines Rept. of Inv. 6680, 1965, 18 pp.

[10] Deardorff, D. K., M. I. Copeland, L. L. Oden, and H. Kato. The Hafnium-Vanadium System. BuMines Rept. of Inv. 6594, 1965, 11 pp.

[11] Barany, R. Heats of Formation of Geothite, Ferrous Vanadate, and Manganese Molybdate. BuMines Rept. of Inv. 6618, 1965, 10 pp.

[12] Steel. New Methods Turn Heat to Electricity. V. 156, No. 14, Apr. 5, 1965, pp. 66, 70, 72.

[13] Heinrich, Robert R., Carl E. Johnson, and Carl E. Crouthamel. Hydrogen Permeation Studies. 2. Vanadium as a Hydrogen Electrode in a Lithium Hydride Cell. J. Electrochem. Soc. v. 112, No. 11, November 1965, pp. 1071–1073.

[14] Watson, Naola V., and Allen B. Scott. Discharge and Recuperation of the Vanadium Pentoxide Electrode. J. Electrochem Soc., v. 112, No. 9, September 1965, pp. 883–886.

[15] Van Fossen, R. H., Jr., T. E. Scott, and O. N. Carlson. The Effect of Strain Rate and Temperature on the Ductility of Pure and Hydrogenated Vanadium. J. Less-Common Metals (Amsterdam, Netherlands), v. 9, No. 6, December 1965, pp 437–451.

tory investigated the effects of nitrogen and carbon on low-temperature embrittlement of high-purity vanadium.[16]

At high pressures in the temperature range 750° to 1,050° C, studies of the oxidation of vanadium showed that sufficient heat is released on the admission of oxygen to produce a self-maintaining burning reaction.[17]

A patent was issued for a semikilled high-strength, low-alloy steel, sold under the trade name of "V Steels," containing essentially 0.02 to 0.20 percent vanadium, 0.008 to 0.024 percent nitrogen, 0.60 to 2.00 percent manganese, 0.12 to 0.50 percent carbon, and the remainder iron.[18] Another patent covered a process for removing vanadiferous deposits from boiler tubes by alternately spraying with an aqueous hydrogen peroxide solution and contacting with a high-velocity jet of water.[19] Patents were issued for a number of catalysts and vanadium extractive processes.

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[16] Thompson, R. W., and O. N. Carlson. Effect of Nitrogen and Carbon on the Low-Temperature Embrittlement of Vanadium. J. Less-Common Metals (Amsterdam, Netherlands), v. 9, No. 5, November 1965, pp. 354–361.

[17] Price, W. R., and J. Stringer. The Oxidation of Vanadium at High Temperatures. J. Less-Common Metals (Amsterdam, Netherlands), v. 8, No. 3, March 1965, pp. 165–185.

[18] Melloy, George F., Joseph D. Dennison, Jr., and Bernard J. Fischer (assigned to Bethlehem Steel Corp.). Vanadium Nitrogen Steel. U.S. Pat. 3,173,782, Mar. 16, 1965.

[19] Sewell, Richard B H., and James R. Brown (assigned to Her Majesty the Queen in the right of Canada). Process for Removal of Vanadium Deposits. U.S. Pat. 3,173,874, Mar. 16, 1965.

Vermiculite

By Timothy C. May [1]

Production of crude vermiculite in the United States during 1965 was 10 percent higher than in 1964, and value increased 23 percent. The quantity and value of exfoliated vermiculite sold or used by producers was approximately the same as in 1964.

Table 1.—Vermiculite production statistics

	1956–60 (average)	1961	1962	1963	1964	1965
United States:						
Production:						
Crude..........thousand short tons..	195	206	205	226	226	249
Value..........thousand dollars..	$2,813	$3,350	$3,293	$3,572	$3,613	$4,460
Average value per ton............	$14.43	$16.26	$16.06	$15.81	$15.99	$17.91
Exfoliated.......thousand short tons..	156	151	152	172	177	177
Value..........thousand dollars..	$9,853	$10,787	$11,152	$13,877	$13,862	$13,424
Average value per ton............	$63.16	$71.44	$73.37	$80.68	$78.32	$75.84
World: Production crude..thousand short tons..	255	283	295	329	343	382

DOMESTIC PRODUCTION

Crude Vermiculite.—Three companies in two States reported production in 1965. W. R. Grace & Co., Zonolite Division, with operations in Lincoln County, Mont., and Laurens County, S.C., was the principal producer. American Vermiculite Co., and Patterson Vermiculite Co., Laurens County, S.C., also were producers.

Exfoliated Vermiculite.—Twenty-four companies with 51 plants, 2 less each than last year, in 33 States exfoliated vermiculite in 1965. California and Florida had four plants each; Illinois, Minnesota, South Carolina, and Texas, three plants each; Missouri, New Jersey, Oregon, and Pennsylvania, two plants each; Alabama, Arizona, Arkansas, Colorado, Georgia, Hawaii, Kansas, Kentucky, Louisiana, Maryland, Massachusetts, Michigan, Montana, Nebraska, New Mexico, New York, North Carolina, North Dakota, Ohio, Oklahoma, Utah, Washington, and Wisconsin, one plant each. W. R. Grace & Co., Zonolite Division, had 19 plants in 16 States and was by far the largest producer.

CONSUMPTION AND USES

Producers of exfoliated vermiculite reported the following end-use percentages: Aggregates (concrete, plaster, cement) 48 percent; insulation (loose fill, block, pipe covering, packing) 31 percent; agriculture (horticulture, soil conditioning, fertilizer carrier, litter) 14 percent; and miscellaneous, 7 percent.

PRICES

The average value of crude, screened, and cleaned vermiculite at the mine in 1965 was $17.91 per short ton. The average value of the exfoliated product f.o.b. pro-

[1] Commodity specialist, Division of Minerals.

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ducers' plant was $75.84 per ton. Over a period of 10 years, 1956–65, the price of crude vermiculite increased 35 percent, and the price of exfoliated vermiculite rose 20 percent.

E&MJ Metal and Mineral Markets quoted nominal yearend prices for crude vermiculite as follows: Per short ton, f.o.b. mines, Montana and South Carolina, $11.50 to $24; and South Africa, c.i.f. Atlantic ports, $29.55 to $40.15.

WORLD REVIEW

Canada.—All the crude vermiculite exfoliated was imported from the United States and the Republic of South Africa. In 1964, 307,000 cubic yards of exfoliated vermiculite, valued at $2.4 million, was produced. Five companies exfoliated vermiculite at the 10 following locations in 1964: British Columbia-Vancouver (two); Alberta-Calgary; Saskatchewan-Regina; Manitoba-Winnepeg and St. Boniface; Ontario-Toronto and St. Thomas; and Quebec-Lachine and Montreal. Loose insulation consumed 78 percent of the output; plaster accounted for 12 percent; insulating concrete 6 percent; and 4 percent was used for underground pipe insulation, and for agriculture. Exfoliated vermiculite is marketed in bags of 3 and 4 cubic feet and sold at 25 to 30 cents per cubic foot.[2]

It was reported that Olympus Mines began operation of the first large-scale concentrator to treat Canadian mined vermiculite ore. The plant was at Stanleyville, 10 miles southwest of Perth, Ontario. The completed plant was designed to produce 300 tons per day.[3]

South Africa, Republic of.—Production of crude vermiculite in 1965 was 13 percent higher than in 1964. Vermiculite was produced by the Transvaal Ore Co., Ltd., at Phalaborwa. For the first time, information was not available on exports of crude vermiculite by destination. Total exports were 2 percent lower in volume than in 1964 and 3 percent lower in value.

[2] Wilson, S. H. Lightweight Aggregates, 1964. Dept. Mines and Tech. Surveys, Ottawa, Canada, April 1965, 6 pp.

[3] Canadian Mining Journal (Quebec). Canadian Developments. V. 86, No. 6, June 1965, p. 10.

Table 2.—Free world production of vermiculite by countries [1, 2]

(Short tons)

Country [1]	1961	1962	1963	1964	1965 [p 3]
Argentina	r 3,919	2,962	r 3,064	r 4,031	e 4,100
India	697	r 477	746	r 473	806
Kenya	---	22	101	r 37	24
South Africa, Republic of	71,118	85,534	98,758	111,872	126,911
Sudan	55	55	---	---	---
Tanzania	157	72	30	144	108
United Arab Republic (Egypt) [2]	85	313	33	459	639
United States (sold or used by producers)	206,637	205,747	226,278	226,299	249,352
Free world total [1 2]	r 282,668	r 295,182	r 329,010	r 343,315	381,940

e Estimate. p Preliminary. r Revised.

[1] Vermiculite is produced in Brazil, but data are not available, and no estimate of production is included in the total.

[2] Includes mica.

[3] Compiled mostly from data available July 1966.

TECHNOLOGY

Research headed the program of the 24th annual meeting of the Vermiculite Institute of Chicago held at Point Clear, Ala., April 24 to 29, 1965. Papers presented included one on the development of Cornel Mix, a synthetic soil in which vermiculite is a major ingredient. The mix is used commercially as a medium for germinating and growing vegetable and flower crops.[4]

A micaceous vein in close association with a massive chromite deposit in the Twin Sisters Mountains, Wash., was found to be composed exclusively of vermiculite. The geologic setting, physical properties, chemical data, differential thermal analysis,

[4] Pit and Quarry. Vermiculite Institute Convention Stresses Expanding Markets. V. 57, No. 12, June 1965, pp. 108–109.

Table 3.—Republic of South Africa: Exports of crude vermiculite by countries
(Short tons)

Destination	1963	1964	1965
Australia	2,031	2,932	NA
Belgium	794	1,442	
Canada	4,839	2,879	
Denmark	1,313	866	
France	7,413	10,343	
Germany, West	7,599	9,922	
Italy	15,721	18,289	
Japan	924	1,687	
Netherlands	1,647	1,127	
Spain	1,368	2,287	
Sweden	585	587	
United Kingdom	28,308	34,502	
United States	14,337	18,417	
Other countries	3,908	2,574	
Total	90,787	107,854	105,947
Total value [1]	$1,723,365	$2,026,972	$1,964,385
Average value	$18.98	$18.79	$18.54

NA Not available.
[1] Converted to U.S. currency at the rate of one rand equals US$1.3948 (1963) US$1.3909 (1964) and US$1.3927 (1965).

Source: Quarterly Information Circular on Minerals for the Republic of South Africa and the Territory of South-West Africa.

X-ray diffraction analysis, and proposed genesis of the Twin Sisters vermiculite were discussed.[5]

The advantages of using vermiculite in concrete mix was mentioned. Requirements for the components, proportioning, and installation of poured-in-place vermiculite concrete for roofs and slabs-on-grade, as they appear in a new American Standard, are described.[6]

Vermiculite concrete was used as a cushioning material in a setup, used for dynamic testing of composite members. The cushioning material was used between the falling mass and the specimen to shape the load pulse transmitted to the specimen. A schematic diagram illustrates the beam setup for dynamic loads.[7]

The insulating properties of vermiculite, particularly as applied to the insulation of industrial chimneys, was covered in a release published by Mandoval Ltd., London, under the management of Rio Tinto-Zinc Group and distributors of crude vermiculite. Technical and specification details, as well as sectional drawings illustrate how vermiculite is used.[8]

The surface morphology of vermiculites from several sources was studied by electron microscopy. Unlike the smooth surfaces of micas, the vermiculite surfaces show micromorphological structural variations, such as small humps, prominent crystallographic steps on the basal cleavage planes, marginal rolling of the layers, and layer buckling.[9]

Results on fusion studies of the mineral vermiculite, the leaching characteristics of the fused mass, and the volume reduction ratios are given. The fixation of spent vermiculite, incinerator ashes, and chemical sludges in vitreous matrices was described. The apparatus for studying volatilization loss was included.[10]

A patent was issued for the use of exfoliated vermiculite in the coating of the exposed surface of bituminous roofing and siding material.[11]

A patent was granted for the production of a flowable, fire-retardant composition that includes exfoliated vermiculite as one of the materials. The composition is used

[5] Gaudette, Henri. Magnesium Vermiculite From the Twin Sisters Mountains, Washington. The Am. Miner., v. 49, Nos. 11 and 12, November–December 1964, pp. 1754–1763.
[6] Barron, L. A. Up-to-the Minute Requirements for Vermiculite Concrete. Mag. of Standards, v. 36, No. 7, July 1965, pp. 208–211.
[7] Perry, E. S. Simple Setup for Applying Impact Loads. Mat. and Res. Standards, v. 5, No. 10, October 1965, pp. 515–516.
[8] Chemical Age (London). Vermiculite for Insulation of Industrial Chimneys. V. 93, No. 2384, Mar. 20, 1965, p. 462.
[9] Raman, K. V., and M. L. Jackson. Vermiculite Surface Morphology. Clays and Clay Minerals, Proc. 12th Nat. Conf., Clays and Clay Minerals, 1963, pp. 423–429; The MacMillan Co., New York 1964.
[10] Rastogi, R. C., J. D. Sehgal, and K. T. Thomas. Investigation of Materials and Methods for Fixation of Low and Medium Level Radioactive Waste in Stable Solid Media. Nuclear Sci. Abs., v. 19, No. 16, Aug. 31, 1965, Abs. 31618.
[11] Klimboff, M. (assigned to Flintkote Co.). Bituminous Roofing and Siding Material Coated with Exfoliated Vermiculite. U.S. Pat. 3,207,619, Sept. 21, 1965.

in the manufacture of extra thick shingles on a conventional asphalt roofing machine.[12]

British patents were issued for the following: A method of making precast lightweight insulating composite structural blocks[13] and a composition consisting of exfoliated vermiculite, expanded perlite, or other low-density silicate which has been treated with a fatty acid, for use in protecting and insulating underground pipes.[14]

A French patent was issued on a method for using vermiculite in the casting ingots of high-melting metals. The vermiculite is introduced into the mold, and the molten metal is then poured around the vermiculite particles.[15]

A German patent was granted for a method that removes oil, benzene, or other liquid hydrocarbon from water. The contaminated water is passed through a container that is loosely filled with exfoliated vermiculite or expanded perlite.[16]

[12] Walker, R. T., and C. C. Schuetz (assigned to U.S. Gypsum Co.). Fire Resistant Asphalt Coating Composition and Shingle. U.S. Pat. 3,180,783, Apr. 27, 1965.

[13] Hewitt, F. (assigned to F. & D. M. Hewitt, Ltd.). British Pat. 994,306. June 2, 1965.

[14] Frey, L. (assigned to Protexulate Ltd.). British Pat. 997,795, July 7, 1965.

[15] French Pat. 1,365,243, May 19, 1964.

[16] German Pat. 1,167,278, Apr. 2, 1964.

Water

By William H. Kerns [1]

Water supply and demand problems received increased domestic and worldwide attention in 1965 from the U. S. and other country governments, Federal and State agencies, industries, associations, and individuals. Although the world as a whole is in no danger of running short of water, it faces the problems of finding or producing and delivering water to the place, at the time, in the quality and quantity required, and at the price man is willing and able to pay.

Expanding population with attendant increased food and other material requirements and growing industrialization have increased fresh-water demands at an astonishing rate. Ironically, the population explosion and rapid industrial development have been the sources of greater amounts of wastes being generated and discharged each year. These wastes have increased pollution and contamination of the water supply, thereby reducing the supply of usable water. Many rivers and streams that for countless decades were capable of draining off waste products can no longer carry the increased waste load and still remain suitable for human and industrial use.

Possible solutions to the water supply problems in the United States include developing new sources of water by tapping the oceans and other natural brines and the skies (desalinating sea and brackish water and by seeding clouds, respectively), regulating and redistributing our streamflow to a greater extent, intensifying pollution control, and other equally costly measures.

Legislation and Government Programs.—The U.S. Congress enacted several major programs to combat water pollution, set up a Federal-State coordinated program for comprehensive water resources planning and development, and established a cooperative Federal-State water resources research and training program. These Federal Acts included:

1. The Water Quality Act of 1965, signed into law by President Johnson on October 2, established the Federal Water Pollution Control Administration to consolidate enforcement, research, and grant programs for pollution control. The Act set up standards of water quality on interstate streams and gave States until July 1, 1967, to develop satisfactory work-quality criteria. If the States have not established acceptable quality criteria by this date, the Federal Government will enforce its own standards. The Act raised the limit of Public Law 660 grants for sewage treatment plant construction from $600,000 to $1.2 million for each project and enlarged the budget for such grants from $100 to $150 million per year for 2 years. In addition, the Act authorized $20 million per year for 4 years to subsidize studies and demonstrations of storm and sanitary sewer separation.

2. The Water Resources Planning Act of 1965, recommended by the Senate Select Committee on National Water Resources in 1961, was signed into law July 22, 1965. The Act provided for the means of full collaboration between States and the Federal Government in comprehensive planning for the best use of our water and related land resources. The Act established a Water Resources Council and provided for the formation of river basin commissions and for financial assistance to the States for coordinated planning of water and resources development and use. Members of the Council, appointed by the President, are the Secretaries of Agriculture; the Army; Interior; Health, Education and Welfare; and the Chairman of the Federal Power Commission. Secretary

[1] Commodity specialist, Division of Minerals.

of the Interior Udall was designated as chairman. The Act authorized the President, with the concurrence of at least half the States concerned, to set up river basin commissions for any river basin or group of related basins. The commissions are to be financed jointly by the participating States and the Federal Government. The New England River Basin Commission was the first commission to be approved by the Federal Water Resources Council under this Act and its formation marked a new era in Federal-State cooperation in the development of the water resources of this Nation—a relationship needed to assure adequate water for the future.

3. The Federal Water Project Recreation Act of 1965 provided for uniform policies with respect to recreation and fish and wildlife benefits and to costs of Federal multipurpose water resource projects.

4. The Solid Waste Disposal Act, an amendment to the Clean Air Act, provided for a national program of research and development, including studies of both reducing the amount of wastes and of recovering and using the wastes that accumulate. Included in these wastes are sewage sludges and solid and semisolid industrial waste products. The Act also provided for technical and financial assistance to State and local governments, and interstate agencies for planning, developing, and conducting solid-waste disposal programs.

The Environmental Pollution Panel of the President's Science Advisory Committee reported its findings on a study[2] of the water, air, and land pollution problems. The effects of pollution, sources of pollution, and recommendation for action were given. The committee favors a system of effluent charges to inhibit discharge of pollutants to waterways and to the atmosphere.

Along the same line, the proceedings[3] of the White House Conference on Natural Beauty called by the President of the United States in Washington, D.C., in May 1965, reported the findings and recommendations of 15 conference panels on as many subjects considered to produce new ideas and approaches for enhancing the beauty of America. Many of the panels considered methods for controlling waste products that are menacing the world we live in, our enjoyment, and our health, and blighting our water, air, and land with the poisons, chemicals, and solids which are byproducts of technology and industry.

In addition, a report[4] analyzed the economic reasoning needed to gain a full understanding of water resource and pollution problems.

A program of water resources research was outlined for the decade 1967-76, with budgets projected to 1971.[5] An approximate doubling of the present research effort was recommended by fiscal year 1971 and expenditures and time schedules were proposed consistent with the apparent priorities of the various research areas in terms of problems to be solved and returns to be expected. In part 1 of the report, the basis for long-range planning of the research is outlined; in part 2, the 14 major problem areas are discussed and recommendations for action are given; and in part 3, current programs in 44 research subcategories are summarized and directional recommendations regarding each given for the decade ending in 1976.

Large international groups gathered first at the United Nations in New York on September 22, then at the Departments of State and Interior in Washington, D.C., on October 3 for up-to-date reviews of the status, technology, and economics of winning fresh water from salt and brackish water. At the First International Symposium on Water Desalination in Washington, D.C., described in more detail in the technology section, an announcement was made of a three-way agreement between the United States, Mexico, and the International Atomic Energy Agency to carry out a technical and economic study for building a large-scale dual-purpose plant to produce fresh water and electricity for the arid region of Lower California and Sonora in Mexico, and California and Arizona in

[2] The White House. Restoring the Quality of Our Environment. President's Science Advisory Committee, Rept. of the Environmental Pollution Panel, November 1965, 317 pp.

[3] White House Conference on Natural Beauty. Beauty for America. Proc. of the White House Conf. on Natural Beauty, Washington, D.C., May 24–25, 1965, 782 pp.

[4] Herfindahl, O. C., and A. V. Kneese. Quality of the Environment. An Economic Approach to Some Problems in Using Land, Water, and Air. Resources for the Future, Inc., Washington, D.C., 1965, 96 pp.

[5] Executive Office of the President, Office of Science and Technology. A Ten-Year Program of Federal Water Resources Research. Fed. Council for Sci. and Tech., Committee on Water Resources Res., February 1966, 88 pp.

the United States. The study would explore basic desalination processes, and types of fuel for the plant. Agreement was also reached in substance at the symposium which was expected to result in an undertaking by the Saudi Arabian Government to construct a water desalting and electric power plant at Jidda, Saudi Arabia. The Department of the Interior was to contribute the design for the desalting portion of the dual-purpose plant which was expected to produce 5 million gallons of fresh water per day and 36 megawatts of electric power and to cost the Saudi Arabian Government approximately $14 million.

The Bechtel Corp. completed a 1-year study of the technical and economic feasibility of a large-scale combination electric and water desalting plant and submitted it to the Metropolitan Water District of Southern California, the Department of the Interior's Office of Saline Water, and the Atomic Energy Commission. Financial assistance for the study, now under review, was provided by the two Federal Government agencies.

Under the Water Resources Research Act of 1964 (Public Law 88-379), the U.S. Department of the Interior, Office of Water Resource Research (OWRR), expanded and coordinated the public water works programs and water research efforts in 1965. Federal-State cooperative water research centers or institutes were established and were operated in each of the 50 States and the Commonwealth of Puerto Rico. Each State center or institute was charged with conducting competent research, investigations, and experiments of either a basic or practical nature, or both, dealing with water and resources related to water and to provide for the training of scientists through such research, investigations, and experiments. Section 100 of the Act authorized an annual allotment of Federal funds to each of the 51 centers. For fiscal year 1966 ending June 30, 1966, the allotment for each center was $87,500; for fiscal year 1967 the funding was the same as for fiscal year 1966. Section 101 of the Act authorized matching funds for water resources research projects at the centers. For these projects the centers were required to match Federal funds dollar for dollar with State or non-Federal funds available to them. Ninety-nine projects were submitted by 26 of the 51 centers, requesting $3 million in matching funds or nearly three times the $1 million available in fiscal year 1966. Sixty-two of these 99 projects were funded with the $1 million available and work was begun on the projects. As authorized by the Act, the first annual report to Congress was published,[6] summarizing the activities and progress of the OWRR for the fiscal year ending June 30, 1965.

To promote the exchange of scientific information in the water resources research field, OWRR contracted with the Science Information Exchange (SIE) of the Smithsonian Institution to prepare catalogs indexing water resource research projects.[7] In volume 1, part 1 of the catalog, 1,545 Federally-supported water resources research projects were listed and in part 2, 501 non-Federally supported water resource research projects were listed. Furthermore, the projects were listed by major categories, and multiple indexes were provided to make the publications particularly useful to the researcher.

A report[8] published by the OWRR had as its main purposes the description in capsule form of the roles of various Federal agencies and other groups in the area of water quality, delineation of the most urgent research problems, and consideration of ways to advance water research.

The Office of Saline Water (OSW) continued its research and development programs toward lowering the cost of producing fresh water from saline water under an impetus of substantially increased funds provided by Congress. Progress reviews on selected OSW programs are given in the technology section of this report and in the OSW report for 1965 to be published in 1966.

Several projects related to water were continued by the Bureau of Mines, such as flood-control, deep-well pumping, and drainage-alleviation in the anthracite coal

[6] U.S. Department of the Interior, Office of Water Resources Research. Cooperative Water Resources Research and Training, 1965 Annual Report. December 1965, 143 pp.

[7] U.S. Department of the Interior, Office of Water Resources Research. Water Resources Research Catalog. V. 1, Part 1. Federally Supported Research in Progress. OWRR-1/1, February 1965, 441 pp. V. 1, Part 2. Non-Federally Supported Research in Progress, OWRR-1/2, September 1965, 149 pp.

[8] McKee, Jack Edward. Report on Guidelines for Investigations Into the Quality Aspects of Water Resources Research. U.S. Department of the Interior, Office of Water Resources Research, January 1966, 22 pp.

fields. These programs implemented Federal and State anti-stream-pollution activities, assisted in conserving natural resources, and enhanced the economy of the anthracite-producing region. Acid-mine drainage control research projects in bituminous coal mines were continued in cooperative studies with the Ohio River Valley Water Sanitation and with the Federal Water Pollution Control Administration.

The Bureau of Mines continued to cooperate with other government agencies in preparing comprehensive water development plans for U.S. river basins. The Bureau continued its fundamental mine hydrology studies to develop methods, techniques, instruments, and engineering principles for defining mine drainage problems prior to development of underground mines and for controlling the drainage of water in mines.

Through its Industrial Water Laboratory, the Bureau of Mines continued to provide consulting boiler-water service to requesting Federal agencies operating heating and power plants; 13,317 water and condensate samples were analyzed from about 10,000 boilers. These analyses were helpful in spotting and correcting corrosion problems in boilers and condensate return lines at government installations.

DOMESTIC SUPPLY

Water supply for the Nation and for specific areas is based largely on the weather and precipitation. Rainfall in 1965 was below normal or deficient in the Northeast, South, and Southeast except for localized wet areas in east-central Texas, Georgia, and the Carolinas. Also deficient was the Pacific Northwest coast where the spring was dry and the same pattern continued into the fall season. Between the dry areas to the northwest and southeast was a broad belt of above-normal precipitation extending from southern California and Arizona, northeastward to the central and northern Great Plains, and the western Great Lakes. Record rains in southern California and Arizona and near-record annual totals in the Lake Superior areas highlighted these wet regions in 1965. This alternation of dry and wet belts appeared to have been part of the worldwide system of weather anomalies during 1965.

Annual runoff, a convenient measure of the water supply potential or manageable supply was greater for the water year of 1965—October 1, 1964, to September 30, 1965—than for the comparable water year of 1964. Runoff was excessive in large areas in the West, in parts of the western Great Lakes and midcontinent regions and in the Northeast. The year began with a dominant pattern of deficient streamflow and ended with three large areas of excessive streamflow: (1) parts or all of the 11 States in the West and the Provinces of British Columbia, Alberta, and Saskatchewan; (2) a large area in central and east-central United States; and (3) Quebec and eastern Ontario. Drought conditions persisted, however, in the southern part of the Northeast. Changes in ground water levels as measured in observation wells during the year were about equally divided between rises and declines. A large area where essentially all the levels rose extended generally from New York and Pennsylvania west through the Great Lakes, Central, and Midwestern States to and including eastern Nevada. In the remainder of the country there seemed to be a random pattern of rises or declines. Great Lake levels, except for Lake Superior, continued to be well below the 105-year average but were generally improved over last year's levels. The greatest deficiencies occurred from October to January, when levels of Lake Michigan-Huron were 3 feet below average; Lake Ontario, 1.5 to 2.3 feet below average; and Lake Erie, 1.6 feet below average. Levels of Lake Superior (regulated) were close to average.[9]

Reports on the mineral and water resources of New Mexico and Washington were published as Committee Prints for the Committee on Interior and Insular Affairs, U.S. Senate, 89th Congress, in 1965. These reports followed the format of the first such report for Montana in 1963, which was used as a guide for re-

[9] Geological Survey (in collaboration with Canada Department of Northern Affairs and National Resources). Water Resources Review: Nov. 1, 1965. Part 2—Summary for the 12 months, Oct. 1, 1964 to Sept. 30, 1965. Nov. 1, 1965, p. 10.

ports for Alaska, Colorado, Idaho, Nevada, South Dakota, and Utah published in 1964, and gave detailed data for the water situation in each State, surface and ground water supply, utilization and storage, waterpower, and selected references.

The first of a series of annual bibliographies on hydrology was published by the U.S. Geological Survey.[10] Hydrology, for purposes of this bibliography, is defined as the science that relates to the waters of the earth, their occurrence, distribution, movement, and chemical and physical properties. This bibliography lists references to books, journal articles, and other publications in the field of hydrology published in the United States during 1963.

Requirements for more and more water create supply problems in many parts of the United States. Industry has turned to saline water to meet some of its requirements, especially to meet cooling-water and process-water needs in areas where saline water is obtainable readily and where the used water can be disposed of without damage to adjacent supplies of fresh water. Locally, water is being desalinized for municipal systems and military installations and for boiler feed or other industrial uses. The growing interest in saline water indicated a need for greater understanding of its occurrence underground, such as amounts available, geologic habitat, chemical characteristics, and relations to supplies of fresh water. Because of this increased interest, a report was published listing selected references and cross indexes on saline ground-water resources in the United States.[11]

An atlas on the water resources of the Appalachian region, Pennsylvania to Alabama, was released by the Geological Survey.[12] The atlas summarized many aspects of the surface and ground water resources of 342 counties of the Appalachian region. Although acid mine drainage is a problem in this area, good water was shown to be generally abundant and offered a potential base for expanded industry and recreation in the region.

CONSUMPTION AND USES

Total withdrawal of water was estimated to exceed 340 billion gallons daily (bgd), compared with 135 bgd in 1940 and 40 bgd in 1900. Based on a total water supply of 1,200 bgd—the average runoff of all streams—the withdrawal was nearly 30 percent of the potential supply.

Not all of the water withdrawn is consumed because much of it is returned to the streams or ground and can be reused over and over again if steps are taken to maintain its quality. Consumption of water for various uses ranges from 50 to 60 percent of the water withdrawn for irrigation to 1 percent for steam-electric power cooling. In 1960, including water conveyance losses but excluding water used for waterpower, 40 percent of the total water withdrawal was used for irrigation, 51 percent for self-supplied industrial users, and the remaining 9 percent for rural and municipal (public supplies) domestic users. Data for 1965 are being compiled by the Geological Survey for a publication similar to Circular 456, "Estimated Use of Water in the United States, 1960."

A survey of water use in industry was conducted by the National Association of Manufacturers and the Chamber of Commerce of the United States in cooperation with the National Technical Task Committee on Industrial Wastes. The results of the nationwide study were published,[13] along with the evaluation of the data and a discussion of the entire spectrum of water; irrigation, health considerations, food control, aquatic life, water for municipalities, and water use by industries. The report is a valuable record of industry's use of water and constitutes a guidepost for future planning. The findings show that substantial quantities of water are being conserved by industry as a re-

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[10] Randolph, J. R., and R. G. Deike (compilers). Bibliography of Hydrology of the United States, 1963. Geol. Survey Water-Supply Paper 1863, 1966, 166 pp.

[11] Feth, J. H. Selected References on Saline Ground-Water Resources of the United States. Geol. Survey Circ. 499, 1965, 30 pp.

[12] Schneider, William H., and others. Water Resources of the Appalachian Region, Pennsylvania to Alabama. Geol. Survey, Hydrologic Investigations Atlas HA-198, 1965, 11 pp.

[13] National Association of Manufacturers and Chamber of Commerce of the United States. Water in Industry. January 1965, 81 pp.

sult of re-use practices and that industry returns to the streams 93 percent of the water withdrawn. Two of every 3 gallons of water withdrawn by industry are used for cooling purposes and normally do not require treatment before discharge. Industry withdraws large quantities of sea water and brackish water, thus helping to conserve fresh water supplies.

A report on a study of the water requirements for the mineral industry and industrial operations closely related to mineral production in New Mexico was published by the Bureau of Mines.[14] Most of the information on source, quantity, distribution, cost, and treatment of water was obtained in interviews with company representatives. Water systems at 46 operations were illustrated by schematic waterflow diagrams. The study revealed that the New Mexico mineral industry in 1962 used about 16 billion gallons of new water and reused 152 billion gallons, a total usage of 168 billion gallons. Consumption amounted to 7.6 billion gallons. The value of mineral product was $42 per 1,000 gallons of new water intake and $88 per 1,000 gallons consumed. Projections indicated that the total demand for new water will increase from 16 billion gallons in 1962 to 24 billion gallons in 1980 and 36 billion gallons in 2000. The report concluded that water—already relatively scarce in arid New Mexico—will be needed in vastly greater quantities by the turn of the century to sustain the mineral industry, which now brings in the bulk of that State's yearly income. This study was patterned after the one for Arizona published in 1963. Similar studies were continued in 1965 for Nevada, Montana, and Wyoming.

Results of a national survey of water use in the mineral industry in 1962, along with analysis of the data and projections for future needs of the mineral industry were published. One report[15] covered the water use in the entire mineral industry, and a second report[16] covered only the water use in the petroleum and natural gas industries and specifically the water use in well drilling, secondary-recovery operations for petroleum, and natural gas processing plants.

A report[17] on water utilization and conservation by petroleum refineries in California indicated that fresh water intake by the State's oil refining industry will increase from 84 million gallons per day (mgd) in 1963 to 128 mgd in 1975. Water is chiefly used for cooling, followed by steam generation, processing, sanitation, and fire fighting. Many of the refineries are accomplishing effective conservation of water by (1) minimum intake of water of the lowest quality possible; (2) optimum recirculation; (3) effective treatment of effluent before discharge; and (4) substitution of air cooling for water cooling. However, these steps may not be enough to assure adequate future water supplies for this industry.

According to the U.S. Atomic Energy Commission (AEC) annual report,[18] heavy water (D_2O) sales to U.S. customers totaled 8,292 pounds in 1965, a slight increase over 1964 sales. Foreign sales during the year were approximately 27.4 tons and leases, principally to Canada for the first Candu reactor at Douglas Point in Ontario, were 186 tons. It was reported that heavy water requirements in the next decade were expected to increase substantially because of increased emphasis in advanced converter reactors such as the heavy water-moderated, organic-cooled reactors which are under development in the United States.

Data from a report[19] on water use in manufacturing in United States are shown in table 1. Total water intake in 1964 increased 16 percent above that of 1959, gross water used (including water intake and water recirculated or reused) increased 17 percent, and water discharged increased 15 percent.

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[14] Gilkey, M. M., and Ronald B. Stotelmeyer. Water Requirements and Uses in New Mexico Mineral Industries. BuMines Inf. Circ. 8276, 1965, 113 pp.

[15] Kaufman, Alvin, and Mildred Nadler. Water Use in the Mineral Industry. BuMines Inf. Circ. 8285, 1966, 58 pp.

[16] Buttermore, Paul M. Water Use in the Petroleum and Natural Gas Industries. BuMines Inf. Circ. 8284, 1966, 36 pp.

[17] Edgerton, Curt D., Jr. Water Utilization and Conservation by Petroleum Refineries in California. BuMines Inf. Circ. 8270, 1965, 24 pp.

[18] U.S. Atomic Energy Commission. Major Activities in the Atomic Energy Programs, January–December 1965. January 1966, p. 76.

[19] U.S. Department of Commerce. Bureau of the Census. Water Use in Manufacturing: 1964. Preliminary Rept. MC 63 (P)-10, March 1966, 11 pp.

Table 1.—Quantity of water used and discharged by manufacturing establishments, by industry group and selected industry: 1959 and 1964

(Billion gallons)

Industry code		Industry groups (total) and subgroups (subtotal)	1959				1964 [p]			
Main code (total)	Subcode (subtotal)		Water intake	Gross water used [1]	Water discharged	No. of employees (thousand)	Water intake	Gross water used [1]	Water discharged	No. of employees (thousand)
19	—	Ordnance and accessories	12	37	10	203	13	48	12	189
20	—	Food and kindred products	624	1,298	577	618	760	1,280	689	626
21	—	Tobacco manufactures	3	44	2	43	3	19	2	31
22	—	Textile mill products	135	182	120	378	148	311	135	353
24	—	Lumber and wood products	140	184	126	75	151	217	123	66
25	—	Furniture and fixtures	3	4	2	31	3	4	3	35
26	—	Paper and allied products	1,937	6,046	1,824	282	2,072	6,038	1,947	250
28	—	Chemicals and allied products	3,240	5,225	3,061	434	3,897	7,614	3,670	498
29	—	Petroleum and coal products	1,319	5,780	1,204	142	1,397	6,159	1,318	1,006
—	2911	Petroleum refining	1,311	5,767	1,199	135	1,388	6,146	1,309	112
30	—	Rubber and plastics products [2]	127	218	119	212	163	336	155	210
31	—	Leather and leather products	12	14	12	26	16	18	15	26
32	—	Stone, clay, and glass products	251	412	264	321	248	386	219	218
33	—	Primary metal industries	3,702	5,673	3,551	852	4,577	6,779	4,312	813
—	331	Steel rolling and finishing	3,238	4,840	3,119	540	4,051	5,806	3,810	522
—	332	Iron and steel foundries	42	60	37	94	28	45	25	87
—	333	Primary nonferrous metal	(3)	(3)	(3)	(3)	385	704	370	42
—	335	Nonferrous rolling and drawing	92	161	87	134	83	167	79	118
—	336	Nonferrous foundries	(3)	(3)	(3)	(3)	8	19	8	17
—	339	Primary metal industries [2]	7	14	6	26	20	34	18	27
34	—	Fabricated metal products	44	71	41	316	57	123	53	258
35	—	Machinery, except electrical	171	251	165	514	157	287	149	532
36	—	Electrical machinery	93	159	88	567	103	261	88	750
37	—	Transportation equipment	260	522	229	1,285	247	663	237	1,203
38	—	Instruments and related products	23	60	22	153	30	80	27	194
39	—	Miscellaneous manufacturing	14	20	13	45	13	22	17	43
—	—	United States, total [4]	12,131	26,257	11,445	6,560	14,055	30,645	13,171	6,414

[p] Preliminary.
[1] Includes water intake and water recirculated or reused.
[2] Not elsewhere classified.
[3] Figures did not meet publication standard.
[4] Figures for 1964 exclude, and figures for 1959 include, establishments classified in Major Groups 23 and 27. In 1959, such establishments had total water intake of 23 billion gallons, gross water use of 58 billion gallons, discharge of 22 billion gallons of water, and employment of 152,000 persons.

Source: Bureau of the Census.

PRICES

Prices paid for water varied widely, depending on the area and type of use. The typical consumer falls into one of three classes: residential, commercial, and industrial. The home owner may pay from 20 to 75 cents per 1,000 gallons, but the national average is 35 cents or 2 cents per day per person. The range of prices for irrigation water is much greater—from 1 cent per 1,000 gallons where streamflow is ample, up to 20 cents or more; however, water delivered to the farmer generally ranges from 0.5 cent to 5 cents per 1,000 gallons. Costs for water in substantial quantities for industrial use, including pumping, treatment, and distribution range from 1 cent to 15 cents per 1,000 gallons. The cost of producing fresh water from saline water remained at $1 to $1.50 per 1,000 gallons, compared with $4 to $5 in 1952 when the Office of Saline Water program began.

The cost for self-supplied new water at 21 mineral industry operations in New Mexico, as reported[20] by the Bureau of Mines, ranged from 1 cent to 20 cents and averaged 8 cents per 1,000 gallons. At five operations, the prices paid per 1,000 gallons of purchased water were 2, 12.5, 15, and 46 cents and $2.14. The cost of power and maintenance, at six operations, for recirculation of water ranged from 0.5 cent to 3 cents and averaged 1.8 cents per 1,000 gallons. Of the 13 operators reporting treatment costs for new water, 4 reported "negligible" cost and 9 reported figures ranging from 3 to 50 cents per 1,000 gallons. The average at these 13 plants was 18.8 cents per 1,000 gallons of new water treated.

A preliminary report of a study made by Bechtel Corp. under the joint sponsorship of the Department of the Interior, the Atomic Energy Commission, and the Metropolitan Water District of Southern California concluded that a large-scale dual purpose nuclear-powered plant producing 150 million gallons per day of fresh water from sea water and 1,800 megawatts of electricity would be feasible. In addition, the report concluded that the cost of the fresh water would be from 22 to 30 cents per 1,000 gallons. An artificial island off the coast of Southern California was proposed as the site for the plant.

WORLD REVIEW

Brazil.—Jupia Dam, on Brazil's Parana River, is the largest earthmoving job ever tackled by dam builders in South America and the largest single hydroelectric project there. It is the first of two dams that make up the Urubupunga project, which will add 4.8 million kilowatts (kw) to Brazilian power capacity. When completed in mid-1967, the $266 million dam will impound a reservoir covering an area of 87,000 acres and contain 24.9 million acre-feet of water, of which 6 million acre-feet will be usable.[21]

Canada.—The fresh-water supply situation in Canada was appraised[22] and the future of Manitoba's water resources was forecasted.[23] The thesis was presented that Canada's fresh water should be held in trust for future generations of Canadians and that if Canada is to prosper as a nation, its water cannot be sold nor should export possibilities even be considered until a great deal more is known about Canada's present water resources and future water requirements. Because Manitoba is a water collecting basin, it has the advantage that ample amounts of water are received most of the time; however, it also has the disadvantage that on occasion the province must cope with excessive amounts of water during flood periods.

Germany, West.—West Germany's largest reservoir project of the century went into service and was expected to alleviate a critical water supply situation in the Ruhr District—the world's most highly concentrated industrial region. With 5 million persons, less than 10 percent of West Germany's population, the Ruhr now accounts for nearly 40 percent of the nation's indus-

[20] Work cited in footnote 14.

[21] Engineering News-Record. Parana River Dam Makes Records in Earthmoving and Hydropower. V. 175, No. 5, July 29, 1965, pp. 22–25.

[22] McNaughton, A. G. L. Canada's Water. Eng. J. (Montreal, Canada). V. 48, No. 6, June 1965, pp. 19–22.

[23] Mundry, N. The Future and Manitoba's Water Resources. Eng. J. (Montreal, Canada). V. 48, No. 10, October 1965, pp. 35–39.

trial output. Supplying this region with sufficient water has been a problem since the late 19th century, especially after World War II when Ruhr industry and population both experienced tremendous growth. This project involved the building of the Bigge Valley Reservoir that took 8 years to construct and when filled will have a capacity of 113,000 acre-feet, which is nearly half of the total capacity of the 14 reservoirs now serving the Ruhr.[24]

Israel.—Local industries will supply a large part of the equipment required for the proposed dual-purpose desalting and power generating plant scheduled for construction near Ashdod in Israel. The project is expected to provide 100 million cubic meters of desalinated water annually and to have a rated output of 200 megawatts in excess of the power required for desalting.[25]

Preliminary reports indicated that a major new source of water had been discovered in the Jerusalem area east of Beit Sahur on the upper rim of the Dead Sea depression that could furnish up to 20,000 cubic meters per day of water not requiring special treatment to reduce mineral content. Jerusalem's Mayor Rouhi al-Khatib intended to seek financial assistance from the central government to develop this potential new water supply which could result in a major turning point in the municipality's development.

Japan.—The Water Resources Development Corp., a quasi-government agency organized in 1962 to cope with Tokyo's almost traditional water shortage, spent $97 million for new water supply projects during the year and earmarked $435 million for water development projects for the city over the next 5 years. Even at the present rate of construction, the corporation expects that the threat of water shortage will hang over the city until 1970 when the capacity of new facilities will exceed the maximum possible daily demand for the first time since the end of World War II.[26]

South Africa, Republic of.—With drought sapping South Africa's water supplies, new devices for purifying water were being examined with keener interest than ever. The latest such device, which was demonstrated and was to be marketed, was a mobile water-sterilizing apparatus that purifies contaminated water, even cesspool or bilharzia-contaminated water, and produces bacteria-free water for human consumption.[27]

Sudan.—The Sudan, like many other underdeveloped countries, rests its economic future on the successful exploitation of its water. The Sudan's prime source of wealth and largest export is Egyptian-type, long-staple cotton. Without more water for irrigation, the country can not expect to expand its output of cotton. The hopes for this expansion rests on Roseires Dam, a 10-mile-long earth and concrete structure across the Blue Nile basin at Damazin Rapids, scheduled for completion in 1966. When completed and filled, the dam will store 2.6 million acre feet of water, which will double the Sudan's water storage capacity and will ultimately add 210,000 kw of electric capacity to the 80,000 kw now available for public supply.[28]

U.S.S.R.—The Tass news agency reported that the U.S.S.R. is considering the construction of two 3,500-megawatt (thermal) graphite-uranium nuclear power reactors near Zhdanov (Donbas), which together would provide 1,200 megawatts of electricity and convert 1 to 1.5 million cubic meters of Azov Sea water to fresh water daily.

United Arab Republic (Egypt).—The Egyption-Russian team that is building the Aswan High Dam across the Nile River, 450 miles south of Cairo was 1 year ahead of schedule at the close of the year but faced the most crucial problem—the job of making granular riverbed material under the dam leakproof, or reasonably so. Leakproofing the riverbead involves injecting grout in quantities and to depths beyond experience anywhere. Completion of the dam was scheduled for July 1967.[29]

United Kingdom.—After July 1 it became illegal to abstract water from virtually all private sources in England and Wales without an annual license. This was

[24] Engineering News-Record. Reservoir Will Aid the Thirsty Ruhr. V. 174, No. 5, Feb. 4, 1965, pp. 41–42.

[25] Bureau of Mines. Mineral Trade Notes. V. 60, No. 5, May 1965, p. 47.

[26] Engineering News-Record. Tokyo Water Shortage May Ease. V. 175, No. 12, Sept. 16, 1965, pp. 156–158.

[27] South African Digest (Petoria, South Africa). New Water Purification Method Tested. V. 12, No. 45, Nov. 12, 1965, p. 13.

[28] Engineering News-Record. Ten-Mile-Long Dam Will Reinforce Sudan's Cottonpicking Economy. V. 174, No. 22, June 3, 1965, pp. 38–40, 45.

[29] Bowman, Waldo G. Aswan Dam's Crucial Phase: Grouting. Eng. News-Record, v. 175, No. 24, Dec. 9, 1965, pp. 48–65.

one of the most important provisions of the Water Resources Act, 1963, which gave the Minister of Housing and Local Government wide powers in the formulation of a national policy on water. The broad responsibilities of the authorities include control of pollution, fisheries, navigation, land drainage, and flood prevention, together with the new function of conservation and development of water resources.

TECHNOLOGY

The Office of Saline Water (OSW) continued research and development seeking to lower the cost of producing fresh water from saline or brackish water. Progress reports on basic research, process development, and demonstration plant projects will be given in the OSW Annual Report for 1965 scheduled for publication by mid-1966. All of the basic research was conducted under contract with other Federal agencies, and with universities, private organizations, and industrial firms. Most of the pilot plants for process development or applied research activities were under construction and operation at the OSW Research and Development Test Station at Wrightsville Beach. N.C.

The five OSW demonstration plants were designed, built, and operated in designated areas to demonstrate the reliability, engineering, operating, and economic potentials of the several sea or brackish water conversion processes. Data obtained from the operation of the plants were being evaluated to form the basis for the design of larger and more efficient plants. A handbook provided reference aids to engineers and designers engaged in saline water conversion to fresh water[30] and a bibliography of saline water conversion literature was compiled.[31]

The Department of the Interior and the San Diego Gas & Electric Co. reached an agreement in September to establish the San Diego Desalting Test Station on property made available by the company at its South Bay powerplant in San Diego County Calif. The State of California through its Department of Water Resources and the city of San Diego will participate in the project and assistance may also be provided by the California Water and Telephone Co. and Western Salt Co. The test station will provide a location for the construction and test operation of modules and equipment components which will provide the technical data that must be developed to provide the engineering basis for the design and construction of sea water conversion plants of 50 million gallons per day and larger.

Taking shape on drawing boards was a water desalting plant designed by Fluor Corp. that will be the largest in the United States. The $3.8 million flash-distillation unit was scheduled to begin operating near Key West, Fla., by late 1966, producing 2.62 million gallons per day of fresh water. An additional unit will be installed at the site at a later date. The Florida Keys currently obtains water by a 130-mile-long U.S. Navy aqueduct from Florida City. This system can deliver 6 million gallons per day, but the Florida Keys Aqueduct Commission expects that the water needs for the Florida Keys will reach 10 million gallons per day by 1982.

Separation of mineral constituents from sea water and other saline waters was investigated.[32] The conclusions were that the three minerals of greatest economic potential in sea water, excluding the primary product—fresh water, were salt (sodium chloride), magnesia, and potash. One sea water desalination plant producing 50 million gallons per day of fresh water and operating at a brine concentration factor of 3 to 1 would also produce 20 percent of the U.S. annual salt requirements, 25 percent of the magnesia, but only 1 percent of the potash.

Only a few basic heavy inorganic chemicals are possible as chemical products from effluent brines from desalination plants and these products must be competitively produced and marketable. Most of the potential products are widely produced and even more widely used. An integrated water-chemical production plant

[30] U.S. Department of the Interior, Office of Saline Water. Saline Water Conversion Engineering Data Book. July 1965, 239 pp.

[31] Schamus, J. J. Bibliography of Saline Water Conversion Literature. U.S. Dept. of Interior, Office of Saline Water. Res. and Dev. Progress Rept. 146, September 1965, 374 pp.

[32] Salutsky, Murrell L. Research on Mineral By-Products From Saline Water. Res. and Dev. Progress Rept. 137, Office of Saline Water, July 1965, 105 pp.

was shown to have some attractive features.[33]

The First International Symposium on Water Desalination, announced by the President of the United States in August 1964, sponsored by the U.S. Department of the Interior in cooperation with the U.S. Department of State, was held in Washington, D.C., from October 3 to 9, 1965. Approximately 1,500 official country delegates, observers, special guests, and general attendants, representing 65 countries and 5 continents, participated in the symposium. About 96 papers were presented on water desalination technology by representatives from at least 20 countries. The United States gave 53 papers; U.S.S.R. 9; Israel 5; United Kingdom and West Germany 4 each; Scotland and Japan, 3 each; and the remaining countries gave one or two papers each.

In conjunction with the symposium, the First International Water Desalination Exposition was held in Washington, D.C. This exposition supplemented the papers and discussions of the symposium in a dramatic and meaningful fashion and enabled the participants to see firsthand what industry and government had done in translating theory and experience into hardware for water desalination.

Acid water drainage from coal mines contributes to river and stream pollution. To assist the coal industry with this problem the Bureau of Mines continued research on various aspects of acid water drainage and related subjects. Ultimate objective of this work was to develop methods for reducing or eliminating stream contamination from this source and to promote water conservation. The Bureau directed major attention to an acid mine drainage control demonstration project in the bituminous coal fields. Further work also was conducted to evaluate the economic and practical potential on mine sealing, mine flooding control, and mine water neutralization.[34]

A mine-water control project, financed jointly by the Department of the Interior and the Commonwealth of Pennsylvania, to prevent flooding anthracite reserves in an underground complex near Tower City, Pa., was started. The mines lie beneath abandoned strip pits. After heavy rain and snow, water funnels through the pits into the underground workings. Project plans for saving the mines and the anthracite reserve call for filling the abandoned pits and grading the surface to provide better runoff.

Pennsylvania's Department of Mines tested a truck-mounted plant for treating acid mine water.[35] The mobile plant, which utilized lime to control acidity of mine drainage, was used to develop water treatment methods at five locations along Pennsylvania streams. Results of the tests were not published.

Research scientists at Indiana University verified that cast overburdens resulting from coal mining operations served a useful purpose by acting as reservoirs for ground water.[36] During a drought in 1964, streams and lakes in a mined area in southwestern Indiana maintained good levels while nearby streams were dry. One mine nearby operated a closed circuit coal preparation plant which got makeup water of good quality from local lakes in the mined area.

In a search for cheaper sewage treatment methods, the Bureau of Mines evaluated coal and coal-derived materials as organic contaminant absorbents for sewage plant effluents. Conventional sewage plant practice of biological treatment followed by removal of organic matter by activated carbon was found to be satisfactory, but initial and regeneration costs for activated carbon are relatively high. Coal was reported to be attractive for this application because it is relatively low in cost and would not have to be regenerated after use because both the coal and absorbed wastes could be profitably burned as fuel.[37] An announcement was made that a $617,000 contract between the Office of Coal Research

[33] McIlhenny, W. F., and P. E. Muehlberg. (The Dow Chemical Co., Freeport, Tex.). The Utilization of By-Products and Related Effects on the Cost of Desalinated Water. Seminar on Economics of Water Desalination, United Nations Headquarters, New York, Oct. 1, 1965, 36 pp.

[34] Bureau of Mines Staff. Bureau of Mines Research and Technologic Work on Coal, 1964. BuMines Inf. Circ. 8277, 1965, pp. 9–15.

[35] Maneval, David R., and H. Beecher Charmbury. Acid Mine Water Mobile Treatment Plant. Min. Cong. J., v. 51, No. 3, March 1965, pp. 69–71.

[36] Truax, Chester N., Jr. Water Storage Potential of Surface Mined Coal Lands. Min. Cong. J., v. 51, No. 11, November 1965, pp. 40–46.

[37] Bureau of Mines Staff. Bureau of Mines Research and Technologic Work on Coal, 1964. BuMines Inf. Circ. 8277, 1965, pp. 98, 99.

of the Department of the Interior and Rand Corp. of Cleveland had been signed for the construction of a pilot plant using coal filters to purify municipal sewage wastes now being discharged into the Potomac River.

At the Meramec Mining Co. Pea Ridge mine 75 miles southwest of St. Louis, Mo., a water settler was installed when it was realized that mining the magnetite ore resulted in abrasive solids in the mine water that would cause rapid pump wear and fill the sumps with settled sludge. It was reported that the settling system did a good job and justified the cost of construction.[38]

A summarization was published[39] on the methods available for the treatment of liquid and gaseous effluents, and methods and processes that have been used or proposed to recover valuable products from plant wastes and to abate water pollution. Water recovered for reuse was reported to be ultimately the major valuable product because of increasing water supply and water treatment costs and mounting charges for using municipal sewage facilities.

In the past, in the treatment of mining wastes, attention was concentrated on pH control and on the removal of oil and other visible and nuisance pollutants. Few mines had availed themselves of biological methods for treating their wastes. An upsurge of interest in the use of these methods has been shown to solve a number of the oil industry's disposal problems. Recent studies established the usefulness of these methods in achieving satisfactory reduction in the biochemical oxygen demand (BOD) and in the phenols, residual oils, and other organics of the refinery waste liquors. The various methods and results of biological treatment available for dealing with aqueous mining wastes were reported.[40]

A study of the design and operation of thickening equipment for closed-water circuits in coal preparation plants indicated that they were justified from two standpoints: economical operation and prevention of stream pollution.[41] From this survey of 14 operating plants using thickeners for water recovery and refuse solid concentration, it was apparent that the gravitational thickener represented a dependable device for these two purposes. Chemical flocculants were required. Average cost of water recovery was 2½ cents per 1,000 gallons of water treated, or 23 cents per ton of dry refuse solids handled. It was concluded that by using gravitational thickeners, water was recovered at a very reasonable price, stream pollution was prevented, and a closed water circuit was achieved requiring a minimum of makeup water.

The National Aeronautics and Space Administration (NASA) drilled the second-deepest disposal well in the United States at its Michoud plant in New Orleans, La., where the gigantic Saturn launch vehicles for the Apollo program were being assembled. It is reported to be the only well that discharges into a water-sand stratum. Some 400,000 gallons per day of waste cleaning solutions and rinse water from cleansing of Saturn components was being injected in the disposal well. The cleaning agents include chromate as well as various acids and alkalis and could not be discharged to a nearby industrial canal because the chromates would harm oyster beds in the bay. Studies showed that the easiest and cheapest alternative for disposal of waste was in a deep well. Chemical and mineral industrial companies can profit by the reported experiences of NASA, the first to discharge their waste materials into a sand strata.[42]

The demand for fuller use of water resources dictated increased performance by waste treatment processes and the development of strong interest concerning the removal of constituents passed by biological processes. The means were reported[43] to be available to design units that will closely reproduce laboratory performance in the field, and that the scope of the chemical treatment has been expanded by the advent of a host of organic polymer coagulants.

[38] Monroe, H. K. Design of a Mine Water Settler at Pea Ridge. Min. Eng., v. 17, No. 12, December 1965, pp. 81–84.

[39] Rickles, Robert N. Waste Recovery and Pollution Abatement. Chem. Eng., v. 72, No. 20, Sept. 27, 1965, pp. 133–152.

[40] Sherwood, Peter W. Treatment of Waste Liquors. Min. Mag. (London), v. 112, No. 5, May 1965, pp. 304–309.

[41] Dale, L. A., and D. A. Dahlstrom. Design and Operation of Thickening Equipment for Closed-Water Circuits in Coal Preparation Plants. Trans. Soc. Min. Eng., v. 232, No. 2, June 1965, pp. 141–149.

[42] Chemical Week. Learning to Whip Well Woes. V. 96, No. 15, Apr. 10, 1965, pp. 113, 115.

[43] Parsons, William A. Chemical Treatment of Sewage and Industrial Wastes. Nat. Lime Assoc. Bull. 215, 1965, 139 pp.

Zinc

By Harold J. Schroeder [1]

CONTENTS

Record zinc consumption and smelter output highlighted an active year for the domestic zinc industry. Consumption in excess of new supplies reduced the stock level at producers to a 14-year low by April, leading to emergency releases from the Government stockpile.

The record smelter production was 1,078,000 tons, and in response to the demand for smelter feed, mine production increased 6 percent to 611,000 tons, the largest quantity since 1952. Producer stocks dropped from 31,000 to 29,000 tons while consumer stocks rose from 108,000 to 152,000 tons during the year.

Import quotas, established in 1958, were terminated during the latter part of the year. General imports of 428,000 tons for ores and concentrates and 153,000 tons for metal were the largest since 1962 and 1959, respectively. Exports of slab zinc decreased from 26,500 to 5,900 tons, the lowest since 1958.

Government stockpiles were reduced by 193,000 tons to a yearend total of 1.31 million tons.

The quoted price of Prime Western grade zinc, East St. Louis market, remained at 14.5 cents per pound throughout the year.

Legislation and Government Programs.—The International Lead-Zinc Study Group met in Tokyo during the first week in November. For 1965, it was estimated that free world consumption would attain a record level of 3.7 million short tons although the rate of growth was the lowest in 7 years. Including net imports from the Soviet bloc countries and sales from the U.S. Government stockpile, new supplies were indicated to exceed consumption by about 140,000 tons, easing the tight supply condition. A study on consumption by the Special Working Group was authorized for publication as soon as publishing arrangements could be made.

U.S. import quotas were terminated by Presidential proclamation, effective October 22 for ores and concentrates and November 21 for metal. The action was guided by a Tariff Commission report submitted June 8

[1] Commodity specialist, Division of Minerals.

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Table 1.—Salient zinc statistics

	1956–60 (average)	1961	1962	1963	1964	1965
United States:						
Production:						
Domestic ores, recoverable content short tons	469,361	464,390	505,491	529,254	574,858	611,153
Value thousands	$113,201	$106,848	$116,413	$122,533	$156,308	$178,284
Slab zinc:						
From domestic ores short tons	407,714	413,282	448,095	474,007	531,967	551,215
From foreign ores do	462,053	433,513	431,300	418,577	422,117	443,187
From scrap do	63,552	55,237	58,880	60,303	71,596	83,619
Total do	933,319	902,032	938,275	952,887	1,025,680	1,078,021
Secondary zinc [1]	200,664	183,357	203,800	208,715	227,713	271,694
Exports of slab zinc short tons	21,689	50,055	36,102	33,853	26,515	5,939
Imports (general):						
Ores (zinc content) do	494,039	415,700	467,398	372,769	357,145	428,040
Slab zinc do	197,383	127,562	141,957	144,757	118,340	152,990
Stocks, December 31:						
At producer plants do	149,764	146,887	144,746	47,910	31,178	28,622
At consumer plants do	92,276	97,155	79,934	97,475	r 108,411	151,873
Consumption:						
Slab zinc do	929,364	931,213	1,031,821	1,105,113	1,207,268	1,354,092
All classes do	1,226,811	1,207,469	1,333,311	1,414,216	1,535,751	1,742,067
Price, Prime Western, East St. Louis cents per pound	11.92	11.55	11.63	12.01	13.57	14.50
World:						
Production:						
Mine short tons	3,476,000	3,845,000	3,950,000	4,075,000	4,425,000	4,750,000
Smelter do	2,601,000	3,580,000	3,755,000	3,830,000	4,110,000	4,240,000
Price: Prime Western, London cents per pound	10.39	9.78	8.43	9.60	14.74	14.12

r Revised.
[1] Excludes redistilled slab zinc.

on the condition of the lead and zinc industries with particular reference to the operation of the quota system, in effect since October 1958.

The program to stabilize the mining of lead and zinc by small producers initiated by Public Law 87–347, providing supplemental payments for eligible production when the market price is less than 14.5 cents per pound, was extended under Public Law 89–238 to January 1, 1971. The extension restricted payments for a calendar year to 1,200 tons of lead and 1,200 tons of zinc for a qualified producer and to a yearly total of $2.5 million for the program. No payments were made during 1965 since the market price equaled the stabilization price.

Public Law 89–9, enacted April 2, authorized release of zinc from the national stockpile in the amount of 150,000 tons for disposal to industry and 50,000 tons for direct government use. In accordance with the authorization, General Services Administration (GSA), from April through August, sold essentially all of the 150,000 tons to domestic producers, importers, and other purchasers for domestic consumption. Of the 50,000 tons authorized for direct government use, approximately 2,000 tons were released to the Bureau of the Mint for coinage purposes and 1,077 tons were released to the Department of Defense.

Public Law 89–322, enacted November 4, authorized release of 200,000 tons of zinc from the national stockpile for disposal to industry. In accordance with this authorization GSA, during November and December, sold 69,175 tons to domestic producers, importers, and other purchasers for domestic consumption.

There was 1,028,627 tons of zinc in the national (strategic) stockpile and 284,241 tons in the supplementary stockpile at the end of the year. The conventional war stockpile objective for zinc, as revised in 1963 by the Office of Emergency Planning (OEP), was zero. Studies continued by OEP to determine stockpile needs to meet the requirements of general nuclear war, including reconstruction.

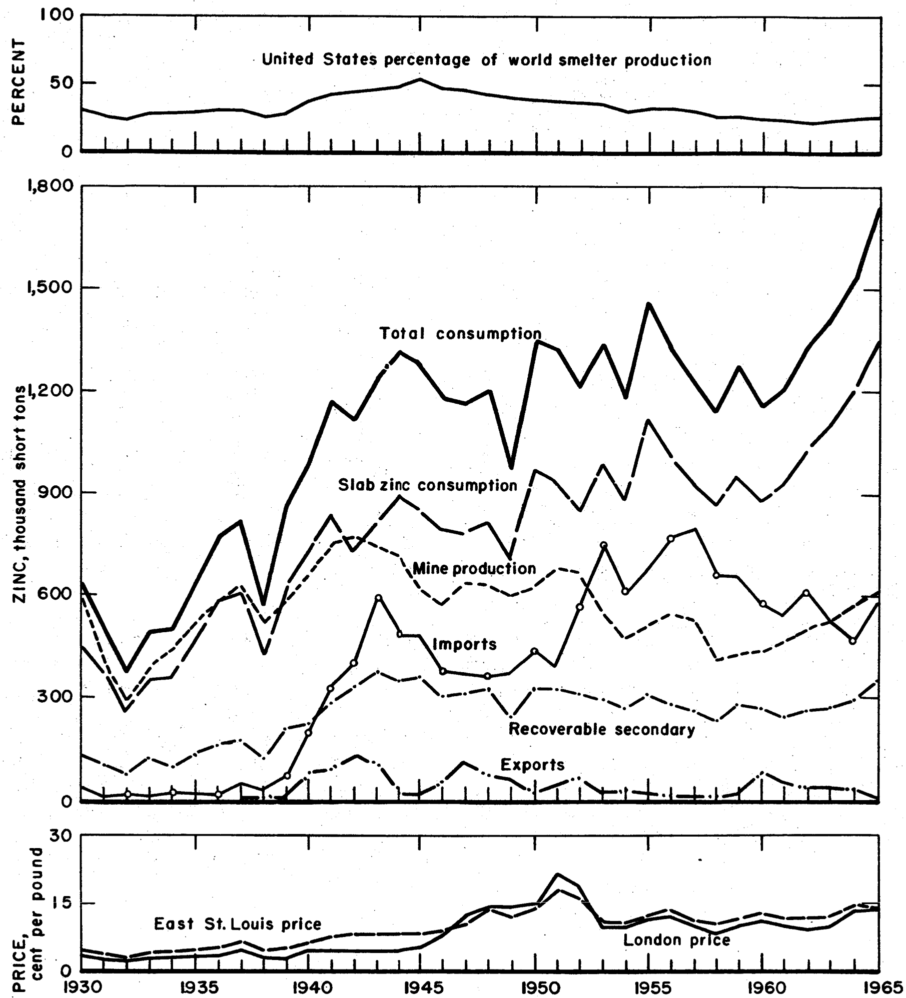

Figure 1.—Trends in the zinc industry in the United States.

DOMESTIC PRODUCTION

MINE PRODUCTION

Mines in the United States produced 611,200 tons of recoverable zinc, an increase of 6 percent over that of 1964 and the highest annual output since 1952. States east of the Mississippi River produced 54 percent of the total output; Western States 42 percent; and West Central States 4 percent.

The sources of zinc production, classified according to types of ore, in 1965 were 53.2 percent from zinc ores; 35.6 percent from lead-zinc ores; 1.1 percent from lead ore; 4.5 percent from copper-lead, copper-zinc, and copper-lead-zinc ores; and 5.6 percent from all other classifications. Details of this breakdown are in table 3 of the chapter on lead in this volume.

Table 2.—Mine production of recoverable zinc in the United States, by States
(Short tons)

State	1956–60 (average)	1961	1962	1963	1964	1965
Arizona	32,231	29,585	32,888	25,419	24,690	21,757
Arkansas	20	37	211	------	------	------
California	2,322	304	322	101	143	225
Colorado	38,209	42,647	43,351	48,109	53,682	53,870
Idaho	49,923	58,295	62,865	63,267	59,298	58,034
Illinois	25,506	26,795	27,413	20,337	13,800	18,314
Kansas	10,416	2,446	3,943	3,508	4,665	6,508
Kentucky	811	1,147	1,172	1,461	2,063	5,654
Missouri	2,121	5,847	2,792	321	1,501	4,312
Montana	38,935	10,262	37,678	32,941	29,059	33,786
Nevada	2,702	453	281	571	582	3,858
New Jersey	3,561	112	15,309	32,738	32,926	38,297
New Mexico	19,026	22,900	22,015	12,938	29,833	36,460
New York	57,322	54,763	53,654	53,495	60,754	69,880
North Carolina	(1)	------	------	13	------	------
Oklahoma	10,223	3,148	10,013	13,245	12,159	12,715
Oregon	------	3	------	3	W	W
Pennsylvania	8,255	23,428	24,308	27,389	30,754	27,635
Tennessee	68,908	81,734	71,548	95,847	115,943	122,387
Texas	------	------	------	------	------	------
Utah	39,780	37,239	34,313	36,179	31,428	27,747
Virginia	20,193	29,163	26,479	23,988	21,004	20,491
Washington	21,367	20,217	21,644	22,270	24,296	22,230
Wisconsin	17,530	13,865	13,292	15,114	26,278	26,993
Total	469,361	464,390	505,491	529,254	574,858	611,153

W Withheld to avoid disclosing individual company confidential data; not included in total.
[1] Less than ½ unit.

The 25 leading zinc-producing mines in the United States, listed in table 4, yielded 75 percent of the total domestic output. The four leading mines supplied 24 percent, and the first eight contributed 40 percent.

Tennessee maintained its rank as the leading producing State with output increasing 6 percent to a record 122,400 tons, about one-fifth of domestic zinc mine output. American Zinc, Lead and Smelting Co. operated its Coy, Grasselli, Mascot No. 2, North Friends Station, and Young mines. Development of the New Market mine and mill, a joint venture between American Zinc, Lead and Smelting Co. and Tri-State Zinc Co., Inc., has been slower than anticipated due to adverse ground conditions but full production of 90,000 tons per month was expected to be achieved by July 1966. The New Jersey Zinc Co. operated its Jefferson City and Flat Gap mines and the United States Steel Corp., Tennessee Coal & Iron Division, operated its Zinc Mine Works mine and mill during the year. The copper-zinc mines of Tennessee Copper Co. contributed a substantial quantity of zinc output to the State total.

Table 3.—Mine production of recoverable zinc in the United States, by months

Month	1964	1965
January	48,548	50,063
February	44,459	48,860
March	47,774	54,887
April	46,387	53,186
May	46,285	48,698
June	45,199	51,694
July	48,149	48,166
August	48,736	50,780
September	46,250	51,466
October	52,447	51,673
November	48,668	51,574
December	51,956	50,106
Total	574,858	611,153

New York output of recoverable zinc increased 15 percent to a record 69,900 tons. St. Joseph Lead Co., the only zinc producer in the State, operated its Balmat and Edwards mines without interruption on a 6-day-week basis. Contributing to the record production was the completion, in the second quarter, of an expansion and modernization program at the Edwards mine and mill.[2]

Idaho remained the leading mine producer in the Western States although output declined 2 percent to 58,000 tons. The Bunker Hill Co. reported 24,050 tons of zinc in concentrate recovered from milling 240,200 tons of ore from its Star Unit mines and 16,885 tons of zinc in concentrate from milling 366,800 tons of ore from

[2] St. Joseph Lead Co. Annual Report. 1965, p. 4.
[3] The Bunker Hill Co. Annual Report. 1965, p. 12.

its Bunker Hill mine.[3] The Page mine of American Smelting and Refining Coompany produced 130,000 tons of ore from which 11,034 tons of zinc plus quantities of lead and silver were recovered.[4]

In Colorado, zinc production increased slightly to 53,900 tons. Leading zinc producing mines were the Eagle of The New Jersey Zinc Co., the Idarado of Idarado Mining Co., the Emperius of Emperius Mining Co., the Sunnyside of Standard Metals Corp., and the Keystone mine operated by McFarland and Hullinger. The Idarado mine produced 375,000 tons of ore grading 3.85 percent zinc, 2.64 percent lead, 0.63 percent copper, and 1.59 ounces of silver per ton. Reserves were increased by 213,000 tons to 3,777,000 tons at yearend.[5] Camp Bird Colorado, Inc., a subsidiary of Federal Resources Corp., resumed operations at its mill in September, treating silver-lead-zinc development ore from the Camp Bird and Revenue mines.

Zinc production in New Jersey was 38,300 tons, the highest output since 1953. The only operating mine was the Sterling of The New Jersey Zinc Co.

Production in New Mexico increased by 22 percent to 36,500 tons, the highest output since 1952. Leading zinc producers were the Hanover mine of The New Jersey Zinc Co.; Kearney mine of American Zinc, Lead and Smelting Co.; Linchburg mine of The New Jersey Zinc Co. leased to L. A. Patten and Associates; Oswaldo mine of Kennecott Copper Corp. leased to The New Jersey Zinc Co.; and the Princess mine of United States Smelting, Refining and Mining Co. (USSR&M Co.) under contract to Frank M. Van Cleave.

In Montana, production of 33,800 tons was the largest since 1962. Most of the output was by The Anaconda Company from mines near Butte and from a slag-fuming operation at East Helena. The largest producing mines were the Anselmo and Badger State, which employed both block-caving and cut-and-fill mining methods.

In Utah, zinc production decreased 1 percent to 27,700 tons, the lowest level since 1925. The United States and Lark mine of USSR&M Co. was the leading zinc producer despite a strike from May 4 to July 22. A shortage of skilled miners also adversely affected output, partially offset by higher ore grade. Other substantial producers were the United Park City mines of United Park City Mines Co., Mayflower mine of Hecla Mining Co., the Ophir mine of USSR&M Co., and the Burgin mine of Kennecott Copper Corp. At the Mayflower mine, 4,164 tons of contained zinc in concentrates were recovered from milling 113,000 tons of ore averaging 4.33 percent lead, 3.90 percent zinc, 0.75 percent copper, and 4.27 ounces of silver per ton.[6]

Pennsylvania output of zinc decreased 10 percent to 27,600 tons, the smallest quantity since 1962. The only operating mine was the Friedensville of The New Jersey Zinc. Co.

Zinc output in Wisconsin increased 3 percent to 27,000 tons, the highest production since 1927. The Eagle-Picher Co., and the American Zinc, Lead and Smelting Co. operated mines and mills throughout the year. The Mifflin Mining Co. closed its mill for repairs in November and the Grimes Mining Co. terminated production at its Burnham mine in November. In May, the Ivey Construction Co. began operating its new flotation mill with ore from the nearby Graysville mine. The New Jersey Zinc Co. announced plans to reopen its mine near Elmo and to construct a 800-ton-capacity mill with operations scheduled by the end of 1966.

In Washington, zinc mine output decreased 8 percent to 22,200 tons, the lowest level since 1962. The Pend Oreille mine, Pend Oreille Mines and Metals Co., yielded 13,713 tons of zinc in concentrate and 4,028 tons of lead in concentrate from 640,600 tons of ore mined and milled.[7]

American Smelting and Refining Company operated their Van Stone mine during the year. American Zinc, Lead and Smelting Co. continued development of their Calhoun property with initial production scheduled for early 1966 at a rate of about 1,000 tons of ore per day.

Arizona mine output declined for the third year to 21,800 tons, the lowest level since 1955. The Iron King mine of Shattuck Denn Mining Corp. continued to be the largest zinc producer in the State. Other zinc-producing properties in the

[4] American Smelting and Refining Company. Annual Report. 1965, p. 13.

[5] Newmont Mining Corp. Annual Report. 1965, p. 7.

[6] Hecla Mining Co. Annual Report. 1965, 24 pp.

[7] Pend Oreille Mines and Metals Co. Annual Report. 1965, p. 3.

Table 4.—Twenty-five leading zinc-producing mines[1] in the United States in 1965, in order of output

Rank	Mine	State	County	Operator	Source of zinc
1	Balmat	New York	St. Lawrence	St. Joseph Lead Co.	Lead-zinc ore.
2	Sterling Hill	New Jersey	Sussex	The New Jersey Zinc Co.	Zinc ore.
3	Young	Tennessee	Jefferson	American Zinc Company of Tennessee	Do.
4	Friedensville	Pennsylvania	Lehigh	The New Jersey Zinc Co.	Do.
5	Butte Hill Zinc Mines	Montana	Silver Bow	The Anaconda Company	Do.
6	Eagle	Colorado	Eagle	The New Jersey Zinc Co.	Do.
7	Star-Morning Unit	Idaho	Shoshone	Hecla Mining Co.	Lead-zinc ore.
8	Austinville and Ivanhoe	Virginia	Wythe	The New Jersey Zinc Co.	Do.
9	Zinc Mine Works	Tennessee	Jefferson	United States Steel Corp.	Zinc ore.
10	Jefferson City	do.	do.	The New Jersey Zinc Co.	Do.
11	Edwards	New York	St. Lawrence	St. Joseph Lead Co.	Do.
12	Bunker Hill	Idaho	Shoshone	The Bunker Hill Co.	Lead-zinc ore.
13	Iron King	Arizona	Yavapai	Shattuck Denn Mining Corp.	Do.
14	Mascot No. 2	Tennessee	Knox	American Zinc Company of Tennessee	Zinc ore.
15	New Market	do.	Jefferson	New Market Zinc Co.	Do.
16	Pend Oreille	Washington	Pend Oreille	Pend Oreille Mines and Metals Co.	Lead-zinc ore.
17	Flat Gap	Tennessee	Hancock	The New Jersey Zinc Co.	Zinc ore.
18	U. S. and Lark	Utah	Salt Lake	United States Smelting, Refining and Mining Co.	Lead-zinc, lead ores.
19	Idarado	Colorado	Ouray and San Miguel	Idarado Mining Co.	Copper-lead-zinc ore.
20	Page	Idaho	Shoshone	American Smelting and Refining Company	Lead-zinc ore.
21	Copperhill	Tennessee	Polk	Tennessee Copper Co.	Copper-zinc ore.
22	Shullsburg	Wisconsin	Lafayette	The Eagle-Picher Co.	Zinc ore.
23	Van Stone	Washington	Stevens	American Smelting and Refining Company	Do.
24	Hanover	New Mexico	Grant	The New Jersey Zinc Co.	Do.
25	Princess	do.	do.	United States Smelting, Refining and Mining Co.	Do.

[1] Excludes old slag dumps.

State included the Old Dick and Copper Queen mines of Cyprus Mines Corp.

Virginia zinc mine production decreased for the fourth year to 20,500 tons, the lowest output since 1960. The New Jersey Zinc Co. operated the Austinville and Ivanhoe mines throughout the year.

In the Tri-State District of Oklahoma, Kansas, and Missouri, production increased to 19,200 tons, the highest level since 1957. The Oklahoma portion of the district accounted for 66 percent of the production and Kansas produced the remainder. The southwest Missouri portion of the district last reported production in 1957.

Zinc output from Illinois reversed a 3-year decline with a substantial increase to 18,300 tons. Increased fluorspar with byproduct zinc production from three mine operators in southern Illinois accounted for most of the increased zinc output. In northern Illinois, the Eagle-Picher Co. continued operation of the Graham mine and reopened the Blackjack mine in March.

Kentucky produced a record 5,700 tons of zinc. Production was from the Hutson zinc mine of The Eagle-Picher Co. and as a byproduct from fluorspar mining operations.

Mine production of 4,300 tons of zinc from Missouri, all as a byproduct from lead mining in southeast Missouri, was the largest output since 1961.

In Nevada, reactivated base-metal mines, including the Pan-American mine, resulted in a nearly sevenfold increase in zinc output to 3,900 tons.

In Maine, exploration and development of copper-zinc deposits in Hancock County was conducted by Black Hawk Mining Corp., a subsidiary of Denison Mines Ltd., and Callahan Mining Co. A mineralized area in Washington County containing zinc and other metals was diamond-drilled by Dolsan Mines, Ltd.

SMELTER AND REFINERY PRODUCTION

The zinc smelting and refining industry operated 13 primary and 8 secondary reduction plants producing slab zinc. Producers of slab zinc also made zinc compounds, alloys, zinc dust, and rolled zinc.

A 1-month closure of the National Zinc Co. smelter at Bartlesville, Okla., from March 7 to April 7, was the only significant interruption to operation by labor strikes during the year. Production at a number of smelters was curtailed due to a shortage of available concentrates relative to the demand for slab zinc.

According to company annual reports, American Zinc, Lead and Smelting Co. was installing new electric smelting and casting facilities at its Monsanto electrolytic plant. The production record at the Josephtown plant of St. Joseph Lead Co. resulted more from improvement in operating techniques than from other factors, as new productive facilities planned and under construction will not be operative until mid–1966. The Bunker Hill Co. has embarked on the largest expansion program in its history with a scheduled $13 million expenditure at their electrolytic zinc plant during the next 3 years. Initially, the expanded plant will be capable of producing about 110,000 tons of zinc per year, a 20-percent increase from present capacity. A new 350-ton-per-day sulfuric acid plant will be built to supplement the existing acid plant.

Slab Zinc.—Domestic smelters achieved a record output of slab zinc, surpassing the earlier 1957 record by nearly 20,000 tons. Included in the 1,078,000 tons of slab zinc output was molten zinc, used directly in alloying operations. Of the total, 994,400 tons was primary metal and 83,600 tons was redistilled secondary zinc. Primary output was 55 percent from domestic ores and 45 percent from foreign ores; 41 percent was electrolytic and 59 percent was distilled slab zinc. Of the 83,600 tons of redistilled secondary slab zinc, primary smelters produced 84 percent and the remainder was obtained from secondary smelters.

In 1965, Special High Grade was the principal grade produced, furnishing 44 percent of the total. Prime Western grade constituted 35 percent, and all other grades the remaining 21 percent.

Pennsylvania was the leading producing State, with Texas ranking second and Oklahoma third. The slab zinc output of Pennsylvania, West Virginia, and Oklahoma was produced by the distillation process; the output of Montana and Idaho by the electrolytic process. Part of the Illinois and Texas slab output was distilled and part was electrolytic.

Primary Smelters and Electrolytic Plants.—Primary reduction plants processed roasted zinc ores and concentrates, zinc fume from Waelz kilns and slag-fuming plants, other primary zinc-bearing materials, and zinc-base scrap.

Capacity for slab zinc production at the primary zinc plants at yearend was reported to be 1,211,850 tons. Electrolytic plants reported 3,246 of their 4,230 electrolytic cells in use at the end of the year and an output of 408,100 tons (80 percent of the 511,500 tons of capacity). The horizontal-retort plants reported 33,244 of their 39,436 retorts in use during 1965. The remaining primary smelters were continuous-distilling vertical-retort plants. Combined horizontal- and vertical-retort production of 656,600 tons was 93 percent of the reported 1965 capacity of 700,350 tons.

Slag-Fuming Plants.—Many lead smelters recover a zinc-fume product from lead blast-furnace slags containing about 7 to 13 percent zinc. Such slags were treated to extract zinc and remaining lead by the following companies in 1965:

Company	*Plant location*
American Smelting and Refining Company	Selby, Calif.
Do	El Paso, Tex.
The Anaconda Company	East Helena, Mont.
The Bunker Hill Co.	Kellogg, Idaho
International Smelting & Refining Co.	Tooele, Utah

Table 5.—Primary and redistilled secondary slab zinc produced in the United States

(Short tons)

	1956–60 (average)	1961	1962	1963	1964	1965
Primary:						
From domestic ores	407,714	413,282	448,095	474,007	531,967	551,215
From foreign ores	462,053	433,513	431,300	418,577	422,117	443,187
Total	869,767	846,795	879,395	892,584	954,084	994,402
Redistilled secondary	63,552	55,237	58,880	60,303	71,596	83,619
Total (excludes zinc recovered by remelting)	933,319	902,032	938,275	952,887	1,025,680	1,078,021

Table 6.—Distilled and electrolytic zinc, primary and secondary, produced in the United States, by methods of reduction

(Short tons)

Method of reduction	1956–60 (average)	1961	1962	1963	1964	1965
Electrolytic primary	349,388	324,399	354,138	358,093	389,383	408,128
Distilled	520,379	522,396	525,257	534,491	564,701	586,274
Redistilled secondary:						
At primary smelters	31,638	35,319	41,732	47,214	57,546	70,306
At secondary smelters	31,914	19,918	17,148	13,089	14,050	13,313
Total	933,319	902,032	938,275	952,887	1,025,680	1,078,021

Table 7.—Distilled and electrolytic zinc, primary and secondary, produced in the United States, by grades

(Short tons)

Grade	1956–60 (average)	1961	1962	1963	1964	1965
Special High Grade	339,552	353,466	392,901	411,254	468,748	479,736
High Grade	108,953	89,496	94,185	104,301	112,056	112,451
Intermediate	24,535	15,368	14,101	18,372	19,050	17,985
Brass Special	84,247	69,681	75,951	98,190	81,034	86,695
Select	1,267	------	130	3,909	326	309
Prime Western	374,765	374,021	361,007	316,861	344,466	380,845
Total	933,319	902,032	938,275	952,887	1,025,680	1,078,021

These five plants treated 628,800 tons of hot and 118,700 tons of cold lead slag plus 8,000 tons of crude ore and zinc residues, all of which yielded 131,100 tons of oxide fume, containing 87,000 tons of recoverable zinc. Corresponding figures for 1964 were 731,200 tons of feed materials, 130,500 tons of fume, and 93,400 tons of recoverable zinc.

Secondary Zinc Smelters.—Zinc-base scrap (principally skimmings and drosses, die-cast alloys, old zinc, engravers' plates, new clippings, and chemical residues) was smelted chiefly at secondary smelters, although about one-third was reduced at primary smelters and most sal ammoniac skimmings were processed at chemical plants.

Details of the zinc recovered in processing copper-base scrap may be obtained in the secondary copper and brass section of the chapter on copper of this volume.

BYPRODUCT SULFURIC ACID

Sulfur dioxide gases produced in roasting zinc sulfide concentrate at primary zinc plants were processed to yield 961,591 tons of sulfuric acid. At several plants, elemental sulfur was burned to produce additional quantities of sulfuric acid.

Table 8.—Primary slab zinc produced in the United States, by States where smelted

(Short tons)

State	1956–60 (average)	1961	1962	1963	1964	1965
Arkansas	17,234	12,342	14,446	11,143	-------	-------
Idaho	53,945	74,736	76,756	81,296	91,761	91,000
Illinois [1]	97,164	78,814	99,055	108,971	114,866	114,131
Montana	156,124	111,223	129,144	118,090	125,334	143,927
Oklahoma	151,982	164,319	147,384	142,707	150,356	154,187
Pennsylvania and West Virginia	216,315	214,308	234,038	248,584	262,981	278,870
Texas	177,003	191,053	178,572	181,793	208,786	212,287
Total	869,767	846,795	879,395	892,584	954,084	994,402
Value (thousand)	$209,594	$193,916	$201,733	$206,187	$260,274	$290,763

[1] Includes production for Missouri for 1956, 1957, and 1960.

Table 9.—Primary slab zinc plants, by group capacity in the United States in 1965

Type of plant	Plant location	Slab zinc capacity (short tons)
Electrolytic plants:		
American Smelting and Refining Company	Corpus Christi, Tex	
American Zinc Co. of Illinois	Monsanto, Ill	
The Anaconda Company [1]	Anaconda, Mont	511,500
Do	Great Falls, Mont	
The Bunker Hill Co	Kellogg, Idaho	
Horizontal-retort plants:		
American Smelting and Refining Company	Amarillo, Tex	
American Zinc Co. of Illinois	Dumas Tex	
Blackwell Zinc Co., Division of American Metal Climax, Inc.	Blackwell, Okla	
The Eagle-Picher Co	Henryetta, Okla	
Matthiessen & Hegeler Zinc Co [2]	LaSalle, Ill	
National Zinc Co	Bartlesville, Okla	700,350
Vertical-retort plants:		
Matthiessen & Hegeler Zinc Co	Meadowbrook, W. Va	
The New Jersey Zinc Co	Depue, Ill	
Do	Palmerton, Pa	
St. Joseph Lead Co [3]	Herculaneum, Mo	
Do	Josephtown, Pa	

[1] Plant not operated in 1965.
[2] Plant closed July 1, 1961.
[3] Electrothermic slag-fuming unit, yielding a slab zinc product.

Table 10.—Secondary slab zinc plants, by group capacity in the United States in 1965

Company	Plant location	Slab zinc capacity (short tons)
American Smelting and Refining Company [1]	Beckemeyer, Ill	53,000
Do	Sand Springs, Okla	
Do	Trenton, N. J	
American Zinc Co. of Illinois	Hillsboro, Ill	
Apex Smelting Co	Chicago, Ill	
Arco Die Cast Metals Co	Detroit, Mich	
W. J. Bullock, Inc	Fairfield, Ala	
General Smelting Co	Bristol, Pa	
Gulf Reduction Co	Houston, Tex	
H. Kramer Co	El Segundo, Calif	
Pacific Smelting Co	Torrance, Calif	
Sandoval Zinc Co	Sandovall, Ill	
Superior Zinc Corp	Bristol, Pa	
Wheeling Steel Corp	Martins Ferry, Ohio	

[1] Plant closed May 1964.

Table 11.—Stocks and consumption of new and old zinc scrap in the United States in 1965
(Short tons)

Class of consumer and type of scrap	Stocks Jan. 1 [1]	Receipts	Consumption: New scrap	Consumption: Old scrap	Consumption: Total	Stocks Dec. 31
Smelters and distillers:						
New clippings	86	1,366	1,338	------	1,338	114
Old zinc	488	4,554	------	4,417	4,417	625
Engravers' plates	211	3,295	------	3,284	3,284	222
Skimmings and ashes	7,430	79,748	73,776	------	73,776	13,402
Sal skimmings	273	180	275	------	275	178
Die-cast skimmings	1,237	3,037	3,152	------	3,152	1,122
Galvanizers' dross	7,670	65,319	67,741	------	67,741	5,248
Diecastings	2,340	44,568	------	43,170	43,170	3,738
Rod and die scrap	1,030	1,707	------	2,462	2,462	275
Flue dust	1,711	7,492	8,853	------	8,853	350
Chemical residues	920	8,144	8,555	------	8,555	509
Total	23,396	219,410	163,690	53,333	217,023	25,783
Chemical plants, foundries and other manufacturers:						
New clippings	------	6	5	------	5	1
Old zinc	7	9	------	8	8	8
Engravers' plates	------	33	------	33	33	------
Skimmings and ashes	1,402	10,689	10,245	------	10,245	1,846
Sal skimmings	6,829	9,036	11,793	------	11,793	4,072
Die-cast skimmings	------	------	------	------	------	------
Galvanizers' dross	------	------	------	------	------	------
Diecastings	27	1,957	------	838	838	1,146
Rod and die scrap	14	53	------	65	65	2
Flue dust	23	53	63	------	63	13
Chemical residues	718	24,360	24,085	------	24,085	993
Total	9,020	46,196	46,191	944	47,135	8,081
All classes of consumers:						
New clippings	86	1,372	1,343	------	1,343	115
Old zinc	495	4,563	------	4,425	4,425	633
Engravers' plates	211	3,328	------	3,317	3,317	222
Skimmings and ashes	8,832	90,437	84,021	------	84,021	15,248
Sal skimmings	7,102	9,216	12,068	------	12,068	4,250
Die-cast skimmings	1,237	3,037	3,152	------	3,152	1,122
Galvanizers' dross	7,670	65,319	67,741	------	67,741	5,248
Diecastings	2,367	46,525	------	44,008	44,008	4,884
Rod and die scrap	1,044	1,760	------	2,527	2,527	277
Flue dust	1,734	7,545	8,916	------	8,916	363
Chemical residues	1,638	32,504	32,640	------	32,640	1,502
Total	32,416	265,606	209,881	54,277	264,158	33,864

[1] Figures partly revised.

Table 12.—Production of zinc products from zinc-base scrap in the United States
(Short tons)

Product	1956–60 (average)	1961	1962	1963	1964	1965
Redistilled slab zinc	63,552	[1] 55,237	[1] 58,880	60,303	71,596	83,619
Zinc dust	25,039	22,878	24,863	23,749	29,742	33,512
Remelt spelter	5,828	4,260	3,540	3,740	3,646	5,324
Remelt die-cast slab	11,432	9,548	10,834	10,168	8,934	14,760
Zinc-die and diecasting alloys	5,927	5,894	5,531	5,894	5,116	5,463
Galvanizing stocks	265	117	369	611	1,684	1,450
Rolled zinc	481	19	14	4	-----	-----
Secondary zinc in chemical products	34,946	35,639	36,331	35,210	36,130	47,997

[1] Includes redistilled slab made from remelt die-cast slab.

Table 13.—Zinc recovered from scrap processed in the United States, by kind of scrap and form of recovery
(Short tons)

Kind of scrap	1964	1965	Form of recovery	1964	1965
New scrap:			As metal:		
Zinc-base	124,342	140,871	By distillation:		
Copper-base	102,913	127,276	Slab zinc [1]	70,681	81,670
Aluminum-base	2,866	2,916	Zinc dust	29,296	32,976
Magnesium-base	209	292	By remelting	5,178	6,611
Total	230,330	271,355	Total	105,155	121,257
Old scrap:			In zinc-base alloys	13,073	18,934
Zinc-base	33,375	43,603	In brass and bronze	137,619	158,063
Copper-base	31,716	34,777	In aluminum-base alloys	5,997	6,613
Aluminum-base	2,832	3,524	In magnesium-base alloys	420	500
Magnesium-base	141	105	In chemical products:		
			Zinc oxide (lead-free)	18,722	27,232
Total	68,064	82,009	Zinc sulfate	6,206	9,059
			Zinc chloride	10,968	11,405
Grand total	298,394	353,364	Miscellaneous	234	301
			Total	193,239	232,107
			Grand total	298,394	353,364

[1] Includes zinc content of redistilled slab made from remelt die-cast slab.

ZINC DUST

Zinc dust data included in the tables are restricted to commercial grades that comply with close specifications as to percentage of unoxidized metal, evenness of grading, and fineness of particles; they do not include blue powder. Zinc content of the dust produced ranged from 94.99 to 99.75 percent, averaging 98.43 percent. Production of zinc dust increased for the third successive year to a record 52,000 tons.

Table 14.—Zinc dust produced in the United States

Year	Short tons	Value: Total	Value: Average per pound
1956–60 (average)	28,964	$8,889,551	$0.153
1961	34,772	10,570,688	.152
1962	40,978	12,539,268	.153
1963	40,362	12,592,944	.156
1964	45,979	15,724,818	.171
1965	51,958	19,328,376	.186

CONSUMPTION AND USES

Both slab and total zinc consumed were at record levels. In the consumption of slab zinc, all major product categories except brass products increased with a record attained for the third consecutive year for zinc-base alloys and for the second consecutive year for galvanizing.

Of the 1.35 million tons of slab zinc used, 54 percent was Special High Grade, 27 percent Prime Western, and the remaining 19 percent all other grades. Galvanizing used mostly Prime Western grade while brass and bronze products consumed mostly the higher grades of zinc. Of the 638,000 tons of slab zinc used in zinc-base alloys, 99 percent was Special High Grade.

Rolling mills used 45,900 tons of slab zinc and remelted and rerolled 17,000 tons of metallic scrap produced in fabricating plants operated in connection with the rolling mills. In addition, a small quantity of purchased scrap (new clippings and old zinc) was melted and rolled. Small quantities of alloying metals were added for some uses. The rolled-zinc industry, however, classified these alloys as rolled zinc.

Net output of salable rolled zinc increased 4 percent to 44,700 tons. Stocks of rolled zinc at the mills declined to 1,600 tons by yearend. Besides shipments of 23,500 tons of rolled zinc, the rolling mills consumed 38,400 tons of rolled zinc in

Table 15.—Consumption of zinc in the United States
(Short tons)

	1956–60 (average)	1961	1962	1963	1964	1965
Slab zinc	929,363	931,213	1,031,821	1,105,113	1,207,268	1,354,092
Ores (recoverable zinc content)	102,989	[1] 97,251	[1] 101,582	[1] 104,705	[1] 105,948	[1] 122,892
Secondary (recoverable zinc content) [2]	194,459	179,005	199,908	204,398	222,535	265,083
Total	1,226,811	1,207,469	1,333,311	1,414,216	1,535,751	1,742,067

[1] Includes ore used directly in galvanizing.
[2] Excludes redistilled slab and remelt zinc.

Table 16.—Slab zinc consumption in the United States, by industry use
(Short tons)

Industry and product	1956–60 (average)	1961	1962	1963	1964	1965
Galvanizing:						
Sheet and strip	187,576	211,300	213,970	238,919	257,328	270,826
Wire and wire rope	37,181	37,608	38,203	39,466	42,793	43,884
Tubes and pipe	68,114	54,957	54,003	56,563	62,166	63,224
Fittings	9,804	6,540	8,039	7,787	8,802	8,641
Other	81,475	[1] 71,672	[1] 74,355	[1] 77,552	[1] 85,247	[1] 95,846
Total	384,150	382,077	388,570	420,287	456,336	482,421
Brass products:						
Sheet, strip, and plate	52,630	60,018	61,210	61,462	64,701	58,864
Rod and wire	35,190	41,018	41,875	43,517	47,246	45,510
Tube	11,108	10,168	10,627	10,786	10,402	10,030
Castings and billets	5,249	4,061	4,923	3,969	3,258	3,050
Copper-base ingots	8,253	12,874	10,884	7,784	8,565	7,402
Other copper-base products	784	384	286	719	923	1,992
Total	113,214	128,523	129,805	128,237	135,095	126,848
Zinc-base alloy:						
Die casting alloy	347,382	337,227	419,042	462,543	517,354	629,809
Dies and rod alloy	6,411	1,629	850	720	604	535
Slush and sand casting alloy	2,423	2,910	3,716	5,356	6,624	7,626
Total	356,216	341,766	423,608	468,619	524,582	637,970
Rolled zinc	42,178	41,204	42,233	42,166	44,181	45,882
Zinc oxide	17,352	18,137	18,517	16,037	19,991	25,781
Other uses:						
Wet batteries	1,184	1,058	1,133	1,216	1,168	1,188
Desilverizing lead	2,548	2,630	2,302	2,095	2,393	2,444
Light-metal alloys	4,198	4,347	4,920	5,660	4,769	8,124
Other [2]	8,324	11,471	20,733	20,796	18,753	23,434
Total	16,254	19,506	29,088	29,767	27,083	35,190
Grand total	929,364	931,213	1,031,821	1,105,113	1,207,268	1,354,092

[1] Includes 30,954 tons used in job galvanizing in 1961, 34,871 tons in 1962, 39,223 tons in 1963, 44,354 tons in 1964, and 51,011 tons in 1965.
[2] Includes zinc used in making zinc dust, bronze powder, alloys, chemicals, castings, and miscellaneous uses not elsewhere mentioned.

Table 17.—Slab zinc consumption in the United States in 1965, by grades and industry use
(Short tons)

Industry	Special High Grade	High Grade	Inter-mediate	Brass Special	Select	Prime Western	Remelt	Total
Galvanizing	27,517	34,601	1,880	104,821	1,066	308,454	4,082	482,421
Brass and bronze	26,247	67,425	264	3,771	1,918	25,720	1,503	126,848
Zinc-base alloys	631,748	2,788	99	------	5	1,618	1,712	637,970
Rolled zinc	22,187	10,360	5,344	7,945	------	46	------	45,882
Zinc oxide	7,035	4	------	------	------	18,742	------	25,781
Other	15,981	1,629	252	10,117	------	6,721	490	35,190
Total	730,715	116,807	7,839	126,654	2,989	361,301	7,787	1,354,092

Table 18.—Rolled zinc produced and quantity available for consumption in the United States

	1964			1965		
		Value			Value	
	Short tons	Total	Average per pound	Short tons	Total	Average per pound
Production: [1]						
Photoengraving plate	(2)	(2)	(2)	12,320	$5,779,667	$0.234
Other plate [3]	W	W	W	W	W	W
Sheet [3]	15,538	$7,929,548	$0.255	W	W	W
Strip and foil	25,580	11,269,831	.220	28,712	12,944,086	.225
Rod and wire	W	W	W	W	W	W
Total rolled zinc	42,964	20,201,411	.235	44,724	21,125,010	.236
Imports	1,774	526,990	.149	1,381	453,000	.164
Exports	6,569	3,978,434	.303	5,120	3,051,000	.298
Available for consumption	38,819	--------	----	41,197	--------	----
Value of slab zinc (all grades)	-----	--------	.136	-----	--------	.146
Value added by rolling	-----	--------	.099	-----	--------	.090

W Withheld to avoid disclosing individual company confidential data.
[1] Figures represent net production. In addition, 14,550 tons in 1964 and 17,023 tons in 1965 were rerolled from scrap originating in fabricating plants operating in connection with zinc rolling mills.
[2] Included in sheet category in 1964.
[3] In 1964 material 0.1 inch or thicker was classed as plate and material less than 0.1 inch thick was classed as sheet. In 1965 material 0.375 inch or thicker was classed as other plate and material less than 0.375 inch thick was classed as sheet.

manufacturing 21,400 tons of semifabricated and finished products.

Rolled zinc was produced in the form of sheet, strip, ribbon, plate, rod, and wire. Its major domestic use was for dry-cell battery cases and similar cases for radio condensers and tube shields. Photoengraving plates, weatherstripping, roof flashing, and household electric fuses were other uses.

CONSUMPTION OF SLAB ZINC BY GEOGRAPHIC AREAS

Ohio, Pennsylvania, Indiana, and Illinois accounted for 58 percent of the slab zinc used in galvanizing. The iron and steel industry used zinc to galvanize steel sheets, wire, tube, pipe, cable, chain, bolts, railway-signal equipment, building and poleline hardware, and other items.

Connecticut again ranked first in consuming slab zinc in brass making, followed by Illinois and Michigan.

Michigan led in the consumption of slab zinc in making zinc-base alloys. Other large consuming States were Illinois, Ohio, New York, and Indiana.

ZINC PIGMENTS AND COMPOUNDS

Production.—Output of zinc pigments and compounds, excluding lithopone, increased to the highest level since 1950. Most of the increase was accounted for by record outputs of lead-free zinc oxide and zinc sulfate. Increases of 3 percent for zinc chloride and leaded zinc oxide also contributed to the advance for all zinc pigments.

Table 19.—Slab zinc consumption in the United States in 1965, by industries and States
(Short tons)

State	Galvanizers	Brass mills [1]	Die casters [2]	Other [3]	Total
Alabama	40,952	W	------	W	42,576
Arizona	W	------	------	W	W
Arkansas	------	------	------	W	W
California	33,825	2,502	10,700	618	47,645
Colorado	W	W	W	W	3,693
Connecticut	3,580	39,391	W	W	46,084
Delaware	W	W	W	W	W
Florida	2,572	------	W	------	W
Georgia	W	------	W	------	W
Hawaii	W	------	------	------	W
Idaho	------	------	W	W	W
Illinois	47,865	18,441	89,385	W	178,052
Indiana	64,656	W	54,457	W	146,176
Iowa	825	------	------	W	W
Kansas	------	------	W	------	W
Kentucky	W	W	------	W	16,334
Louisiana	1,917	------	------	W	W
Maine	W	------	------	------	W
Maryland	W	W	------	W	32,632
Massachusetts	3,833	W	------	W	8,174
Michigan	4,724	12,853	170,310	W	189,798
Minnesota	2,231	------	------	------	2,231
Mississippi	W	------	------	------	W
Missouri	6,728	W	7,583	W	17,723
Nebraska	W	W	------	W	1,766
New Hampshire	------	W	------	------	W
New Jersey	3,764	6,140	W	3,041	W
New York	5,393	7,497	71,712	W	93,156
North Carolina	W	------	W	------	W
Ohio	94,723	W	99,578	1,257	W
Oklahoma	3,643	------	W	W	8,078
Oregon	499	W	W	W	600
Pennsylvania	70,443	W	22,151	W	134,725
Rhode Island	553	W	------	W	583
Tennessee	864	------	W	W	2,692
Texas	14,487	W	W	W	50,263
Utah	W	W	------	------	W
Virginia	356	W	W	W	1,396
Washington	1,165	------	------	W	2,266
West Virginia	13,468	W	------	W	15,395
Wisconsin	1,722	W	W	W	17,128
Undistributed	53,551	38,521	110,382	101,447	287,139
Total[4]	478,339	125,345	636,258	106,363	1,346,305

W Withheld to avoid disclosing individual company confidential data; included with "Undistributed."
[1] Includes brass mills, brass ingot makers, and brass foundries.
[2] Includes producers of zinc-base alloy for diecastings, stamping dies, and rods.
[3] Includes slab zinc used in rolled zinc products and in zinc oxide.
[4] Excludes remelt zinc.

Table 20.—Production and shipments of zinc pigments and compounds [1] in the United States

Pigment or compound	1964				1965			
	Production (short tons)	Shipments			Production (short tons)	Shipments		
		Short tons	Value [2]			Short tons	Value [2]	
			Total	Average per ton			Total	Average per ton
Zinc oxide [3]	163,305	174,303	$41,970,758	$241	187,829	186,570	$48,751,733	$261
Leaded zinc oxide [3]	12,237	13,613	3,246,038	238	12,554	11,850	3,736,226	315
Zinc chloride, 50° B [4]	50,977	49,624	W	W	52,635	54,296	W	W
Zinc sulfate	46,314	46,606	7,021,601	151	53,104	50,544	7,340,632	145

W Withheld to avoid disclosing individual company confidential data.
[1] Excludes lithopone; figure withheld to avoid disclosing individual company confidential data.
[2] Value at plant, exclusive of container.
[3] Zinc oxide containing 5 percent or more lead is classed as leaded zinc oxide.
[4] Includes zinc chloride equivalent of zinc ammonium chloride and chromated zinc chloride.

Pigments and compounds were made from various zinc-bearing materials including ore, slab zinc, scrap, and residues. Plants producing zinc pigments and compounds numbered 16 for zinc oxide, 8 for zinc sulfate, 8 for zinc chloride, and 1 for lithopone.

Lead-free zinc oxide was made by several processes; 67 percent was made from ores and residues by the American process, 20 percent from metal by the French process, and 13 percent from scrap residues and secondary materials by other processes. Leaded zinc oxide was made from ores; zinc chloride was made from slab zinc and secondary zinc materials; and zinc sulfate was made from ores and secondary materials.

Leaded zinc oxide was produced in several grades, classified according to lead content. The more than 5 to 35 percent grade constituted most of the production. Relatively small quantities of grades 5 percent or less, more than 35 to 50 percent, and more than 50 percent were produced.

Lithopone, a coprecipitate of zinc sulfide

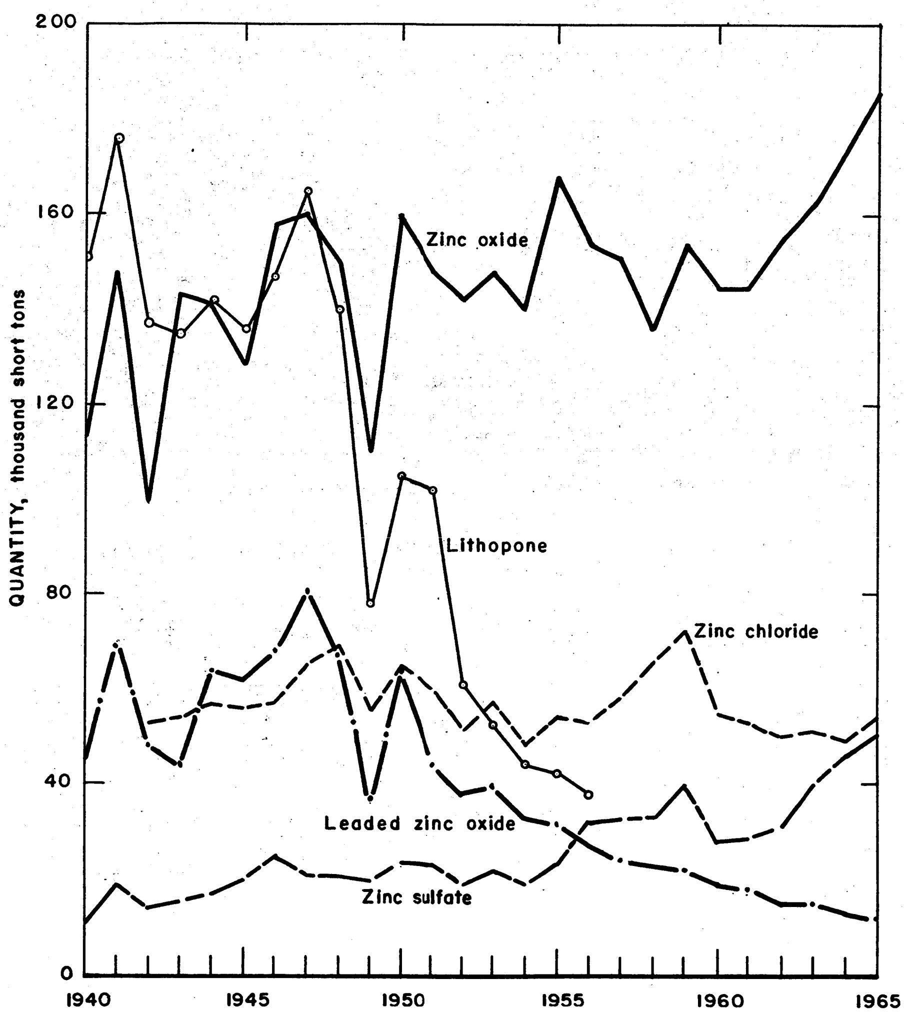

Figure 2.—Trends in shipments of zinc pigments.

and barium sulfate, was produced but figures are withheld to avoid disclosing individual company confidential data.

Consumption and Uses.—Shipments of lead-free zinc oxide were 186,600 tons, 7 percent more than in 1964 with most of the increase in shipment to the rubber industry. The quantity received by the rubber, paint, and ceramic industries accounted for 77 percent of the total shipped.

The paint industry received 92 percent of the 11,900 tons of leaded zinc oxide shipped.

Lithopone was used principally in paint, varnish and lacquer, chemicals, paper, rubber, and floor coverings.

The principal uses of zinc chloride were for battery making, galvanizing, vulcanizing fiber, preserving wood, and refining oil, as well as for fungicides, solder, and tinning fluxes.

The chief uses of zinc sulfate were in rayon and agriculture. Other uses were in glue manufacture, flotation reagents, rubber, and medicine.

Prices.—Prices for French process, lead-free zinc oxides advanced 0.50 cent in

Table 21.—Zinc content of zinc pigments [1] and compounds produced by domestic manufacturers, by sources

(Short tons)

Pigment or compound	1964: Zinc in pigments and compounds produced from— Ore: Domestic	1964: Ore: Foreign	1964: Slab zinc	1964: Secondary material	1964: Total zinc in pigments and compounds	1965: Zinc in pigments and compounds produced from— Ore: Domestic	1965: Ore: Foreign	1965: Slab zinc	1965: Secondary material	1965: Total zinc in pigments and compounds
Zinc oxide	70,728	13,487	19,991	26,136	130,342	80,399	19,054	25,782	24,683	149,918
Leaded zinc oxide	4,714	2,780	-----	-----	7,494	4,942	2,854	-----	-----	7,796
Total	75,442	16,267	19,991	26,136	137,836	85,341	21,908	25,782	24,683	157,714
Zinc chloride [2]	-----	-----	W	W	12,315	-----	-----	W	W	12,740
Zinc sulfate	W	W	-----	6,206	14,921	W	W	-----	9,059	17,925

W Withheld to avoid disclosing individual company confidential data.
[1] Excludes zinc sulfide and lithopone; figures withheld to avoid disclosing individual company confidential data.
[2] Includes zinc content of zinc ammonium chloride and chromated zinc chloride.

Table 22.—Distribution of zinc oxide and leaded zinc oxide shipments, by industries

(Short tons)

Industry	1956–60 (average)	1961	1962	1963	1964	1965
Zinc oxide:						
Rubber	77,001	71,534	80,247	82,776	93,568	103,057
Paints	32,748	30,405	31,381	34,382	31,176	30,249
Ceramics	9,608	10,058	11,092	9,381	9,447	10,009
Chemicals	NA	NA	NA	NA	NA	11,365
Agriculture	NA	NA	NA	NA	NA	977
Photocopying	NA	NA	NA	NA	NA	W
Coated fabrics and textiles [1]	3,571	1,185	202	W	W	W
Floor covering	1,236	1,174	457	W	438	363
Other and unspecified	24,081	30,852	31,470	35,732	39,674	30,550
Total	148,245	145,208	154,849	162,271	174,303	186,570
Leaded zinc oxide:						
Paints	22,423	16,533	14,959	14,899	13,124	10,951
Rubber	889	1,474	735	574	489	899
Other and unspecified						
Total	23,312	18,007	15,694	15,473	13,613	11,850

W Withheld to avoid disclosing individual company confidential data, included with "Other."
NA Not available.
[1] Figures for 1959–62 for rayon withheld to avoid disclosing individual company confidential data.

Table 23.—Distribution of zinc sulfate shipments, by industries
(Short tons)

Year	Rayon		Agriculture		Other		Total	
	Gross weight	Dry basis	Gross weight	Dry basis	Gross weight	Dry basis	Gross weight	Dry basis
1956–60 (average)	20,514	18,362	7,595	6,583	5,695	4,831	33,804	29,776
1961	12,284	11,007	5,673	5,086	10,934	9,926	28,891	26,019
1962	W	W	8,544	7,313	22,687	20,359	31,231	27,672
1963	W	W	10,785	9,407	29,326	23,674	40,111	33,081
1964	18,066	16,103	11,248	9,807	17,292	11,231	46,606	37,141
1965	21,204	18,886	14,331	12,449	15,009	10,637	50,544	41,972

W Withheld to avoid disclosing individual company confidential data, included with "Other."

March to a yearend quotation in cents per pound in carlots, freight allowed, of 17.00 cents for Green Seal grade and 17.25 cents for White Seal grade. American process, lead-free zinc oxide, leaded zinc oxide of the 35-percent grade, and leaded zinc oxide of the 50-percent grade were quoted at 14.75, 15.75, and 16.00 cents, respectively, throughout the year.

Zinc chloride (50° Baumé) was quoted at 5.55 cents per pound throughout the year. Zinc sulfate (monohydrate, 36 percent) in less than carlots was quoted at 9.50 cents per pound until March 29 when it increased to 10.25 cents where it remained for the balance of the year.

Foreign Trade.—Exports of zinc oxide increased 9 percent with shipments to 43 countries. Canada, Turkey, and Colombia received 31, 17, and 14 percent of the total, respectively. Lithopone exports declined to half the 1964 level and were the lowest since 1962.

Substantial increases in imports of zinc oxide and zinc sulfate accounted for most of the 42-percent gain for imports of all zinc pigments and compounds. Mexico and Canada supplied 55 and 34 percent, respectively, of the zinc oxide imports. Zinc sulfate imports were provided 50 percent from Mexico, 34 percent from Belgium-Luxembourg, and 14 percent from West Germany.

Table 24.—U.S. exports of zinc pigments

Kind	1964		1965	
	Short tons	Value (thousands)	Short tons	Value (thousands)
Zinc oxide	2,435	$707	2,660	$818
Lithopone	1,184	192	609	187
Total	3,619	899	3,269	1,005

Table 25.—U.S. imports for consumption of zinc pigments and compounds

Kind	1964		1965	
	Short tons	Value (thousands)	Short tons	Value (thousands)
Zinc oxide	8,708	$1,704	11,596	$2,319
Zinc sulfide	393	123	392	120
Lithopone	172	21	190	34
Zinc chloride	1,200	188	1,099	186
Zinc sulfate	1,245	123	2,817	305
Zinc cyanide	59	42	60	46
Zinc compounds, n.s.p.f.	653	188	1,577	472
Total	12,430	2,389	17,731	3,482

STOCKS

Producer Stocks.—Stocks of slab zinc at producer plants were 31,200 tons at the beginning of the year, declined to a low of about 20,000 tons at the end of April, then increased to 28,600 tons by yearend. This was the lowest yearend stocks recorded since 1951.

Consumer Stocks.—Stocks of slab zinc at consumer plants of 108,400 tons at the start of the year were drawn down about 25,000 tons by the end of April, followed by a rapid buildup to a record yearend level of 151,900 tons. Sales of zinc from the Government stockpile was an important factor in reversing the downward trend of industrial stocks during the early part of the year.

Table 26.—Stocks of zinc at zinc-reduction plants in the United States, Dec. 31

(Short tons)

	1961	1962	1963	1964	1965
At primary reduction plants	143,494	142,059	46,374	30,680	27,635
At secondary distilling plants	3,393	2,687	1,536	498	987
Total	146,887	144,746	47,910	31,178	28,622

Table 27.—Consumer stocks of slab zinc at plants, Dec. 31, by industries

(Short tons)

Date	Galvanizers	Brass mills [1]	Zinc diecasters [2]	Zinc rolling mills	Oxide plants	Other	Total [3]
Dec. 31, 1964	r 56,110	r 10,438	r 35,540	3,535	282	r 2,506	r 108,411
Dec. 31, 1965	80,750	19,752	42,999	4,588	444	3,340	151,873

r Revised.

[1] Includes brass mills, brass ingot makers, and foundries.

[2] Includes producers of zinc-base alloy for diecastings, stamping dies, and rods.

[3] Stocks on Dec. 31, 1964, and Dec. 31, 1965, include 436 and 419 tons, respectively, of remelt spelter.

PRICES

Prime Western grade zinc was quoted throughout 1965 at 14.5 cents per pound and at 15.0 cents delivered price.

A foreign producer price, established in 1964, was the equivalent of 13.75 cents per pound throughout the year. Prices on the London Metal Exchange fluctuated in a narrow range around the producer price.

During 1965, the quoted price for new clippings ranged from 9.25 to 11.25 cents per pound, averaging 10.50 cents. For old zinc, the quotation ranged from 5.75 to 7.75 cents and averaged 7.13 cents per pound.

Table 28.—Average monthly quoted prices of 60-percent zinc concentrate at Joplin, and common zinc (prompt delivery or spot), East St. Louis and London [1]

Month	1964			1965		
	60-percent zinc concentrates in the Joplin region (per ton)	Metallic zinc (cents per pound)		60-percent zinc concentrates in the Joplin region (per ton)	Metallic zinc (cents per pound)	
		East St. Louis	London [2,3]		East St. Louis	London [2,3]
January	$80.00	13.05	11.98	$92.00	14.50	14.62
February	80.00	13,00	12.27	92.00	14.50	14.53
March	80.00	13.00	12.57	92.00	14.50	14.33
April	81.64	13.34	13.55	92.00	14.50	14.33
May	84.00	13.50	15.56	92.00	14.50	14.69
June	84.00	13.50	16.20	92.00	14.50	14.26
July	84.00	13.50	17.47	92.00	14.50	14.08
August	84.00	13.50	15.53	92.00	14.50	13.78
September	84.00	13.50	15.08	92.00	14.50	13.59
October	87.64	13.98	15.05	92.00	14.50	13.96
November	92.00	14.50	15.51	92.00	14.50	13.55
December	92.00	14.50	15.56	92.00	14.50	13.74
Average for year	84.44	13.57	14.74	92.00	14.50	14.12

[1] Joplin: Metal Statistics, 1966. East St. Louis: Metal Statistics, 1966. London: E&MJ Metal and Mineral Markets.

[2] Conversion of English quotations into U.S. money based on average rates of exchange recorded by Federal Reserve Board.

[3] Average of daily mean of bid and asked quotations at morning session of London Metal Exchange.

Table 29.—Average price received by producers of zinc, by grades

(Cents per pounds)

Grade	1961	1962	1963	1964	1965
Special High Grade	11.58	11.43	11.66	14.17	15.05
High Grade	11.42	11.47	11.61	13.64	14.55
Intermediate	12.12	11.84	11.79	14.03	14.70
Brass Special	11.52	11.76	11.80	13.90	14.62
Select	11.60	12.88	11.29	13.55	14.88
Prime Western	11.32	11.45	11.35	12.97	14.16
All Grades	11.45	11.47	11.55	13.64	14.62
Prime Western; spot quotation at St. Louis [1]	11.55	11.63	12.01	13.57	14.50

[1] Metal Statistics, 1966.

FOREIGN TRADE

Exports.—Exports of slab zinc decreased from 26,500 to 5,900 tons, the lowest level since 1958. The Republic of Korea received 31 percent, India 31 percent, and Brazil 13 percent of total exports.

Imports.—Termination of import quotas, effective October 22 for ores and November 21 for metal, resulted in a marked increase in imports during the last quarter of the year. For the full year, general imports

Table 30.—U.S. exports of slab and sheet zinc, by countries

(Short tons)

Destination	Slabs, pigs, and blocks				Sheets, plates, strips, or other forms, n.e.s.			
	1962	1963	1964	1965	1962	1963	1964	1965
North America:								
Canada	495	337	53	211	1,512	1,541	2,652	2,144
Mexico	1	---	216	1	21	25	23	19
Other	16	16	51	20	80	60	88	108
Total	512	353	320	232	1,613	1,626	2,763	2,271
South America:								
Argentina	---	---	51	(1)	36	48	30	18
Brazil	262	128	---	789	12	15	25	42
Chile	39	163	331	172	43	35	42	60
Colombia	---	663	565	23	213	37	53	33
Venezuela	7	13	325	100	119	86	111	92
Other	110	1	1	4	24	12	28	47
Total	418	968	1,273	1,088	447	233	289	292
Europe:								
Belgium-Luxembourg	---	---	---	---	20	34	34	12
Denmark	---	---	55	---	164	230	180	74
Germany, West	2	14	224	2	32	59	1,172	1,572
Italy	---	---	---	---	29	113	124	38
Netherlands	---	---	---	---	127	123	186	59
Sweden	---	---	---	---	231	227	215	29
Switzerland	---	---	---	---	221	205	152	5
United Kingdom	112	---	4,837	1	242	261	254	168
Other	733	---	736	52	228	369	601	183
Total	847	14	5,852	55	1,294	1,621	2,918	2,140
Africa:								
South Africa, Republic of	---	---	---	62	80	89	104	114
Other	106	78	448	49	3	6	32	3
Total	106	78	448	111	83	95	136	117
Asia:								
India	32,625	30,155	13,066	1,822	19	16	28	10
Japan	1	147	662	31	---	---	2	1
Korea, South	903	1,969	1,900	1,858	1	8	81	---
Philippines	10	6	938	225	37	31	60	33
Other	680	163	2,056	517	40	86	255	105
Total	34,219	32,440	18,622	4,453	97	141	426	149
Oceania	---	---	---	---	13	40	37	151
Grand total	36,102	33,853	26,515	5,939	3,547	3,756	6,569	5,120

Table 31.—U.S. exports of zinc, by classes

Year	Zinc ore, concentrates (zinc content)		Slabs, pigs, or blocks		Sheets, plates, strips, or other forms, n.e.s.		Zinc scrap and dross (zinc content)		Semifabricated forms, n.e.c.		Zinc dust	
	Short tons	Value (thousands)	Short tons	Value (thousands)	Short tons	Value (thousands)	Short tons	Value (thousands)	Short tons	Value (thousands)	Short tons	Value (thousands)
1956–60 (average)	175	$33	21,689	$5,303	3,834	$2,754	9,847	$1,056	3,175	$579	557	$190
1961	1,670	124	50,055	11,196	3,219	2,271	5,900	871	3,036	1,317	717	224
1962	136	46	36,102	8,050	3,547	2,391	7,940	956	1,613	1,254	676	240
1963	17	6	33,853	7,506	3,756	2,742	1,794	539	1,532	1,163	759	261
1964	39	12	26,515	7,240	6,569	3,978	6,448	1,379	5,666	2,451	1,828	542
1965	NA	NA	5,939	1,765	5,120	3,051	5,617	1,153	2,764	1,931	NA	NA

NA Not available beginning Jan. 1, 1965.

(imports for immediate consumption plus entries into bonded warehouses) were the largest since 1962 for ores and since 1959 for metal.

Imports of zinc fume, not shown in the tables, were reported by the Bureau of the Census to have been 22,775 tons containing 17,043 tons of dutiable zinc. Mexico was the source for nearly all the fume. Also, imports of materials not elsewhere specified, with a content of more than 10 percent zinc, amounted to 5,090 tons containing 4,705 tons of zinc.

Tariff.—Duties on unmanufactured zinc and zinc containing materials remained unchanged and were as follows: Slab zinc, 0.7 cents per pound; zinc ores and concentrates, 0.67 cents per pound; zinc fume, 0.67 cents per pound; zinc scrap, 0.75 cents per pound; and zinc dust, 0.7 cents per pound.

WORLD REVIEW

NORTH AMERICA

Canada.—Mine production increased 25 percent to a record 911,400 tons of zinc in concentrates, further establishing Canada's position as the world's largest producer of zinc. The increase was largely attributed to commencement of mining at the Pine Point mine in the Northwest Territories, the Cupra mine in Quebec, and the Willecho mine in Ontario; also the first full year of operation at the Brunswick No. 12 mine in New Brunswick and at the Lake Dufault mine in Quebec. Slab zinc output also increased to a record 358,600 tons with the three electrolytic zinc plants of Consolidated Mining & Smelting Co. of Canada Ltd. (COMINCO), Hudson Bay Mining and Smelting Co. Ltd., and Canadian Electrolytic Zinc Ltd., operating throughout the year.[8]

COMINCO's zinc metal production was a record 213,082 tons and in December achieved output equivalent to the newly expanded annual plant capacity of 232,000 tons. The combined zinc-lead production derived approximately 48 percent from the company's Sullivan mine, 12 percent from other company mines, 29 percent from ores and concentrates purchased from Pine Point Mines Ltd., and 11 percent from other purchased ores and concentrates. Extraction of ore from company properties was 2,301,000 tons at the Sullivan mine, 256,000 tons from the Bluebell lead-zinc mine, and 416,000 tons from the H. B. mine. Ore reserves at company mines tributary to the Trail smelter (Sullivan, Bluebell, and H. B.) at September 30 totaled 73.9 million tons containing 8.3 million tons of lead and zinc. Full scale production was attained late in the year at the Northwest Territory lead-zinc mine of Pine Point Mines Ltd. (78 percent owned by COMINCO). The ore reserve at this property was 21.5 million tons averaging 7.2 percent zinc and 4.0 percent lead.[9]

According to the annual report of Reeves MacDonald Mines Ltd., the company mined and milled 409,500 tons of ore at its Remac, British Columbia, mine and

[8] Fraser, D. B. Zinc and Lead. Miner. Res. Division, Dept. of Mines and Tech. Surveys (Ottawa, Canada), Miner. Inf. Bull. MR–81, 1966, p. 33.

[9] Consolidated Mining & Smelting Co. of Canada, Ltd. Annual Report. 1965, 20 pp.

Table 32.—U.S. imports of zinc, by countries

(Short tons)

Country	1956–60 (average)	1961	1962	1963	1964	1965
Ores (zinc content):[1]						
North America:						
Canada	152,657	119,113	192,423	134,303	156,385	201,353
Guatemala	6,660	13,870	2,511	1,430	3	4
Honduras	2,491	6,851	7,048	8,234	7,709	6,786
Mexico	183,433	186,174	165,005	138,185	103,879	117,354
Other	572	---	---	---	---	---
Total	345,813	326,008	366,987	282,152	267,976	325,497
South America:						
Argentina	55	---	---	---	10,518	---
Bolivia	5,200	572	1,791	4,395	3,540	4,093
Chile	646	(2)	518	---	1,741	---
Peru	97,462	74,369	77,501	73,788	62,864	73,721
Other	93	53	13	8	---	---
Total	103,456	74,994	79,823	78,191	78,663	77,814
Europe:						
Germany, West	1,152	11	---	---	---	1,341
Italy	2,953	---	---	---	---	---
Spain	7,078	---	---	---	---	---
Other	1,423	109	19	---	---	---
Total	12,606	120	19	---	---	1,341
Africa:						
South Africa, Republic of	15,281	7,551	9,589	8,614	6,086	11,267
Other	750	2	---	---	1,118	9,445
Total	16,031	7,553	9,589	8,614	7,204	20,712
Asia:						
Philippines	1,304	3,203	24	9	7	9
Other	82	---	---	79	57	---
Total	1,386	3,203	24	88	64	9
Oceania: Australia	14,747	3,822	10,956	3,724	3,238	2,667
Grand total: Ores	494,039	415,700	467,398	372,769	357,145	428,040
Blocks, pigs, or slabs:						
North America:						
Canada	95,379	71,628	72,825	73,817	75,712	88,554
Mexico	16,445	8,598	12,334	13,219	12,791	12,787
Total	111,824	80,226	85,159	87,036	88,503	101,341
South America: Peru	11,825	7,519	7,615	7,574	7,569	10,323
Europe:						
Belgium-Luxembourg	20,323	12,854	23,232	21,904	r 5,557	8,889
Germany, West	5,893	779	1,162	6,103	265	230
Italy	8,128	1,820	992	907	---	2,129
Spain	---	6,756	2,572	6,270	2,723	1,768
United Kingdom	850	(2)	---	1,183	682	---
Yugoslavia	5,071	3,198	3,310	1,185	441	887
Other	4,133	561	640	440	r 1,275	694
Total	44,398	25,968	31,908	37,992	10,943	14,597
Africa:						
Congo (Leopoldville)	18,776	11,420	10,882	9,590	10,878	12,614
Rhodesia and Malawi	2,826	1,400	4,643	1,982	62	---
Total	21,602	12,820	15,525	11,572	10,940	12,614
Asia: Japan	1,962	---	---	---	---	12,995
Oceania: Australia	5,772	1,029	1,750	583	385	1,120
Grand total: Blocks, pigs, or slabs	197,383	127,562	141,957	144,757	118,340	152,990

r Revised.

[1] Zinc content less certain allowable deductions for processing losses, effective Sept. 1, 1963.

[2] Less than ½ unit.

Table 33.—U.S. imports for consumption of zinc, by classes

Year	Ore (zinc content)[1]		Blocks, pigs, and slabs		Sheets, plates, strips, and other forms	
	Short tons	Value (thousands)	Short tons	Value (thousands)	Short tons	Value (thousands)
1956–60 (average)	497,313	$53,009	196,926	$45,662	788	$263
1961	357,653	31,920	125,186	27,540	1,183	354
1962	387,321	31,817	135,995	28,478	1,303	365
1963	371,919	30,757	132,332	27,942	1,532	413
1964	311,435	35,831	134,118	31,898	1,774	527
1965	402,936	53,829	153,957	42,605	1,381	453

Year	Old and worn out		Dross and skimmings		Zinc dust		Total value[2]
	Short tons	Value (thousands)	Short tons	Value (thousands)	Short tons	Value (thousands)	
1956–60 (average)	187	$28	714	$97	69	$15	$99,074
1961	303	32	1,107	146	86	28	60,020
1962	861	120	1,907	286	909	207	61,273
1963	1,461	231	1,415	215	2,608	589	60,147
1964	1,274	227	2,501	425	3,269	797	69,705
1965	1,576	337	3,125	667	244	57	97,948

[1] Zinc content less certain allowable deductions for processing losses, effective September 1, 1963.
[2] In addition, manufactures of zinc were imported as follows: 1956–60 (average) $518,060; 1961, $787,496; 1962, $1,138,940; 1963, $978,619; 1964, $1,338,891 (revised); 1965, $962,369.

produced concentrates containing 13,669 tons of zinc plus values in lead, silver, and cadmium. Development during the year consisted of 6,114 feet of drifts, 2,436 feet of raises, and 26,353 feet of diamond and long hole drilling.

Sheep Creek Mines Ltd., Windermere, British Columbia, reported production at the Mineral King property for the year ending May 31, 1965, to have been 169,000 tons of ore grading 4.08 percent zinc and 1.65 percent lead. Milling yielded 10,513 tons of 55.3 percent zinc concentrate plus recovered lead and silver. Reserves at the end of the year totaled 266,000 tons of ore, compared with 351,000 tons at the start of the year.[10]

Hudson Bay Mining and Smelting Co. Ltd., operated its zinc-copper-lead mines along the Manitoba-Saskatchewan boundary. The mill treated 1,640,000 tons of ore—53.3 percent from the Flin Flon mine and the balance from the Chisel Lake, Stall Lake, Coronation, and Schist Lake mines—which yielded 113,435 tons of 47.1 percent zinc concentrates plus copper and lead concentrates. The Coronation mine was closed in August due to depletion of reserves. Exploration disclosed more ore than was mined during the year and proven reserves at yearend totaled 16.8 million tons averaging 4.5 percent zinc. The electrolytic plant at Flin Flon treated 111,965 tons of zinc concentrate, 47,970 tons of zinc fume and stack dust from the copper smelter, and 6,446 tons of purchased materials to produce 71,435 tons of slab zinc.[11]

Willroy Mines Ltd., at its Manitouwadge, Ontario, operation milled 294,000 tons of ore from its operation and 283,300 tons of custom ore from Willecho Mines Ltd. The mill feed averaged 4.21 percent zinc, 0.69 percent copper, 0.23 percent lead, and 1.75 ounces of silver per ton and yielded concentrates which contained 21,695 tons of zinc. Development included drifting 1,388 feet for a total completed drift length of 4,774 feet towards the Big Nama Creek ore body. The ore reserve at yearend at the Willroy mine was 760,000 tons, averaging 2.56 percent zinc, 1.40 percent copper, and 0.92 ounces of silver per ton.[12]

Noranda Mines Ltd., operated the Geco mine at Manitouwadge, Ontario, during 1965. Production was at the rate of 3,634 tons per day averaging 4.26 percent zinc, 1.97 percent copper, and 2.17 ounces of

[10] Sheep Creek Mines, Ltd. Annual Report. 1965, 11 pp.
[11] Hudson Bay Mining and Smelting Co. Ltd. Annual Report. 1965, pp. 9–12.
[12] Willroy Mines Ltd. Annual Report. 1965, pp. 1–3.

Table 34.—U.S. imports for consumption of zinc, by countries
(Short tons)

Country	1956–60 (average)	1961	1962	1963	1964	1965
Ores (zinc content):[1]						
North America:						
Canada	160,606	110,312	135,430	131,125	117,866	202,004
Guatemala	6,292	7,244	8,375	3,692	6	4
Honduras	1,741	1,574	4,154	8,613	6,374	8,246
Mexico	189,426	140,057	139,374	138,419	105,059	104,939
Other	521	(²)	(²)	---	---	---
Total	358,586	259,187	287,333	281,849	229,305	315,193
South America:						
Argentina	32	---	---	---	12,442	10
Bolivia	4,700	1,018	681	3,492	2,084	2,932
Chile	907	7	216	324	---	---
Peru	100,187	69,473	75,333	67,113	57,076	60,619
Other	50	81	22	30	---	---
Total	105,876	70,579	76,252	70,959	71,602	63,561
Europe:						
Germany, West	1,460	12	1	---	---	1,341
Italy	2,834	2,189	695	---	---	---
Spain	4,776	8,122	947	---	---	---
Other	883	---	---	---	---	---
Total	9,953	10,323	1,643	---	---	1,341
Africa:						
South Africa, Republic of	11,402	6,218	10,391	11,438	6,384	11,425
Other	359	9	11	766	1,118	8,084
Total	11,761	6,227	10,402	12,204	7,502	19,509
Asia:						
Philippines	511	4,426	2,663	43	16	25
Other	44	16	(²)	59	28	---
Total	555	4,442	2,663	102	44	25
Oceania: Australia	10,582	6,895	9,028	6,805	2,982	3,307
Grand total: Ores	497,313	357,653	387,321	371,919	311,435	402,936
Blocks, pigs, or slabs:						
North America:						
Canada	95,350	71,628	72,850	73,817	75,762	88,585
Mexico	16,363	8,527	12,334	12,619	12,794	12,787
Total	111,713	80,155	85,184	86,436	88,556	101,372
South America: Peru	11,825	7,582	7,615	7,574	7,519	10,356
Europe:						
Belgium-Luxembourg	20,371	12,380	16,829	16,070	14,668	9,101
Germany, West	5,669	1,431	1,889	1,585	2,939	248
Italy	8,144	1,820	992	907	---	2,129
Spain	562	4,560	2,429	4,666	4,993	3,230
United Kingdom	850	(²)	---	623	575	336
Yugoslavia	5,021	3,277	2,750	1,564	909	887
Other	3,526	417	642	302	1,999	826
Total	44,143	23,885	25,531	25,717	26,083	16,757
Africa:						
Congo (Leopoldville)	18,776	11,420	10,882	9,590	10,878	12,614
Rhodesia and Malawi	2,716	1,107	5,033	2,305	697	---
Other	59	8	---	---	---	---
Total	21,551	12,535	15,915	11,895	11,575	12,614
Asia: Japan	1,967	---	---	---	---	11,092
Oceania: Australia	5,727	1,029	1,750	710	385	1,766
Grand total: Blocks, pigs, or slabs	196,926	125,186	135,995	132,332	134,118	153,957

[1] Zinc content less certain allowable deductions for processing losses, effective Sept. 1, 1963.
[2] Less than ½ unit.

Table 35.—World mine production of zinc (content of ore) recoverable where indicated, by countries [1,2]

(Short tons)

Country [2]	1961	1962	1963	1964	1965 p [3]
North America:					
Canada	443,099	501,937	497,180	729,939	911,432
Greenland e	8,800	4,400	---	---	---
Guatemala [4]	r 8,737	899	1,289	---	938
Honduras	r 7,324	r 7,258	[5] 8,234	r 9,445	12,265
Mexico	296,492	276,330	264,354	r 259,708	247,883
United States [4]	464,390	505,491	529,254	574,858	611,153
Total	r 1,228,842	r 1,296,315	1,300,311	r 1,573,950	1,783,671
South America:					
Argentina	35,502	r 34,639	r 31,677	r 25,257	33,000
Bolivia (exports)	5,878	4,021	5,124	10,755	15,088
Brazil	---	---	---	---	5,787
Chile	179	547	557	r 1,108	1,225
Colombia e	1,400	300	100	110	55
Peru	[4] 191,658	[4] 178,839	[4] 216,392	r 260,873	285,930
Total	234,617	r 218,346	r 253,850	r 298,103	341,085
Europe:					
Austria [4]	6,651	7,264	7,816	8,004	7,609
Bulgaria	81,500	88,700	81,130	r 86,300	e 86,200
Finland	r 51,175	57,509	73,142	69,436	76,070
France	17,284	15,735	20,060	r 18,564	23,413
Germany:					
East e	7,700	r 7,700	r 7,700	r 7,700	8,800
West	r 134,495	r 124,343	r 119,213	r 122,699	128,199
Greece	19,342	18,939	20,062	r 14,135	14,000
Hungary	2,400	2,500	2,900	r 3,200	e 3,200
Ireland	184	---	---	---	1,584
Italy	150,315	r 144,430	117,979	r 122,720	127,363
Norway	10,285	12,566	13,669	13,062	e 13,600
Poland	153,857	159,961	162,150	166,669	203,707
Portugal	---	12	190	1,049	3,256
Spain	96,983	86,554	101,118	r 97,509	42,378
Sweden	87,558	90,227	r 104,015	r 85,209	e 85,200
U.S.S.R. e,4	440,000	450,000	450,000	450,000	454,000
Yugoslavia	66,009	67,367	r 97,317	r 101,193	101,213
Total e,2	r 1,326,000	r 1,334,000	r 1,378,000	r 1,367,000	1,380,000
Africa:					
Algeria	46,448	46,215	r 39,700	38,932	42,334
Congo, Republic of (Brazzaville)	1,411	786	786	5,578	e 7,600
Congo, Republic of the (Léopoldville)	109,828	105,530	114,139	116,338	131,345
Morocco	44,951	37,942	36,418	r 46,678	56,458
South-West Africa [4]	14,905	25,201	36,715	35,312	33,049
Tunisia	4,596	4,727	4,809	r 3,681	4,499
Zambia	45,084	45,084	42,100	r 51,800	66,100
Total	267,223	265,485	r 274,667	r 298,319	341,385
Asia:					
Burma	r 7,865	r 9,036	r 8,865	r 8,438	8,579
China, Mainland e	110,000	110,000	110,000	110,000	110,000
India	5,622	6,099	6,460	6,520	5,861
Iran [6]	14,880	8,270	e 11,000	r 15,400	e 15,400
Japan	185,474	212,174	218,209	r 238,602	243,469
Korea:					
North e	100,000	100,000	110,000	110,000	115,000
South	496	463	1,245	2,800	7,844
Philippines	3,652	4,916	4,291	2,355	2,270
Thailand e	990	1,045	940	1,520	2,325
Turkey	9,127	6,801	5,044	r 6,268	7,700
Total e	438,000	459,000	476,000	r 502,000	518,000
Oceania: Australia	348,496	378,036	r 393,647	r 385,953	387,087
World total e	r 3,845,000	r 3,950,000	r 4,075,000	r 4,425,000	4,750,000

e Estimate. p Preliminary. r Revised.

[1] Data derived in part from the International Lead and Zinc Study Group Monthly Bulletin, Yearbook of the American Bureau of Metal Statistics, The United Nations Statistical Yearbook, the Statistical Summary of the Mineral Industry (Overseas Geological Surveys, London), and Metal Statistics (Metallgesellschaft) Germany.

[2] Czechoslovakia and Rumania also produce zinc, but production data are not available; no estimates are included in totals.

[3] Compiled mostly from data available August 1966.

[4] Recoverable.

[5] United States imports.

[6] Year ended March 20 of year following that stated.

Table 36.—World smelter production of zinc by countries [1,2]
(Short tons)

Country	1961	1962	1963	1964	1965 p [3]
North America:					
Canada	268,007	280,158	284,021	337,728	358,599
Mexico [4]	57,119	62,730	62,557	65,506	64,712
United States	846,795	879,395	892,584	954,084	994,402
Total	1,171,921	1,222,283	1,239,162	1,357,318	1,417,713
South America:					
Argentina	15,373	18,487	21,716	24,471	26,015
Brazil	---	---	---	---	e 85
Peru	35,006	36,309	r 61,248	r 68,016	69,384
Total	50,379	54,796	r 82,964	r 92,487	95,484
Europe:					
Austria	13,302	13,325	13,074	14,215	14,455
Belgium [5]	270,670	227,248	227,437	245,308	264,334
Bulgaria	24,385	57,017	61,800	64,595	65,036
France (including dust)	183,918	186,471	r 186,392	r 209,706	211,680
Germany:					
East e	1,100	5,500	11,000	11,000	11,000
West	155,373	143,127	115,969	117,988	118,724
Hungary	1,300	1,700	r 1,700	r 1,500	e 1,500
Italy	87,647	r 86,055	r 82,332	r 80,483	89,175
Netherlands	43,643	40,839	39,421	r 41,559	44,997
Norway	51,287	49,576	51,419	r 53,304	57,749
Poland	200,633	r 199,408	199,739	206,022	209,880
Spain	57,865	68,981	71,353	r 71,023	60,074
U.S.S.R. e	470,000	515,000	515,000	510,000	515,000
United Kingdom	104,031	108,949	110,911	122,396	117,742
Yugoslavia	40,640	43,325	46,566	49,066	50,778
Total e 1	1,706,000	1,747,000	r 1,734,000	r 1,798,000	1,832,000
Africa:					
Congo, Republic of the (Léopoldville)	62,788	61,759	58,118	61,237	62,853
Zambia	r 34,243	44,576	54,510	51,491	52,387
Total	r 97,031	106,335	112,628	112,728	115,240
Asia:					
China, mainland (refined) e	100,000	100,000	100,000	100,000	100,000
Japan	234,163	270,402	291,382	r 366,576	377,088
Korea, North e	65,000	65,000	70,000	r 75,000	80,000
Total e	399,000	435,000	461,000	r 542,000	557,000
Oceania: Australia	155,338	188,079	201,350	r 207,795	222,867
World total e	3,580,000	3,755,000	3,830,000	r 4,110,000	4,240,000

e Estimate. p Preliminary. r Revised.
[1] Czechoslovakia and Rumania also produce zinc, but production data are not available; no estimates are included in the totals.
[2] Data derived in part from the International Lead and Zinc Study Group Monthly Bulletin, Yearbook of the American Bureau of Metal Statistics, the United Nations Monthly Bulletin and Statistical Yearbook, Statistical Summary of the Mineral Industry (Overseas Geological Surveys, London), and Metal Statistics (Metallgesellschaft) Germany.
[3] Compiled mostly from data available August 1966.
[4] In addition, other zinc-bearing materials were as follows: 1961, 1,992; 1962, 1,890; 1963, 3,400; 1964, 3,839; and 1965, 7,241.
[5] Includes production from reclaimed scrap.

silver per ton. Exploration added 956,000 tons of ore to a yearend total reserve of 23.8 million tons averaging 4.78 percent zinc, 2.17 percent copper, and 2.32 ounces of silver per ton.[13]

In Quebec, Quemont Mining Corp. Ltd., milled 657,000 tons of ore grading 2.29 percent zinc plus values in copper, silver, gold, and pyrite, yielding 21,262 tons of 53.3 percent zinc concentrate. The ore reserve at yearend was estimated at 2 million tons averaging 2.35 percent zinc.[14] According to its annual report for the year ending Aug. 31, 1965, Solbec Copper Mines Ltd., mined and milled 497,000 tons of ore

[13] Noranda Mines Ltd. Annual Report. 1965, p. 6.
[14] Quemont Mining Corp. Ltd. Annual Report. 1965, p. 4.

yielding concentrates containing 16,407 tons of zinc plus values in copper, lead, gold and silver. The reserve at yearend was 603,000 tons averaging 4.92 percent zinc, 1.56 percent copper, 0.80 percent lead, and 1.68 ounces of silver per ton. Cupra Mines Ltd., began shipment of ore to the nearby Solbec Copper Mines Ltd., mill during September and continued mine development towards an annual rate objective of 300,000 tons. Ore reserves to a depth of 2,522 feet totaled 1.3 million tons with an average grade of 4.0 percent copper, 5.2 percent zinc plus values in lead and silver.[15] Sullico Mines Ltd., mined and milled 993,000 tons of copper-zinc ore yielding concentrates containing 531 tons of zinc. All reserves have been drilled and blasted and the mining operations remaining are to extract as much of the broken ore as possible.[16] Normetal Mining Corp. Ltd., mined and milled at the rate of 961 tons of ore per calendar day yielding concentrates containing 24,984 tons of zinc plus quantities of copper, gold, and silver.[17]

In the Mattagami Lake district of Quebec, Mattagami Lake Mines Ltd., milled 1,406,000 tons of ore averaging 11.7 percent zinc and 0.7 percent copper to produce 294,822 tons of 52.2 percent zinc concentrate. The reserve at the end of the year was 19.5 million tons containing 10.6 percent zinc and 0.7 percent copper.[18] Orchan Mines Ltd., milled 369,000 tons of ore averaging 13.34 percent zinc and 1.25 percent copper, yielding concentrates containing 43,293 tons of zinc. Ore reserves at yearend were 2.8 million tons containing 10.99 percent zinc and 1.26 percent copper. Concentrates from both mills were shipped to the zinc reduction plant of Canadian Electrolytic Zinc Ltd., at Valleyfield, Quebec, which produced nearly 74,000 tons of slab zinc, an average of about 200 tons per day. An expansion program, scheduled for completion during the second half of 1966, will increase capacity to 400 tons per day.[19]

Other Quebec producers of zinc included Coniagas Mines, Manitou-Barvue Mines, and Lake Dufault Mines.

In the Atlantic Provinces, Heath Steele Mines Ltd., mined and milled zinc-lead-copper ore from its mine near Bathurst, New Brunswick, at a rate of 750 tons per day. Brunswick Mining & Smelting Corp. Ltd., operated its zinc-lead-copper Brunswick No. 12 mine and was constructing a second concentrator with a daily ore capacity of 2,250 tons to treat ore from the open pit No. 6 mine being developed for operation early in 1966. A subsidiary company, the East Coast Smelting and Chemical Co., continued construction of a lead-zinc Imperial Smelting Furnace scheduled for completion in 1966.[20]

In Newfoundland, Buchans Mining Co. Ltd., milled 366,000 tons of ore yielding 115,945 tons of copper, lead, and zinc concentrates.[21]

Honduras.—Phase II of a major expansion program at the El Mochito mine, completed in July, increased productive capacity by 25 percent to 500 tons of ore per day. Phase III of the program, scheduled for completion in 1966, will increase mining and milling capacity to 750 tons per day. In 1965, the mill treated a record 174,000 tons of lead-zinc-silver ore which yielded concentrates containing 10,927 tons of zinc. The ore reserve at yearend was 1.03 million tons with an average grade of 7.67 percent zinc, 7.59 percent lead, and 18.6 ounces of silver per ton.[22]

Mexico.—The single condenser horizontal zinc retort plant of Zincamex, S.A., at Saltillo, Coahuila, placed in operation in 1964, is described in a journal article.[23]

In July, American Smelting and Refining Co. (Asarco) sold 51 percent of its Mexican operating subsidiary, Compañia Minero Asarco, S.A. The sale was to a group of Mexican industrialists who subsequently made substantial ownership available to the Mexican public through listing the new company, known as Asarco Mexicana, S.A., on the Mexican stock exchange. The sale accomplished the revision in ownership required by the Mexican Mining Law of

[15] Cupra Mines Ltd. Annual Report. 1965, p. 36.
[16] Sullico Mines Ltd. Annual Report. 1965, p. 21.
[17] Noranda Mines Ltd. Annual Report. 1965, p. 17.
[18] Mattagami Lake Mines Ltd. Annual Report. 1965, pp. 6–7.
[19] Noranda Mines Ltd. Annual Report. 1965, p. 22.
[20] Fraser, D. B. Zinc and Lead. Miner. Res. Division, Dept. of Mines and Tech. Surveys (Ottawa, Canada), Miner. Inf. Bull. MR–81, 1966, p. 38.
[21] American Smelting and Refining Co. Annual Report. 1965, p. 13.
[22] New York and Honduras Rosario Mining Co. Annual Report. 1965, 20 pp.
[23] Engineering and Mining Journal. Pyro-Processing Zinc in Mexico. V. 166, No. 7, July 1965, pp. 85–87.

1961 to qualify for certain tax and mining concession benefits. Asarco will continue to provide comprehensive technical and administrative services to the Mexican company and to market the exportable products.[24]

In July, American Metal Climax, Inc., sold its remaining 49 percent interest in Metalurgica Mexicana Peñoles, S.A., to the Mexican group that originally acquired a 51 percent share of the company in 1961.[25]

According to the annual report of San Francisco Mines of Mexico Ltd., for the year ending June 30, 1965, a total of 917,000 tons of ore was milled from the company's San Francisco and Clarines mines and produced 100,100 tons of 56.24 percent zinc concentrate plus values in lead, copper, silver, and gold. Ore reserves at the end of the fiscal year were 5.8 million tons averaging 7.40 percent zinc, 5.09 percent lead, and 0.52 percent copper.

Compania Fresnillo, S.A. (49 percent owned by the Fresnillo Co.), operated lead-zinc-silver producing units at Fresnillo in Zacatecas, at Naica in Chihuahua, and at Zimapan in Hidalgo. In the year ending June 30, 1965, the company milled a total of 1,136,000 tons of ore yielding 41,780 tons of zinc in salable metal. Ore reserves at yearend at the Fresnillo and Naica units totaled 4.6 million tons containing 4.7 percent zinc, 4.9 percent lead, and 5.1 ounces of silver per ton.[26]

SOUTH AMERICA

Argentina.—Cia. Minera Aguilar, S.A., a subsidiary of St. Joseph Lead Co., continued operation of a lead-zinc-silver mine in the Province of Jujuy in northern Argentina and through affiliated companies operated a zinc smelter and electrolytic zinc plant. All of the zinc produced was marketed in Argentina, and Aguilar has embarked on an expansion program to increase output a minimum of 50 percent by 1968.[27]

Brazil.—The Brazilian Department of Mineral Production conducted exploration for zinc at the Januaria and Vazante deposits in Minas Gerais. Reserves of zinc at these and other locations in Brazil appear adequate to establish production.[28]

Peru.—Cerro de Pasco Corp. produced a record 67,590 tons of slab zinc from concentrates of its own mines. In addition, 78,819 tons of zinc in concentrates were produced for export. Cerro's La Aroya electrolytic zinc plant capacity will increase from 67,500 to 80,000 tons a year by mid-1966 upon completion of a turbulent-layer roaster. A further increase to approximately 85,000 tons per year is expected early in 1967 when a 50-ton-per-day pilot plant is placed in operation for recovery of metals contained in zinc leach residue. Experience with the pilot plant will facilitate the design and construction of a much larger commercial facility.[29]

Cia. Minerales Santander, Inc., a St. Joseph Lead Co. subsidiary, produced a record 54,717 tons of zinc concentrate at its open pit lead-zinc-silver mine in the Peruvian Andes. Preparations were underway for a gradual transition to underground mining.[30] Other zinc producers included Cia. Minera Atacocha, S.A., The Chavin Mines Corp., Cia. des Mines de Huaron, Cia. Minera Milpo, S.A., Northern Peru Mining Co., and Volcan Mines Co.

EUROPE

Finland.—The Vihanti mine continued as the leading zinc producer in Finland, yielding 83,462 tons of 55.3 percent zinc concentrate from 538,000 tons of ore. The Pyhasalmi copper-zinc mine produced 44,419 tons of 54.5 percent zinc concentrates from 716,000 tons of ore.

Ireland.—Irish Base Metals Ltd., a subsidiary of Northgate Exploration Ltd., began production from their lead-zinc-silver mineral deposit at Tynagh during the last quarter of 1965. The mill capacity of 2,000 tons per day will not be attained for a number of months due to problems associated with treating the complex ore. Initial production will be from a sulfide ore zone accessible to open pit mining methods and calculated to contain 3.2 million tons of ore averaging 8.43 percent lead, 7.15

[24] American Smelting and Refining Company. Annual Report. 1965, p. 14.
[25] American Metal Climax, Inc. Annual Report. 1965, p. 18.
[26] Fresnillo Co. Annual Report. 1965, pp. 8–9.
[27] St. Joseph Lead Co. Annual Report. 1965, p. 6.
[28] Canadian Mining Journal. V. 86, No. 11, November 1965, p. 28.
[29] Cerro Corp. Annual Report. 1965, p. 4.
[30] St. Joseph Lead Co. Annual Report. 1965, p. 7.

percent zinc, 0.5 percent copper, and 3.02 ounces of silver per ton. A surface oxidized zone contains 2.1 million tons of ore and a sulfide zone planned for underground mining contains 3.5 million tons. Sparked by the new Tynagh development, there is estimated to be 15 to 20 firms active in exploring for base metal deposits in Ireland.[31]

Italy.—Mineraria e Metallurgica di Pertusola was enlarging its Salafossa lead-zinc mill to double the productive monthly capacity to 4,000 tons of lead plus zinc concentrates. The company's Crotone electrolytic zinc plant was being enlarged to a planned 40,000-ton annual capacity by 1968.[32]

Poland.—Zinc metal and oxide output was planned to be doubled during 1966–70. Construction of the zinc works in the Tarnowakie Gory area, claimed to be the largest nonferrous metal plant in Europe, was nearing completion.[33]

Portugal.—The Terramonte lead and zinc mines have been reopened following purchase of the mining concession by a group of Canadian, Belgian, and American investors. Portuguese Government officials expect the output to be large enough to make Portugal self-sufficient in zinc.[34]

Spain.—Ground failure at Spain's largest zinc mine, the Asturianas de Minas Amelia near Reocin, caused closure of the mine from early in January until past midyear.

Sweden.—According to the company's annual report, mines of the Boliden Mining Co., Ltd., yielded 94,500 tons of zinc concentrate containing 51,700 tons of zinc. A slag fuming plant treating copper-furnace slag completed its first full year of operation and produced 25,100 tons of zinc fume.

United Kingdom.—The Imperial Smelting Corp. Ltd., achieved a record slab zinc output at the Avonmouth plant but an industrial dispute at the Swansea plant resulted in a decline of 4 percent to 117,526 tons for the corporation's total production. Work began on construction of a new furnace at Avonmouth for operation in 1968 with a capacity 60 percent larger than the Swansea furnace.[35]

AFRICA

Algeria.—A 26-percent increase in output of zinc carbonate concentrate from the Ouarsenis mine near Algiers was more than offset by smaller output of zinc sulfide concentrate from the El Abed and Oued Zounder mines near the Moroccan border. A new deposit discovered at the El Abed mine during 1964, expected to extend the life of the operation by 10 to 15 years, was under development during 1965 and scheduled for mining in 1966.[36]

Congo (Léopoldville).—Union Minière du Haut-Katanga's Kipushi concentrator milled 1,280,000 tons of copper-zinc ore to produce 228,600 tons of 58.4 percent zinc concentrates. A subsidiary of the company, Société Generalé Industrielle et Chimique du Katanga, roasted 152,100 tons of the zinc concentrate, producing sulfuric acid and 126,100 tons of roasted concentrate. During the year, 106,600 tons of roasted concentrate was sold to Société Metallurgique du Katanga (Metalkat) for reduction to zinc and 90,600 tons of raw and roasted concentrates were delivered for export. Metalkat produced 63,861 tons of electrolytic zinc.[37]

South-West Africa.—Tsumeb Corp. Ltd., in the year ending June 30, 1965, mined and milled, at the Tsumeb property, 812,000 tons of complex copper-lead-zinc sulfide and oxide ore averaging 3.90 percent zinc. Zinc contained in concentrates sold and taken into account, was 10,200 tons compared with 9,000 tons in 1964.[38]

Zambia.—The Zambia Broken Hill Development Co. Ltd. (Rhodesia Broken Hill Development Co. Ltd., prior to April 3, 1965), operated the Broken Hill mine and treated 232,000 tons of the ore in the heavy-medium plant which yielded 138,000 tons of sink product. The flotation plant treated 137,900 tons of the sink product

[31] Northern Miner (Toronto, Canada). V. 31, Oct. 21, 1965, p. 13.
[32] World Mining. V. 18, No. 6, June 1965, p. 52.
[33] Mining Journal (London). V. 265, No. 6802, Dec. 31, 1965, p. 483.
[34] Bureau of Mines. Mineral Trade Notes. V. 62, No. 5, May 1966, p. 19.
[35] The Rio Tinto-Zinc Corp. Ltd. Annual Report. 1965, pp. 39–40.
[36] U.S. Embassy, Algiers, Algeria. Dept. of State Airgram A-461, Apr. 22, 1966.
[37] Union Minière du Haut-Katanga. Annual Report. 1965, 47 pp.
[38] Newmont Mining Corp. Annual Report. 1965, p. 6.

plus 9,500 tons of mixed fines and silicate ore, yielding 39,043 tons of zinc concentrate averaging 56.8 percent zinc. The leach plant treated roasted zinc concentrate, flotation plant tailing, and zinc silicate ore, totaling 93,000 tons averaging 38.4 percent zinc. Leach solution was processed in the electrolytic plant to yield 29,692 tons of slab zinc. The Imperial-type vertical furnace treated 141,600 tons of sintered mill fines, slags, residues, and other material to produce 26,458 tons of slab zinc. The reserve of ore at yearend was 5.1 million tons grading 26.4 percent zinc and 12.8 percent lead.[39]

ASIA

Burma.—The Burma Corp., a joint venture between the Government of Burma and the Burma Mines Ltd., London, was nationalized January 18 and renamed the People's Bawdwin Industry. Their Bawdwin lead-zinc-silver mine was closed in 1963. A recent study financed by the United Nations Special Fund and the Burmese Government disclosed reserves for at least 20 years of operation at twice the previous production rate.[40]

India.—Cominco-Binani Zinc Ltd., a joint venture of Metal Corporation of India Ltd., and the Consolidated Mining & Smelting Co. of Canada Ltd., continued construction of a 22,000-ton-per-year electrolytic zinc plant near Cochin in Kerala State. Although general economic conditions in India have caused some delays, completion is still anticipated in 1966.[41]

Thailand.—The Thai Government plans to invite bids from companies, with at least 50 percent of their assets held by Thais, for a mining and smelting operation based on an oxidized zinc deposit in Tak province. Reserves are estimated at 3.8 million tons averaging 35 percent zinc.[42]

OCEANIA

Australia.—The Broken Hill district of New South Wales continued to be the leading Australian zinc-producing area. Mining companies operating and ranked in order of their output were: New Broken Hill Consolidated Ltd.; The Zinc Corp. Ltd.; North Broken Hill Ltd.; and Broken Hill South Ltd. Combined output was 2,805,000 tons of zinc-lead-silver ore, yielding 545,000 tons of zinc concentrate averaging 53.1 percent zinc.

Sulphide Corp. Pty. Ltd., operated its Imperial smelting-type furnace at Cockle Creek, New South Wales. Output increased 15 percent for slab zinc to 61,900 tons but decreased 5 percent to 24,900 tons for lead bullion.[43]

Mount Isa Mines Ltd., during the fiscal year ended June 30, 1965, milled 775,000 tons of silver-lead-zinc ore and produced 23,237 tons of zinc in concentrates. A labor strike commencing late in 1964 was settled February 17 and operations were back to normal by June 1965. Construction projects to expand capacity to 16,000 tons of ore per day were also suspended during the strike and completion of the program will be delayed.[44]

The Electrolytic Zinc Co. of Australasia Ltd., produced a record 155,400 tons of slab zinc at its Risdon, Tasmania, electrolytic plant during the fiscal year ending June 30, 1965 (154,100 tons in 1964). The company's mining-milling operations in the Read-Rosebery district milled 322,000 tons of ore yielding 117,800 tons of zinc, lead, and copper concentrates.[45]

[39] The Zambia Broken Hill Development Co. Ltd. Annual Report. 1965, pp. 7–10.
[40] Mining Journal (London). 1965 Mining Annual Review. p. 254.
[41] The Consolidated Mining & Smelting Co. of Canada Ltd. Annual Report. 1965, p. 9.
[42] Bureau of Mines. Mineral Trade Notes. V. 62, No. 5, May 1966, p. 19.
[43] The Rio Tinto-Zinc Corp. Ltd. Annual Report. 1965, p. 34.
[44] Mount Isa Mines, Ltd. Annual Report. 1965, 28 pp.
[45] E Z Industries Ltd. Annual Report. 1965, pp. 4–5.

TECHNOLOGY

A comprehensive coverage of zinc technology reported in the scientific and technical press is included in the 1,368 items contained in the monthly issues of the 1965 Zinc Abstracts, jointly published by the Zinc Development Association (London) and the American Zinc Institute.

The International Lead-Zinc Research Organization (ILZRO) sponsored about 56 projects in 1965 to develop fundamental knowledge or particular applications of zinc or zinc containing materials. Progress reports of these projects are released biannually by means of the ILZRO Research Digest.

Results of several research investigations were published by the Bureau of Mines[46] and Geological Survey.[47]

Representative of the many published results of research were papers on geochemical exploration of zinc containing deposits,[48] the relationship of certain elements associated with sphalerite as a guide to undertsanding the genesis of mineral deposits,[49] and geological studies of mineral districts containing important zinc reserves.[50]

Articles on extractive metallurgy described a mathematical model related to varying plant operating practices in the slag fuming practice,[51] and a two-stage zinc condenser to separate the zinc into one fraction containing most of the lead, iron, and indium impurities and into another fraction containing most of the cadmium.[52] Patents have been granted for a pressure leaching process to extract zinc from a residue containing zinc ferrite,[53] and also for an electrolytic process to produce zinc containing less than five parts per million of lead.[54]

Zinc electroplating of small parts in a semi-automated plant was described.[55] An anodizing process has been developed to improve corrosion resistance, abrasion resistance, and to add color for marketability of zinc and zinc alloy products.[56] A patent was granted for a continuous process to produce a dull-finish zinc coating on steel strip by first hot-dip galvanizing, and then heating the steel by electromagnetic induction.[57]

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[55] Metallurgia (Manchester, England). Programmed Barrel Plating. V. 72, No. 429, July 1965, pp. 13-16.

[56] Radtke, Schrade F. Anodizing Protects and Decorates Zinc Surfaces. Materials in Design Eng., v. 62, No. 4, October 1965, pp. 116-118.

[57] Wright, Wilbert H. (assigned to National Steel Corp.). Method for Galvanizing Steel. U.S. Pat. 3,190,768, June 22, 1965.

An electron-microscope study has been made on the aging of an aluminum-25 percent zinc alloy at temperatures in the range of 100 to 200° C.[58] Research was reported on effects of additions of aluminum, cadmium, and silicon to counteract the adverse corrosion effect of iron in zinc used for galvanic anodes.[59] A patent was granted for a sacrificial zinc anode comprised of a core of zinc alloyed with 0.03 to 4.0 percent of iron, nickel, or cobalt bonded to the main zinc body.[60]

Research on solubility of zinc sulfide in basic media and NH_4Cl at varying pressure and temperature led to determination of suitable conditions for improved growth of cubic zinc sulfide crystals.[61] A patent was granted on a process for blending proper proportions of nodular and acicular-shaped zinc oxides, then adding sulfuric acid and potassium dichromate to form zinc chromate.[62] Another patent was granted for a method of growing zinc oxide crystals from a zinc oxide crystal seed and a mass of nutrient zinc oxide in an aqueous medium containing lithium ions and certain metal hydroxides.[63]

In a study of container materials for processing spent atomic reactor fuel materials, it was determined that types 405 and 440C stainless steel offer better resistance to attack by zinc vapor than do the 300-series steels which suffer attack by nickel leaching.[64]

Basic research includes investigations of surface structure and polymorphic transformations in sphalerite crystals,[65] flotability of crushed zinc oxide pellets as affected by several doping agents,[66] and a technique for producing large zinc crystals.[67]

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[59] Southin, R. T. Some Observations on the Microstructure of Zinc Alloy Anodes. J. Inst. Metals (London), v. 93, pt. 12, August 1965, pp. 428–431.

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Majumdar, A. J., and Rustum Roy. P–T Dependence of the Sphalerite$\rightleftarrows$Wurtzite Inversion in ZnS. Am. Miner., v. 50, Nos. 7 and 8, July–August 1965, pp. 1121–1125.

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Zirconium and Hafnium

By John G. Parker [1]

Three domestic zircon placer operations were reduced to two during the year, one in Florida and the other in Georgia, and total production and sales decreased slightly. Australian production increased more than 20 percent. Imports of zircon, mostly from Australia, increased almost 33 percent. Output of zirconium sponge from two domestic companies was only 60 percent of that in 1964; production of hafnium oxide, sponge, and chunklets also was much lower.

Legislation and Government Programs.—General Services Administration (GSA) sold 199 short tons of zircon concentrate, the last of this nonobjective material contained in the national stockpile; a small quantity of baddeleyite also was sold.

The sale of zircon concentrate of Australian origin lowered the stocks held by GSA to 18,237 tons of zirconium-bearing materials, including 16,514 tons of baddeleyite and 1,723 tons of material containing 23.5 percent zirconium oxide. The Atomic Energy Commission (AEC), as of June 30, 1965, had an inventory of 2,375 tons of equivalent zirconium sponge and 44 tons of equivalent hafnium crystal bar.

Table 1.—Salient zirconium and hafnium statistics in the United States

(Short tons)

	1964	1965
Zircon:		
Production	W	W
Imports	44,413	58,873
Exports	2,500	1,761
Consumption [1]	29,520	35,500
Stocks, yearend, dealers and consumers [1]	39,515	42,900
Zirconium oxide:		
Production [2]	r3,500	4,100
Producers stocks, yearend [3]	1,084	1,090

r Revised. W Withheld to avoid disclosing individual company confidential data.
[1] Excludes foundries.
[2] Excludes that used in metal manufacture.
[3] Excludes that used in metal manufacture and the equivalent zirconia content of refractories.

DOMESTIC PRODUCTION

The Trail Ridge mine at Starke, operated by E. I. du Pont de Nemours & Co., Inc., remained as the principal producer of zircon from Florida beach sands. Two companies, Titanium Alloy Manufacturing Division, National Lead Co., and The Florida Minerals Co., ceased operations near Jacksonville and at Vero Beach, respectively. Humphreys Mining Co., operator of the Skinner mine owned by National Lead near Jacksonville, began producing zircon and titanium minerals at a new plant on Du Pont's property at Folkston, Ga. Overall production at the three operations in Florida and the one in Georgia dropped 3 percent, sales decreased 4 percent, and value of sales, 5 percent.

Data were compiled by a Bureau of Mines resource office on West Coast zircon deposits, which are mostly marginal to submarginal. Mining of these deposits will depend upon development of new or expanded markets for zircon and on a substantial need for coproduct heavy minerals.[2]

Although Reactive Metals, Inc., Ashtabula, Ohio, produced a substantial quantity of zirconium chunklets, output of this metal form was much less than in 1964. This company produced no zirconium

[1] Commodity specialist, Division of Minerals.
[2] Kauffman, A. J., Jr., and Dean C. Holt. Zircon: A Review, With Emphasis on West Coast Resources and Markets. BuMines Inf. Circ. 8268, 1965, 69 pp.

sponge; thus, the only large sponge metal producers were Wah Chang Corp., Albany, Oreg.; and Carborundum Metals Climax, Inc. (CMC), Parkersburg, W. Va. and Akron, N.Y. The latter firm, successor to Carborundum Metals Co., was formed as a jointly-held company of The Carborundum Co. and Climax Molybdenum Co. of Michigan, a subsidiary of American Metal Climax, Inc. Sponge production from Wah Chang and the Parkersburg plant of CMC was slightly over 60 percent of the 1964 output. These companies and Reactive Metals made hafnium oxide and Inc. (CMC), Parkersburg, W. Va., and hafnium sponge and chunklets; the oxide was 70 percent, and the metal was only a little over 30 percent of what they were the previous year. Hafnium ingot production from Reactive Metals and CMC was about 40 percent that of 1964. Scrap, residues, and other material generated in these operations were only a little over 20 percent those generated the previous year. Zirconium ingots were produced from sponge or chunklets at CMC, Akron, N.Y.; Reactive Metals, Niles, Ohio; Harvey Aluminum, Inc., Torrance, Calif.; and Wah Chang. Production of ingot decreased 36 percent to 617 tons.

Zirconium powder, totaling about 25 tons, was produced by CMC; Wah Chang; Foote Mineral Co., Exton, Pa.; and Nuclear Materials & Equipment Corp. (NUMEC), Apollo, Pa. Some hydride was made by Titanium Alloy Manufacturing Division, National Lead Co., Niagara Falls, N.Y. Of 272 tons of scrap generated by processors, 195 tons was reused. The output of miscellaneous zirconium metal items, mostly as fabricated and mill products, exceeded 500 tons.

Gross weight production of zirconium-bearing alloys rose 56 percent. The principal producers of these materials were Union Carbide Corp., Alloy, W. Va., and Niagara Falls, N.Y.; Vanadium Corporation of America, Cambridge, Ohio; and Ventron Corp., formerly Metal Hydrides, Inc., Beverly, Mass.

Hafnium crystal bar, produced by Foote and NUMEC, was slightly over 50 percent that of 1964.

Zirconium oxide output, excluding that used in metal production and that used by the large refractory companies, was about 4,100 tons, an increase of 17 percent over the corrected 1964 total, about 3,500 tons. Titanium Alloy Manufacturing Division; Norton Co., Huntsville, Ala.; and Zirconium Corporation of America (ZIRCOA), Solon, Ohio, produced most of this material; smaller quantities were made by Tizon Chemical Corp., Flemington, N.J., and Foote Mineral Co.

Production of zircon- and zirconia-refractories rose over 36 percent to about 27,600 tons, containing about 13,200 tons equivalent zirconia. The five largest producers of these refractories are Corhart Refractories Co., at its plants in Buckhannon, W. Va., Corning, N.Y., and Louisville, Ky.; The Chas. Taylor Sons Co., Cincinnati, Ohio, and South Shore, Ky.; Harbison-Carborundum Corp., Falconer, N.Y.; Walsh Refractories Corp., St. Louis, Mo.; and A. P. Green Fire Brick Co., Remmey Division, Philadelphia. Pa. Other firms include Harbison-Walker Refractories Co., Mount Union, Pa.; H. K. Porter Co., Inc., Refractories Division, St. Louis, Mo.; Titanium Alloy Manufacturing Division; and ZIRCOA. Eight domestic refractory companies produced zircon brick; 6, zirconia brick; 11, zircon crucibles; and 7, zirconia crucibles.[3]

Zirconium compounds such as sulfate, acetate, chloride, carbonate, nitrate, hydrate, and various zirconates were made by Tizon Chemical Corp. and Titanium Alloy Manufacturing Division.

Millers of zircon concentrates, for chemical and ceramic opacifier applications, included Titanium Alloy Manufacturing Division; M&T Chemicals Inc., Andrews, S.C.; Howmet Corp., Minerals Division, formerly Frank Samuel & Co., Camden, N.J.; and Continental Mineral Processing Co., Sharonville, Ohio.

CONSUMPTION AND USES

As in the past, the major use of zircon was in foundry sand. Some domestic mineral dealers ship all their zircon concentrates to foundries or foundry supply houses; other dealers estimate they sell almost two-thirds of their concentrates for ultimate foundry use. An increasing ap-

[3] The Refractories Institute. Product Directory of the Refractories Industry in the United States, 1965. Pittsburgh, Pa., October 1965, 246 pp.

plication was in foundry mold facings. However, climbing costs of zircon led to the belief that chromite sand and silica might be used more widely as substitutes. Investment shell casting used a new, graded zircon which could be recovered economically. Because of the uniform low expansion of zircon throughout the shell, large, smooth, precision forms could be produced with this method.

Consumption of zircon concentrate and milled zircon for other purposes consisted of about 27,800 tons, an increase of 17 percent, for refractory, ceramics, abrasive, and chemical production and about 7,700 tons, an increase of 32 percent, for the manufacture of metal and alloys.

Zircon bricks were the most common of the refractory items containing the various zirconium materials. Available figures show that the equivalent of more than 1.2 million 9-inch bricks of zircon and zirconia, as brick and shapes made predominantly from these materials, was shipped in 1965. Quantity rose 31 percent over that of 1964.[4] The approximate weight of zircon in a 9-inch brick is 12 pounds; that of stabilized zirconia is 16 pounds. Zircon and zirconia refractories of high density and low porosity were used in glass-melting furnaces. Fabricated zirconia, used in refractory shapes, is usually converted to the stable cubic phase by adding a small quantity of calcium oxide or magnesium oxide during fusion.

As an opacifier, zirconium oxide and silicate (zircon) were used in glazes, enamels, and other ceramic treatment where they control texture, promote crazing resistance, and increase color stability and reflectance. Zircon was used also in some types of spark plug porcelains.

Stabilized zirconium oxide forms tough, dense, thermal shock-resistant die nibs, or inserts, which were used in extruding ferrous metals and copper alloys such as brass. The low thermal conductivity, specific heat, and low coefficient of friction of zirconia permit use of lower extrusion pressures. Zirconia was a component of a composite, radiation-cooled heat shield being developed for superorbital vehicles, and prefired zirconia nozzles were used in metal pouring and continuous casting.

In the field of catalysts zirconia, alone or combined with other oxide carriers, was used to crack crude oils, to hydrogenate hydrocarbons, and to assist in producing butadiene, a synthetic rubber. Applied in colloidal form to film, it increased the adhesion of the light-sensitive emulsion.

Zirconium diboride jackets on thermocouples in open hearth furnaces assisted continuous temperature measurements by permitting temperature control automation, eliminating overheating, and accelerating melting.

In lesser or developing uses, a dichromate liquor employing zirconic acid was a superior leather-tanning agent. Zirconium and cobalt salts were components of a rapid, paint-drying agent. Addition of small quantities of zirconium oxychloride or zirconium nitrate reduced the caking tendency of sodium chloride. Zirconates, usually of barium, cadmium, calcium, lead, lithium, or magnesium, were combined with certain titanates in dielectric, refractory ceramic materials, such as capacitors and insulators.

Metallurgical applications included adding various quantities of zirconium to alloys to improve corrosion resistance, refine grain size, and distribute sulfide inclusions evenly. In magnesium alloys it formed iron and silicon compounds which were precipitated to the crucible bottom and eliminated with the slag. Corrosion-resistant zirconium metal linings were used in centrifugal pumps built to process food and chemicals.

In nuclear technology, Zircaloy continued as the most used zirconium alloy in cladding uranium fuel assemblies and as a pressure tube structural material because of its low thermal-neutron cross section and high-temperature water corrosion resistance. Also, zirconium hydride was used as a moderator in a nuclear fuel element. This had particular application in SNAP-10A, the auxiliary power reactor orbited in the spring. High-purity hafnium, with its high thermal-neutron cross section, continued to have value as an absorber in control rods for certain nuclear power reactors.

Fine zirconium powders, with a relatively long-burning life balanced with specific force, were developed as a rocket fuel component. Zirconium and hafnium microspheres, with free-flowing characteristics,

[4] U.S. Department of Commerce, Bureau of the Census. Refractories. Current Ind. Repts., Summary for 1964, Ser. M32C(64)–5, Aug. 5, 1965, 6 pp.; Second Quarter 1965, Ser. M32C (65)–2, Sept. 8, 1965, 3 pp.; Fourth Quarter 1965, Ser. M32C(65)–4, Mar. 10, 1966, 3 pp.

were said to have application in flame spray and powder metallurgy techniques.

Pure zirconium wool was used as filler in flashbulbs, readily igniting and providing a fast, intense light.

Hafnium-clad tantalum, capable of withstanding temperatures up to 4,000° F, was used on rocket nozzles.

STOCKS

Zircon concentrates and milled zircon held by dealers and millers at yearend were 15,200 tons, an almost 20 percent increase over the 1964 tonnage; those of principal consumers except foundries increased only about 3 percent to 27,700 tons. Yearend stocks of zirconium oxide stored by consumers, excluding those held by metal makers and the equivalent zirconia content of refractories, were 1,090 tons.

PRICES

Zircon concentrate, zirconium oxide, and various forms of zirconium and hafnium metal were quoted as follows:

	Price
Zircon:	
Domestic, containing 66 percent ZrO_2, f.o.b. Starke, Fla., per short ton [1]	$47.25
Source not indicated, containing 66 percent ZrO_2, Camden, N.J., per short ton, bulk, after August 23 [1]	59.50
Imported, sand, containing 65 percent ZrO_2, c.i.f. Atlantic ports, per long ton, in bags [1]	61.00
Domestic, granular, 1- to 5-ton lots, from works, per pounds, in bags [2]	.03625
After Nov. 29, 1965 [3]	.04875
Zirconium oxide: [2 3]	
Various purities and physical forms, in lot sizes to carloads, per pound, usually in bags	.33 to 1.50
Zirconium: [4]	
Reactor grade sponge, lots over 100 pounds, per pound	5.25
After May 3	6.25
1,000 pounds, per pound, after November 29	5.75
Strip, hot and cold rolled, per pound, all year	11.00 to 18.00
Plate, per pound	11.00 to 16.00
After November 29, per pound, nominal	10.00
Bars, forged or hot rolled, per pound	11.00 to 15.00
After November 29, per pound, nominal	12.00
Hafnium: [5]	
Sponge, per pound	75.00
Bar and plate, rolled, per pound	138.00

[1] E&MJ Metal and Mineral Markets. V. 36, Nos. 1–52, January–December 1965.
[2] Oil, Paint and Drug Reporter. V. 187, Nos. 1–26, Jan. 4–June 28, 1965; v. 188, Nos. 1–21, July 5–Nov. 22, 1965.
[3] ———. V. 188, Nos. 22–26, Nov. 29–Dec. 27, 1965.
[4] Steel. V. 156, Nos. 1–17, Jan. 4–April 26, 1965; v. 156, Nos. 18–26, May 3–June 28, 1965; v. 157, Nos. 1-26, July 5–Dec. 27, 1965; v. 157, Nos. 22–26, Nov. 29–Dec. 27, 1965.
[5] American Metal Market. V. 72, Nos. 1–248, January–December 1965.

Late in the year, the price of zircon in barrels dropped from $0.01 to $0.0025 per pound more than that in bags; prices for milled zircon were $0.0025 less per pound than were those for granular zircon.

European prices of zircon sand containing 66 to 67 percent ZrO_2 climbed from £19½ to £31 per long ton, c.i.f., but dropped to £28 to £30 late in November. Zirconium oxide, shown as calcined opacifier, was delivered in London at £350 per long ton.[5]

There was a very slight decrease in the unit value of domestic zircon sold in 1965.

[5] Metal Bulletin (London). Nos. 4960–5060, Jan. 1, 1965–Dec. 31, 1965.

FOREIGN TRADE

Exports.—U.S. companies exported 1,761 tons of zirconium ore and concentrate valued at $286,571 to 14 countries, almost one-half by weight and over one-third by value to Canada with most of the remainder to Mexico, Chile, Japan, Argentina, Peru, and Colombia. Unwrought zirconium and zirconium alloys plus waste and scrap, totaling 103,967 pounds worth $720,433, were shipped to 10 countries, principally the United Kingdom. Exports of semifabricated zirconium and alloys, to 18 countries, totaled 109,359 pounds worth $1,212,371. Of these Canada received 53 percent valued at over $625,000 and the United Kingdom received 23 percent worth over $315,000; other less important recipients included Japan, West Germany, and France.

Imports.—Shipments of zircon concentrate to the United States increased nearly one-third over those of 1964. Unwrought zirconium totaling 36,866 pounds valued at $175,432 was imported from the United Kingdom; unwrought zirconium alloys, imported almost exclusively from Japan, totaled 60,175 pounds worth $6,658, France shipped 110,231 pounds of ferrozirconium valued at $23,675 to the United States. Zirconium oxide, totaling 25,105 pounds worth $17,045, was received almost entirely from the United Kingdom although a very small quantity of high-priced material was received from Switzerland. Other zirconium compounds, totaling 811,346 pounds valued at $106,910, were received from five countries. Almost 70 percent of this quantity was sent from Japan and over 25 percent from the United Kingdom. Imports from Canada, Austria, and West Germany of unwrought hafnium metal, waste, and scrap totaled 332 pounds worth $3,717. The small quantity from West Germany carried 57 percent of the total value for the category.

Table 2.—U.S. imports for consumption of zircon, by countries
(Short tons)

Country	1956–60 (average)	1961	1962	1963	1964	1965
Argentina	-----	-----	-----	-----	40	-----
Australia	34,804	31,225	27,001	50,004	42,903	57,744
Austria	-----	-----	-----	11	-----	-----
Brazil [1]	66	4	-----	-----	-----	-----
Canada [2]	69	-----	1	24	848	1,027
Nigeria	554	-----	544	981	622	-----
South Africa, Republic of	683	2,576	3,326	1,523	-----	-----
United Kingdom [2]	67	-----	-----	-----	-----	102
Total:						
Quantity	36,243	33,805	30,872	52,543	44,413	58,873
Value	$1,030,555	$873,376	$844,939	$1,715,878	$1,184,021	$1,689,936

[1] Concentrate from Brazil includes some baddeleyite.
[2] Believed to be country of shipment rather than country of origin.

WORLD REVIEW

Australia.—Shipments of zircon concentrate for the first three quarters of 1965 totaled 169,648 tons having an average value at separation plant of $23.21 per ton. The States of New South Wales and Queensland in eastern Australia shipped 89 percent of the concentrate, Western Australia, the remainder. Exports for January through September totaled 163,053 tons having a f.o.b. unit value of $29.74. Almost 90 percent of the exports were to six countries, including over 20 percent each to the United States and the United Kingdom.[6] Early in the year the largest single bulk cargo of its type, including 4,000 tons of zircon and over three times as much rutile, was shipped to North America.

Several publications were issued presenting detailed information on Australian and other companies mining heavy mineral

[6] Bureau of Mineral Resources, Geology and Geophysics (Canberra, Australia). Quarterly Bulletin of Mineral Sands Statistics, September Quarter, 1965. Jan. 14, 1966.

Table 3.—Free world production of zirconium concentrates by countries
(Short tons)

Country	1961	1962	1963	1964	1965[p1]
Australia	152,836	149,904	r207,011	r202,762	251,150
Brazil [2]	7,405	2,642	392	r569	NA
India	e10	NA	NA	NA	NA
Malagasy Republic	353	390	428	r564	709
Malaysia (zircon exports)	63	67	r289	r165	651
Nigeria	833	-----	886	-----	-----
Senegal	5,939	2,575	3,383	r611	NA
South Africa, Republic of	7,607	7,581	2,648	-----	-----
United Arab Republic (Egypt)	105	188	44	NA	NA
United States	W	W	W	W	W

e Estimate. p Preliminary. r Revised. NA Not available.
W Withheld to avoid disclosing individual company confidential data.
1 Compiled from data available April 1966.
2 Chiefly baddeleyite.

sands.[7] Two companies expanded or planned expansion of production on North Stradbroke Island near Brisbane, Queensland. The zircon reserve on the Cudgen "RZ" property on the island was believed to be about 700,000 tons. A dry separation plant that is being built at Hexham, near Newcastle, New South Wales, will have an initial capacity of 27,500 tons zircon, and is scheduled for completion late in 1965. This plant will process concentrates from leases at Big Swan Bay where a new concentrating plant commenced operations in the fall. The operator, Associated Minerals Consolidated, Ltd., announced Gold Fields group sales of 70,687 tons of zircon, about 3 percent more than in the fiscal year 1964; zircon products from three separation plants totaled 63,115 tons, about 2 percent greater than in fiscal year 1964.[8] In Western Australia output of zircon concentrate from the mining and wet separation plant at Yoganup and the dry separation plant at Capel operated by Westralian Oil N.L. rose to 9,100 tons in fiscal year 1965. In this time the company shipped 13,126 tons from Bunbury.

Brazil.—The Directorate of Internal Revenue published a schedule effective for the first half of 1965, showing assessed unit values for computing the Brazilian mineral commodity tax. A 10-percent tax was imposed on zirconium ores, baddeleyite or $17.65 per short ton, and zircon (caldasite) valued at 19,200 cruzeiros per metric ton or $9.41 per short ton. Subsequently the National Nuclear Energy Commission established a 600-ton export quota for concentrates of baddeleyite and caldasite.

France.—The French Bureau de Recherches Géologique et Minière was reported to have investigated zirconium-titanium deposits in Brittany and Normandy.[9]

Senegal.—North of Dakar, beach sands were estimated to contain 600,000 tons of zircon.[10]

TECHNOLOGY

The zirconium-hafnium ratio in zircons from calc-alkaline igneous rocks was found to decrease with the color index, to be lowest in nepheline syenites of the alkaline series, and, in rocks of the same composition, was more variable in near-surface varieties than in the deep-seated types.[11] Natural glasses caused by impact were shown to contain baddeleyite and silica formed by high-temperature fusion of zircon-bearing rocks.[12]

Gravity and magnetic methods used for separating zircon from iron-bearing sands

[7] Metal Bulletin (London). Beach Sand Minerals. Special Issue, November 1965, 48 pp.
N.S.W. Rutile Mining Company Pty. Ltd. The Australian Mineral Sands, Brisbane, Australia, 1965.
[8] Associated Minerals Consolidated, Ltd. Thirteenth Annual Report, Sydney, Australia, 1965, 15 pp.
[9] Mining Journal (London). V. 265, No. 6782, Aug. 13, 1965, pp. 114–115.
[10] Metal Bulletin (London). No. 4999, May 21, 1965, p. 27.
[11] Chessex, Ronald, and Michel Delaloye. (Hafnium and Yttrium Contents of Zircons). Schweizerische Mineralogische und Petrographische Mitteilungen (Zurich, Switzerland), v. 45, No. 1, 1965, pp. 294–315 (in French).
[12] El Goresy, Ahmed. Baddeleyite and its Significance in Impact Glasses. J. Geophys. Res., v. 70, No. 14, July 15, 1965, pp. 3453–3456.

were described.[13] A milling technique was developed for obtaining a greater opacifying value from a given quantity of zircon with particles 10 microns and less. It entailed separating the material, usually centrifugally, into three grain-size fractions, the coarsest being about 35 percent of the original batch and the other two finer fractions with particles from 0.1 to 3 microns.[14]

Finely divided zirconium oxide was recovered from solid zirconyl nitrate by calcination.[15] Research was continued on developing an economical process for making pure zirconium starting with the caustic fritting of zircon sand. Caustic frits—a mixture of sodium zirconate and sodium silicate prepared by heating zircon sand with caustic soda—were washed with water to remove soluble sodium silicate and hydrolyze the zirconate to impure hydrous zirconium oxide. The washed frit was converted to pure zirconyl compounds by any one of seven different methods.[16]

Very high-purity zirconia and hafnia powders, with average particle sizes of 100–200 angstroms, were prepared continuously by heating their alkoxides at 325° to 450° C. At room temperature the zirconia powder is cubic, but is transformed completely to monoclinic above 400° C and is densified at lower temperatures than is commercial spectrographic-grade (99.9 percent) zirconia.[17]

In ceramic research, refractory oxides, including zirconia, were flame sprayed as a protection against zinc deposited on metallic parts.[18] An abrasive material, of high impact-strength and containing a mixture of a eutectic of alpha-alumina and zirconia as well as their crystals averaging no greater than 300 microns, was prepared.[19] Dead-burned magnesite and finely divided zircon were used in a refractory batch mixture suitable for making a fired, volume stable, refractory shape. Spaced deposits of stabilized zirconia were distributed through the forsterite matrix, which was the reaction product between MgO in the magnesite and SiO_2 in the zircon.[20]

Zirconium and hafnium were identified and differentiated by a simple, sensitive test which, in the absence of iron, preferably used a hydrochloric acid medium. Certain anions, which form masking complexes with zirconium and hafnium, should not be present.[21]

In Bureau studies on phase equilibria, it was found that the hafnium-vanadium system had one cubic intermetallic compound and a eutectic point at 1,395° C and 20 weight-percent vanadium;[22] the average zirconium value at various sampling temperatures in part of the magnesium-zirconium liquidus ranged from less than 1 weight-percent below 900° C to nearly 3 weight-percent at about 1,400° C.[23] X-ray techniques, including high-temperature diffractometry and single crystal methods, and differential thermal analysis were used in studying the monoclinic to tetragonal inversion of zirconium dioxide;[24] it believed that the high-temperature phase, metastable tetragonal zirconia, could not exist at room temperature if a critical crystallite size of about 300 angstroms was exceeded;[25] zirconia single-crystal whiskers were shown to grow best from oxide dis-

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[13] Shannon, W. T., W. Kitt, and T. Marshall. Separation of Ilmenite and Zircon From Waikato North Head Iron Sands. New Zealand J. Sci. (Wellington), v. 8, No. 2, June 1965, pp. 214–227.

[14] Costain, Thomas S., Elliott L. Weinberg, Arthur H. Luley, and Ralph R. Danielson (assigned to American Can Co.). Finely Milled Zircon for Opacifying Glazes. U.S. Pat. 3,210,204, Oct. 5, 1965.

[15] Klimaszewski, Irvin C. (assigned to Pittsburgh Plate Glass Co.). Process for Preparing Zirconium Oxides. U.S. Pat. 3,193,346, July 6, 1965.

[16] Choi, Hyung Sup. Preparation of Pure Zirconyl Compounds From Zircon Caustic Frit. Canadian Min. and Met. Bull. (Montreal, Canada), v. 58, No. 634, February 1965, pp. 193–198.

[17] Mazdiyasni, K. S., C. T. Lynch, and J. S. Smith. Preparation of Ultra-High-Purity Submicron Refractory Oxides. J. Am. Ceram. Soc., Ceram. Abs., v. 48, No. 7, July 21, 1965, pp. 372–375.

[18] Ornitz, Martin N. (assigned to Blaw-Knox Co.). Preventing Attack of Metallic Furnace Parts by Condensed Low-Melting Metals. U.S. Pat. 3,196,056, July 20, 1965.

[19] Marshall, Douglas W., and Steven J. Roschuk (assigned to Norton Co.). Fused Alumina-Zirconia Abrasives. U.S. Pat. 3,181,939, May 4, 1965.

[20] Good, William R., and Ben Davies (assigned to Harbison-Walker Refractories Co.). Volume Stable Refractory and Method of Making Same. U.S. Pat. 3,192,059, June 29, 1965.

[21] Johnson, Arnold R., Jr. Neothorin Spot Test for Zirconium and Hafnium. J. Chem. Education, v. 42, No. 8, August 1965, p. 439.

[22] Deardorff, D. K., M. I. Copeland, L. L. Oden, and H. Kato. The Hafnium-Vanadium System. BuMines Rept. of Inv. 6594, 1965, 11 pp.

[23] Crosby, R. L., and K. A. Fowler. Determination of a Part of the Magnesium-Zirconium Liquidus. BuMines Rept. of Inv. 6673, 1965, 19 pp.

[24] Grain, Clark F., and Ronald C. Garvie. Mechanism of the Monoclinic to Tetragonal Transformation of Zirconium Dixoide. BuMines Rept. of Inv. 6619, 1965, 19 pp.

[25] Garvie, Ronald C. The Occurrence of Metastable Tetragonal Zirconia as a Crystallite Size Effect. J. Phys. Chem., v. 69, No. 4, April 1965, pp. 1238–1243.

solved in molten baths of $Na_2B_4O_7$ and LiCl at temperatures less than 1,100° C;[26] and metallurgists used the high-temperature X-ray technique to obtain a new value for the temperature of transformation of the alpha to the beta phase in high-purity crystal bar hafnium.[27]

In equilibrium studies on the hafnium-carbon binary system, it was determined that hafnium carbide was the only intermediate phase observable and, from melting point data, it was found that the most refractory composition was at 47.5 atomic-percent carbon where the carbide melted at 3,830° C.[28]

In ternary systems containing zirconium and hydrogen, hafnium affected the hydriding characteristics of zirconium in five respects. Two of the single phase regions, alpha and gamma, were stabilized; decomposition pressures in the multiphase region between the alpha and beta fields were raised; the eutectoid reaction was moved to high temperatures; hydrogen absorption was reduced; and a split decomposition at the eutectoidal point in part of the ternary was introduced.[29] Five phases were determined in a ternary system derived from hydrided zirconium-hafnium alloys. The phases are as follows: face-centered cubic and tetragonal, orthorhombic lambda, and two hexagonal. One of the latter was found in the gamma region derived from the low-temperature metal allotrope and the other, designated theta, occurs in the alpha plus gamma regions of one alloy.[30]

In a series of studies the rate of effusion of zirconium tetraiodide was measured and a new sublimation temperature estimated, zirconium triiodide was reduced under pressure with zirconium from liquid zirconium tetraiodide, and the triiodide subsequently disproportionated to the diiodide via an intermediate phase.[31]

The eminent metallurgist, W. J. Kroll, discussed developments leading to the reduction of zirconium chloride to ductile zirconium.[32] Scientists at the Naval Research Laboratory initiated low-temperature thermal conductivity studies on zone-refined hafnium.[33] Research was continued on alloys containing zirconium, either as a main component as in the Zircaloys or as an important though minor constituent of other base alloys. Papers presented at the fall meeting of the Electrochemical Society were concerned with corrosion, hydriding, deformation and fracture, and effects of irradiation, composition variation, and heat treatment on zirconium and its alloys.[34] The failure of a Zircaloy-2 to stainless steel braze in corrosion testing, investigated by electron beam microprobe, was attributed to the diffusion of iron into the zirconium alloy and to the very low chromium content of the transition zone. This method was used also in identifying and measuring the phases present and examining the corroded surfaces of Zircaloy test speciments.[35] Impact, burst, and delayed-failure tests and yield-point studies were used on specimens of some zirconium alloys to determine effects of certain factors in deformation processes on ductility.[36]

A newly developed alloy containing minor quantities of columbium, chromium, and tin with zirconium, showed improved

[26] Johnson, Robert C., and John K. Alley. Growth and Properties of Zirconia and Titania Whiskers From Fused Salt Baths. BuMines Rept. of Inv. 6667, 1965, 15 pp.

[27] Romans, P. A., O. G. Paasche, and H. Kato. The Transformation Temperature of Hafnium. J. Less-Common Metals (Amsterdam, Netherlands), v. 8, No. 3, March 1965, pp. 213–215.

[28] Sara, R. V. The Hafnium-Carbon System. Trans. Met. Soc. AIME, v. 233, No. 9, September 1965, pp. 1683–1691.

[29] Katz, O. M., and J. Alfred Berger. The Zirconium-Hafnium-Hydrogen System at Pressures Less Than 1 Atm: Part 1—A Thermochemical Study. Trans. Met. Soc. AIME, v. 233, No. 5, May 1965, pp. 1005–1013.

[30] Katz, O. M., and J. Alfred Berger. The Zirconium-Hafnium-Hydrogen System at Pressures Less Than 1 Atm: Part II—A Structural Investigation. Trans. Met. Soc. AIME, v. 233, No. 5, May 1965, pp. 1014–1021.

[31] Sale, F. R., and R. A. J. Shelton. Studies in the Chemical Metallurgy of the Titanium Group Metals. I. The Vapour Pressure Over Solid Zirconium Tetraiodide. II. The Preparation and Characterisation of Zirconium Triiodide and Zirconium Diiodide. III. The Disproportionation of Zirconium Triiodide. J. Less-Common Metals (Amsterdam, Netherlands), v. 9, No. 1, July 1965, pp. 54–69.

[32] Kroll, W. J. A Contribution to the History of Ductile Titanium and Zirconium. J. Less-Common Metals (Amsterdam, Netherlands), v. 8, No. 6, June 1965, pp. 361–367.

[33] Schriempf, J. T. Basic Studies of the Metallic State (The Thermal Conductivity of Hafnium). Rept. of NRL Progress, July 1965, pp. 32–33; PB 168228.

[34] The Electrochemical Society, Inc. Extended Abstracts of Electrothermics and Metallurgy Division (Pres. at Buffalo, N.Y., Oct. 10–14, 1965). V. 3, No. 2, 1965, 142 pp.

[35] Landis, F. P., R. W. Merchant, and P. D. Zemany. The Electron Beam Microprobe as a Tool in Materials Engineering. Mat. Res. Standards, v. 5. No. 5, May 1965, pp. 219–229.

[36] Ostberg, Gustaf. Some Observations on the Ductility of Zirconium Alloys, With Special Reference to the Effect of Hydrogen. J. Inst. of Metals (London), v. 93, pt. 7, March 1965, pp. 223–230.

corrosion resistance characteristics.[37] Widmanstatten markings characterize one of two distinct phases, β'', in quenched zirconium alloys. Hardening of the alloy is due largely to the other phase, omega, which forms from the beta phase during quenching and during isothermal aging below 500° C.[38] Powder metallurgy techniques were used in strengthening Zircaloy-2 by mechanically dispersing inert Y_2O_3 particles of less than 3 microns in size in a hydride reactor-grade mill scrap, with the dispersant contributing significant increases in yield strengths at temperatures up to 650° C and reducing the creep rate. Oxygen contamination, responsible for most of the strengthening, poses a serious technological problem.[39]

Methods were described for making copper- and nickel-base alloys containing small additions of zirconium;[40] a technique was shown for using alizarin red S to determine zirconium quantitatively in copper-zirconium alloys;[41] and pretest solution annealing, at temperatures up to 1,700° C, was found to improve creep properties in an alloy of columbium with 1 percent zirconium.[42] Hafnium, in quantities up to 12 percent, was found suitable for use in a molybdenum cast alloy,[43] and a superplastic zirconium-alloy handling almost as easily as hot plastic or glass was developed.[44]

A gel produced by mixing initially a water-soluble salt, such as zirconium sulfate, with an alkali metal silicate, such as Na_2SiO_3, was processed further to a content of 10 percent ZrO_2 and 90 percent SiO_2. As a cracking catalyst it significantly increased gasoline production up to a pH of 9.9.[45] The prospective aerospace use of hafnium was spurred by Government contract research on the processing of hafnium-tantalum alloys and the cladding and fabricating of rocket-engine components.[46] Superconductive wires of columbium and zirconium were used in the outer two of three coils of a magnet with a field of 67,000 gauss tested at Argonne National Laboratory. These supermagnets are compact and operate more economically than do conventional electromagnets, and with their powerful fields could contain hot gas plasmas or serve as shielding against radiation.[47]

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[37] Bertea, Octavian, James R. Gross, and Stanley R. Seagle (assigned to National Distillers and Chemical Corp.). Corrosion Resistant Zirconium Base Alloys Containing Cb, Cr, and Sn. U.S. Pat. 3,205,070, Sept. 7, 1965.

[38] Cometto, D. J., G. L. Houze, Jr., and R. F. Hehemann. The Omega Transformation in Zirconium-Niobium (Columbium) Alloys. Trans. Met. Soc. AIME, v. 233, No. 1, January 1965, pp. 30–39.

[39] Antony, K. C., and H. H. Klepfer. Dispersion-Strengthened Zirconium Alloys. J. Less-Common Metals (Amsterdam, Netherlands), v. 8, No. 1, January 1965, pp. 36–46.

[40] Freche, John C., Thomas J. Riley, and William J. Waters (assigned to National Aeronautics and Space Administration). Nickel-Base Alloy. U.S. Pat. 3,167,426, Jan. 26, 1965.
Pels, Alan R., and Herman F. Petsch (assigned to National Distillers and Chemical Corp.). Process for Making a Copper-Chromium-Zirconium Alloy. U.S. Pat. 3,194,655, July 13, 1965.

[41] Stern, D. G. The Determination of Zirconium in Copper-Zirconium Alloy. Metallurgia (Manchester, England), v. 71, No. 423, January 1965, pp. 51–52.

[42] McCoy, H. E. Creep Properties of the Nb—1% Zr Alloy. J. Less-Common Metals (Amsterdam, Netherlands), v. 8, No. 1, January 1965, pp. 20–35.

[43] Semchyshen, Marion (assigned to American Metal Climax, Inc.). Molybdenum-Hafnium Alloy Casting. U.S. Pat. 3,169,860, Feb. 16, 1965.

[44] Steel. Superplasticity: Metals Draw Almost as Easily as Hot Plastic. V. 156, No. 24, June 14, 1965, pp. 66, 68, 71.

[45] Plank, Charles J., Edward J. Rosinski, and Robert B. Smith (assigned to Socony Mobil Oil Co., Inc.). Silica-Zirconia Cracking Catalyst for Hydrocarbons. U.S. Pat. 3,193,492, July 6, 1965.

[46] Metal Bulletin (London). No. 5050, Nov. 23, 1965, p. 25.

[47] Materials in Design Engineering. Powerful Magnet Possible Thanks to New Materials. V. 61, No. 5, May 1965, pp. 169, 172.

Minor Metals

By Staff, Division of Minerals

CONTENTS

ARSENIC [1]

Domestic Production.—Domestic production of white arsenic, As_2O_3, was derived entirely as a byproduct of smelting arsenic-containing copper ores by The Anaconda Company at Anaconda, Mont., and American Smelting and Refining Company at Tacoma, Wash. The Anaconda Company discontinued production of white arsenic in 1965. Arsenic metal was not produced.

Consumption and Uses.—Most of the white arsenic produced in 1965 was consumed in manufacturing lead and calcium arsenate insecticides.

Arsenic compounds also were used in weed killers, glass manufacture, cattle and sheepdips, dyestuffs, and wood preservatives. Arsenic acid is used to dessicate cotton plants to remove leaves for mechanical picking of the cotton. About 4,000 tons of the acid is used annually. Mono- and di-sodium methyl arsenates are used to control Johnson grass in cotton fields. The use of arsenic compounds is increasing rapidly for weed killing; about 8,000 tons of these arsenates are used annually. Arsenilic acid is used in chicken feed.

Apparent consumption of white arsenic decreased 2 percent compared with that of 1964.

Table 1.—Consumption of arsenic wood preservatives in the United States

(Short tons)

Year	Consumption of wood preservatives	
	Wolman salts (25 percent sodium arsenate)	Other
1963	1,721	1,392
1964	1,970	1,646
1965 p	1,656	1,853

p Preliminary.

Source: U.S. Department of Agriculture, Forest Service.

Stocks.—Stocks of white arsenic declined 14 percent while shipments increased 15 percent, and total new supply (production and imports for consumption) was about 600 tons less than in 1964.

Prices.—The price of both crude and refined white arsenic was increased 0.3 cent per pound on January 4 by the American Smelting and Refining Co.[2] Bulk carloads of crude, minimum 95 percent white arsenic, increased to 3.2 cents per pound and barrelled carloads went up to 4.8 cents per pound, f.o.b., Tacoma, Wash., and Laredo, Tex. The price of refined white arsenic in bulk carload quantities was raised to 4.1 cents per pound and barrelled carload lots went up to 5.7 cents

[1] Prepared by Arnold M. Lansche.
[2] American Metal Market. V. 72, No. 1, Jan. 4, 1965, p. 22.

per pound, f.o.b., Laredo, Tex. These prices were maintained for the rest of the year. The price of lead arsenate in 50-pound bags began in 1965 at 27 cents per pound and the quote was increased on August 16 to 29 cents per pound and remained at this price through December 31. Lead arsenate in 1-pound bags opened the year at 36 cents per pound, the price was quoted in the Oil, Paint and Drug Reporter on August 16 at 41 cents per pound and remained at this price for the rest of the year.

The London price, quoted from the Metal Bulletin, for white arsenic in 1965 was £40 to £45 per long ton (5 to 5.63 cents per pound), unchanged from 1964, for 98 percent minimum. Arsenic metal on the London market opened the year at £400 per long ton or 50 cents per pound; on January 8 the quotation was increased to £425 (53.125 cents); and on July 6 the price was again raised to £445 (55.625 cents) and remained at this price for the rest of the year.

Foreign Trade.—No exports of white arsenic were reported.

A total of 360,829 pounds of arsenic metal was imported. Sweden supplied the majority of the metal imported; Canada provided 190 pounds; West Germany, 11 pounds; and Switzerland, 13 pounds. Arsenic sulfide compounds came from Belgium-Luxembourg, 26 tons, and West Germany, 20 tons. The United Kingdom supplied 154 tons of sodium arsenate; Australia, 10 tons of sheepdip; and other arsenic compounds came from Canada, 2 pounds; France, 20 pounds; and the United Kingdom, 3 pounds.

World Review.—*Southern Rhodesia.*—The arsenic oxide refining plant that was being built at Que Que in connection with the Government-owned gold ore roasting plant was completed in 1964.

Technology.—Patents were issued on a composition of arsenic-bearing material which was claimed to decrease the rate of corrosion of ferrous metal when applied;[3] a process for preparing arsenic acid compounds;[4] the removal of arsenic contam-

[3] Creech, Barnard C., Lawrence V. Collings, and Paul Shapiro (assigned to Sinclair Research Inc., New York). Aqueous Ammoniacal Solution Containing a Complex Arsenic Compound. U.S. Pat. 3,168,392, Feb. 2, 1965.

[4] Moyerman, Robert M., and Philip J. Ehman (assigned to the Ansul Company, Marinette Wis.). Manufacture of Arsenic Acids. U.S. Pat. 3,173,937, Mar. 16, 1965.

Table 2.—U.S. imports for consumption of white arsenic (As_2O_3 content), by countries

Country	1963		1964		1965	
	Short tons	Value	Short tons	Value	Short tons	Value
Canada	2	$264	35	$4,486		
France	2,116	130,781	3,430	231,022	3,447	$238,333
Mexico	10,641	811,643	11,860	937,986	10,288	888,761
Sweden	1,800	115,767	2,847	208,804	1,691	135,835
U.S.S.R.			13	1,080	99	8,091
Total	14,559	1,058,455	18,185	1,383,378	15,525	1,271,020

Table 3.—U.S. exports and imports of arsenicals, by classes

(Pounds)

Class	1956–60 (average)	1961	1962	1963	1964	1965
Exports:						
Calcium arsenate	1,018,919	669,932	942,399	186,577	1,537,484	(1)
Lead arsenate	1,833,269	928,797	1,422,795	802,664	1,871,803	(1)
Imports for consumption:						
White arsenic (As_2O_3 content)	23,316,620	38,966,394	31,515,599	29,117,679	36.370,155	31,049,571
Metallic arsenic	103,385	132,389	229,439	337,582	307,885	360,829
Sulfide	65,113	55,116	66,160	35,824	55,116	92,358
Sheepdip	50,994		14,765	19,656	19,686	20,470
Calcium arsenate	12,800					
Sodium arsenate	218,745	211,034	255,466	272,946	321,290	308,980

[1] Beginning Jan. 1, 1965, no longer separately classified.

Table 4.—Free world production of white arsenic, by countries [1]

(Short tons)

Country	1961	1962	1963	1964	1965 p [2]
Brazil	64	164	323	r 207	282
Canada	r 210	80	94	r 162	150
France	r 10,357	7,477	r 11,668	r 12,563	[3] 11,436
Germany, West (exports)	r 154	75	62	r 42	78
Japan	1,047	1,011	904	r 550	e 600
Mexico [4]	r 18,418	r 16,352	r 14,666	r 16,380	15,188
Peru	388	572	683	r 685	550
Portugal	330	634	622	r 410	[5] 440
Rhodesia, Southern		1,207	605	206	e 70
Spain	343	234	r 161	r 158	130
Sweden	12,153	6,342	r 16,369	r 19,809	e 20,000
Free world total e	59,000	49,600	61,000	64,500	68,000

e Estimate. p Preliminary. r Revised.
[1] Arsenic may be produced in Argentina, Austria, China, Czechoslovakia, East Germany, Finland, Hungary, U.S.S.R. (estimated range 5,600), United Kingdom, and Yugoslavia, but there is too little information to estimate production. Estimate included in world total for Belgium and United States. U.S. figure withheld to avoid disclosing individual company confidential data.
[2] Compiled mostly from data available May 1966.
[3] Exports.
[4] Including black arsenic.
[5] Estimated equivalent recoverable arsenic trioxide content of concentrates produced.

inant from platinum-alumina catalytic composites;[5] the production of high-purity $AsCl_3$ using As_2O_3 and HCl;[6] the use of nickel arsenides to promote phase separation in liquid-liquid extraction;[7] a phosphor composition;[8] and a process for separating arsenic from ores and catalyst compositions using gaseous H_2S, steam, and inert gases.[9]

CESIUM AND RUBIDIUM [10]

The consumption of cesium and rubidium source materials, each, were larger in 1965 than in 1964, but the tonnages continued to be small.

Domestic Production.—Four firms processed pollucite to cesium products, and two of these firms processed rubidium source materials to rubidium products. American Potash & Chemical Corp., Trona, Calif., produced cesium compounds. Penn Rare Metals Inc., Division of Kawecki Chemical Co., Revere, Pa., produced cesium and rubidium metals and compounds. The Dow Chemical Co., Midland, Mich., produced cesium metal. MSA Research Corp., Callery, Pa., produced cesium metal and rubidium compounds.

Productions of cesium metal and compounds and rubidium metal were much larger in 1965 than in 1964. The output of rubidium compounds was much smaller in 1965 than in 1964. Production data are withheld to avoid disclosing company confidential information.

Consumption and Uses.—Pollucite and rubidium source material consumptions were larger in 1965 in contrast to 1964, but the tonnages were small.

Cesium continued to be of interest for high-velocity propellant for rocketry and also for the generation of electrical energy.

In April, a space vehicle reportedly containing a nuclear reactor weighing about 250 pounds, a cesium ion engine weighing about 2 pounds, 1 pound of cesium, and various other equipment were put into orbit by an Atlas-Agena rocket for flight tests.

[5] Gleim, William K. T. (assigned to Universal Oil Products Company, Des Plaines, Ill.). Removal of Arsenic Contaminant From Platinum-Alumina Catalytic Composites. U.S. Pat. 3,177,-158, Apr. 6, 1965.
[6] Cobel, George B., and William R. Fronk (assigned to The Dow Chemical Co., Midland, Mich.). Process of Producing High-Purity Arsenic Trichloride From a Slurry of As_2O_3. U.S. Pat. 3,194,631, July 13, 1965.
[7] Collopy, Thomas Joseph, John Herbert Mueller, and Wendell Sims Miller (assigned to the U.S. Atomic Energy Commission). Use of Nickel Arsenides and Nickel to Promote Phase Separation in Liquid-Liquid Extraction. U.S. Pat. 3,202,476, Aug. 24, 1965.
[8] Subbarao, Eleswarapu C., and Don E. Harrison (assigned to Westinghouse Electric Corp., Pittsburgh, Pa.). Arsenate and Phosphate Phosphors. U.S. Pat. 3,210,289, Oct. 5, 1965.
[9] Espinosa, Mariano Hernandez-Vaquero (assigned to Empresa Nacional Calvo Sotelo de Combrestilles Liquidos y Lubricantes, St., Madrid, Spain). Process for the Removal of Arsenic or Arsenic Compounds. U.S. Pat. 3,220,796, Nov. 20, 1965.
[10] Prepared by Donald E. Eilertsen.

In space, the nuclear reactor supplied thermoelectric power for storage batteries which supplied electricity to operate various instruments and the ion engine using cesium as a propellant.

Two lightweight cesium-operated atomic clocks were airborne to 11 countries to precisely synchronize clocks at 22 timekeeping centers.[11]

Some applications reported for cesium chemicals were cesium monobromide and cesium monoiodide for optical crystals, cesium monoiodide for phosphors, cesium hydroxide for alkaline storage battery electrolyte and desulfurization of heavy oil, cesium nitrate for microwave reflector, cesium fluoride for fluorination catalyst, and cesium chloride and cesium monobromide for the production of electrolytic cesium metal.

Sometimes rubidium and some of its compounds can be used as alternatives for cesium and its compounds.

A rubidium magnetometer proved to be useful in archeological exploration.[12]

Foreign Trade.—Data on the exports of cesium and rubidium metals and their compounds were not available for publication.

Import figures on cesium metal were not available for publication. Imports for consumption of cesium chloride were 384 pounds, valued at $12,591, from West Germany, and 27 pounds, valued at $2,072, from the United Kingdom. Imports of other cesium compounds were 431 pounds valued at $13,641, from West Germany, and 22 pounds valued at $557, from United Kingdom. No rubidium was imported.

World Review.—*Mozambique.*—A total of 5.5 tons of pollucite valued at $876 was exported in 1964, all to the United States.

Rhodesia, Southern.—Pollucite outputs by Bikita Minerals Ltd., during 1959-64 were reported as follows: 1959—2 tons, valued at $504; 1960—5 tons, valued at $1,680; 1961—10 tons, valued at $2,800; 1962—20 tons, valued at $5,107; 1963—no output; and 1964—26 tons, valued at $6,376, based on R£1 equals U.S. $2.80.[13]

Technology.—Bureau of Mines metallurgists continued studies on the extraction of cesium and rubidium from pollucite. Petroleum researchers developed methods to detect less than 0.01 milligram per liter of cesium and/or rubidium in oilfield brine or water.[14]

Atomic Energy Commission research on cesium and rubidium included studies on the heat transfer properties, solvent extraction, and toxicity of radioactive cesium.[15]

The National Aeronautics and Space Administration (NASA) continued its interest in cesium for possible space applications as heat transfer medium and as working fluid in electric propulsion and space power systems. Briefly, various studies were continued on determining some of the properties of cesium liquid or vapor, investigating the chemical compatibility of cesium with certain alloys, testing space flight cesium-filled thermionic power con-

[11] Electronic News. Airborn Atomic Clocks. 22 Time Stations Synchronized. V. 10, No. 480, Mar. 22, 1965, p. 91.

[12] Breiner, Sheldon. The Rubidium Magnetometer in Archeological Exploration. Science, v. 150, No. 3693, Oct. 8, 1965, pp. 185-193.

[13] Metal Bulletin (London). Bikita's Pollucite Outputs. No. 5030, Sept. 14, 1965, p. 25.

[14] Collins, A. Gene. Methods of Analyzing Oilfield Waters: Cesium and Rubidium. BuMines Rept. of Inv. 6641, 1965, 18 pp.

[15] Atomic Energy Commission. Fundamental Nuclear Energy Research 1965. A Supplemental Report to the Annual Report to Congress. December 1965, 338 pp.

Table 5.—Prices of cesium and rubidium and some of their salts

Item	1 to 277 grams (per gram)	1 to 9 pounds (per pound)	10 to 99 pounds (per pound)	100 to 999 pounds (per pound)	1000 pounds and more (per pound)
Cesium, 99.6 percent	$0.70-$1.80	$250-$275	$200-$225	$150-$175	$100
Cesium, 99.98 percent	.90- 2.00	300- 325	250- 275	190- 220	125
Cesium salts, technical grade:					
Carbonate and chloride	.21- .27	32	30		
Fluoride	.26- .32	40	38		
Hydroxide	.30- .36	45	43		
Rubidium, 99.5 percent	.70- 1.80	275- 300	200- 250	150- 175	100
Rubidium, 99.8 percent	.90- 2.00	325- 375	250- 315	190- 220	125
Rubidium salts, technical grade:					
Carbonate	.27- .31	41	39		
Chloride	.33- .40	47	45		
Fluoride	.48- .53	60	58		
Hydroxide	.56- .62	67	65		

Source: Penn Rare Metals Division, Kawecki Chemical Co.

verters, and ground-testing experimental models of cesium ion engines requiring long-time operation for space voyages.

A book on the occurrences, properties, and chemistry of cesium and rubidium [16] and a comprehensive brief digest on cesium compounds [17] were published.

Patents were issued on methods to produce cesium,[18] high-purity cesium,[19] and cesium compounds.[20]

GALLIUM [21]

Intraplant consumption of gallium metal was down 87 percent in 1965 compared with 1964, whereas shipments showed a large increase.

Domestic Production. — Production of gallium metal increased 21 percent compared with 1964; the rise was attributed principally to increased activity in the semiconductor electronic field. Gallium metal was produced by the Aluminum Company of America's plant at Bauxite, Ark., and by The Eagle-Picher Co. Miami plant near Quapaw, Okla. The Eagle-Picher Co. also produced gallium oxide, gallium trichloride, and the alloy gallium arsenide. Production data are company confidential.

Consumption and Uses.—Shipments of gallium metal increased 50 percent in 1965 compared with 1964. Gallium was used in selenium rectifiers, glass-joint sealing materials, intermetallic semiconductors, solid lubricants in low temperature and high-vacuum environments, thermometers, devices that convert electricity to light, minor backing, and analysis of uranium to increase the sensitivity of the determination.

Statistics on shipments are company confidential.

Prices.—Market prices per gram of various-grade gallium from bauxite sources were the same as in 1964 and are given in table 6.

Foreign Trade.—General imports of gallium totaled 2,240 pounds, valued at more than $106,000. France supplied 26 pounds, valued at $4,384; West Germany 155 pounds, valued at $15,267; Japan 2 pounds, valued at $975; Switzerland 314 pounds, valued at $79,402; and the United Kingdom 1,719 pounds, value unknown.

World Review.—*Czechoslovakia.* — Production of pure gallium was begun at the Spolana plant in Kaznejov near Plzen. It was also reported that a plant is being built to produce gallium in bulk quantities. Gallium output was a byproduct from a process used to obtain germanium.

Japan.—The Nippon Light Metal Co. plans to produce gallium on a commercial basis from bauxite.

Table 6.—Market prices of gallium from bauxite sources in 1965

(Per gram)

Quantity	Percent of purity 99.99	99.999	99.9999
Up to 999 grams	$1.40	$1.50	$1.70
1,000 to 4,999 grams	1.20	1.30	1.50
5,000 to 24,999 grams	1.10	1.15	1.35
Over 25,000 grams	.95	1.00	1.20

Technology.—The Bureau of Mines continued studies of extracting germanium and gallium from flue dust and of superconducting alloys which contain gallium.

National Aeronautics and Space Administration Technical Brief 65–10007 describes thermocompression bonding of a gold wire to a gallium-arsenide wafer to produce a surface barrier diode with good conduction characteristics and recovery times in fractions of a nanosecond. Technical Brief 65–10020 describes a device

[16] Perel'man, F. M. Rubidium and Caesium. Pergamon Press, Ltd., (Macmillan Co.), New York, 1965, 144 pp.

[17] Kirk, Raymond E., and Donald F. Othmer. Cesium—Cesium Compounds. Encyclopedia of Chemical Technology. Interscience Publishers (Division of John Wiley & Sons), New York, v. 4, 2d ed., 1964, pp. 855–867.

[18] Berthold, Cornelius E. (assigned to San Antonio Chemicals, Inc., Delaware). Process for Preparing Cesium and Alloys Thereof. U.S. Pat. 3,207,598, Sept. 21, 1965.

Blue, Robert D., and Robert Moolenaar (assigned to The Dow Chemical Co., Midland, Mich.). Cesium Production. U.S. Pat. 3,201,229, Aug. 17, 1965.

Horner, Donald E., David J. Crouse, Jr., and Keith B. Brown (assigned to the U.S. Atomic Energy Commission). Extraction of Cesium From Aqueous Solution Using Phenols. U.S. Pat. 3,179,503, Apr. 20, 1965.

[19] Moolenaar, Robert J., Robert S. Karpiuk, and Marshall P. Neipert (assigned to The Dow Chemical Co., Midland, Mich.). Production of High-Purity Cesium. U.S. Pat. 3,164,461, Jan. 5, 1965.

[20] Berthold, Cornelius E. (assigned to San Antonio Chemicals, Inc., Delaware). Process for Preparing Cesium Compounds From Cesium Alum. U.S. Pat. 3,207,571, Sept. 21, 1965.

[21] Prepared by Arnold M. Lansche.

that increases the useful incoherent-light output of light emitting diodes made of gallium arsenide.

Reports were published on the homogenous vapor phase transport of tellurium doped gallium arsenide-phosphide using water vapor;[22] a vapor-growth process for preparation of single crystal gallium arsenide;[23] and observation by anomalous transmission of X-rays of imperfections in single crystals of gallium arsenide grown by the Czochralski and the horizontal gradient freeze methods.[24]

A patent was issued on a gallium arsenide semiconductor tunnel diode device.[25]

Epitaxial heterojunctions of gallium arsenide-gallium antimonide and indium arsenide-gallium antimonide were prepared and their electrical and electro-optical properties were investigated.[26]

GERMANIUM [27]

Domestic production of germanium from primary source materials in 1965 was approximately double the low production level indicated for 1964, as factory sales of semiconductor devices continued to increase and producer inventories of metal and reprocessing scrap reached reasonable alignment with demand. The germanium share of the increase in semiconductor output was, however, substantially less than that indicated for silicon and the intense competition of silicon in the electronics field resulted in a downward pressure on price of domestically produced dioxide and metal and a substantial reduction in the quoted price of imported materials. Imports of germanium as metal, dioxide, and scrap increased significantly in quantity but declined in value per pound.

Domestic Production.—Production of refined germanium was estimated at 90,000 pounds, of which 30,000 pounds was refined from new germanium feed materials and 60,000 pounds from reprocessing manufacturing scrap. Refinery operations continued well below capacity and mostly on an intermittent basis in balance with manufacturers requirements. A substantial inventory of germanium enriched segregates was indicated as available at refineries for conversion to germanium dioxide and to metal. Plants operated by The Eagle-Picher Co., Miami, Okla., and American Zinc Co., Fairmont, Ill., utilized domestically produced feed materials and reprocessed manufacturing scrap. The Carteret, N.J., refinery of American Metal Climax, Inc., and the Towanda, Pa., plant of Sylvania Electric Products, Inc., utilized imported feed materials and manufacturing scrap. Kawecki Chemical Co., Revere, Pa., and United Minerals and Chemical Corp., New Brunswick, Pa., operate refineries devoted essentially to reprocessing scrap.

The manufacturing residues and sludges returned to the refineries for treatment average 70 percent of the refined germanium entering the manufacturing cycle and result from processes of etching, slicing, and lapping of the crystal. This material is returned to the refineries for processing by leaching and chemical purification to germanium dioxide and reduction to metal.

Consumption and Uses.—The only significant use of germanium is in the electronics industry as semiconductors. Single junction diodes comprise the largest element and transistors the remainder. Factory sales of single-junction diodes utilizing germanium increased some 35 percent in volume in comparison with 1964 and germanium transistors increased 16 percent. The gain in factory sales of single-junction diodes including germanium and silicon was 48 percent and for transistors, 49 percent and indicates the major gain in silicon utilization, especially in transistor use. The unit values of both germanium and silicon devices were lower than in 1964.

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[22] Gottlieb, G. E. Vapor Phase Transport and Epitaxial Growth of $GaAs_{1-x}P_x$ Using Water Vapor. J. Electrochem. Soc., v. 112, No. 2, February 1965, pp. 192–196.

[23] Leonhardt, H. R. Synthesis of GaAs by Vapor Transport Reaction. J. Electrochem. Soc., v. 112, No. 2, February 1965, pp. 237–240.

[24] Jungbluth, E. D. X-ray Diffraction Topographs of Imperfections in Gallium Arsenide by Anomalous Transmission of X-rays. J. Electrochem. Soc., v. 112, No. 6, June 1965, pp. 580–583.

[25] Pell, Erik M. (assigned to General Electric Co., New York). Gallium Arsenide Semiconductor Devices. U.S. Pat. 3,200,017, Aug. 10, 1965.

[26] Rediker, R. H., S. Stopek, and E. D. Hinkley. Electrical and Electro-Optical Properties of Interface—Alloy Heterojunctions. Trans. AIME, v. 233 (Met. Soc.), 1965, pp. 463–467.

[27] Prepared by Donald E. Moulds.

Germanium dioxide is used in manufacture of special-type glasses and luminescent materials. The infrared transparency of either monocrystalline or polycrystalline germanium and high index of refraction is utilized for construction of lenses, prisms, and filters in infrared optical systems. Germanium compounds for use in deposition of epitaxial layers to achieve a wide range of semiconductor requirements are used in semiconductor manufacture. Other germanium compounds such as germanates and tetrahalides are available.

Prices.—Price quotations, cents per gram, for the various grades, in lots of 10 kilograms, delivered to buyer works as listed by the American Metal Market at the opening of 1965 was as follows:

	Cents per gram
First reduction	25.20
Intrinsic quality	27.00
Single crystal	56.00
Dioxide high purity	15.10

The above quotations continued unchanged to mid-September when the quotation basis was changed to dollars per kilogram and, following a price reduction announced by African Metals Corp., agents for a major foreign producer, the quotation for intrinsic quality metal indicated a spread from \$233 to \$261.25 per kilo in 10-kilo lots and dioxide was similarly quoted at \$130 to \$143.25. African Metals Corp. announced a second reduction effective in mid-October and the American Metal Market quotation subsequently indicated a spread of \$209 to \$261.25 for metal and \$112 to \$143.25 for dioxide. This quotation continued throughout the remainder of the year.

Foreign Trade.—Imports of germanium dioxide increased from 936 pounds in 1964 to 3,152 pounds, valued at \$133,800. The valuation per pound in 1965 was \$44 in comparison with the average of \$50 per pound in 1964. West Germany supplied 94 percent and Belgium-Luxembourg the remainder. Imports of metal totaled 83 pounds in comparison with 78 pounds in 1964 and the United Kingdom supplied 60 pounds; Belgium-Luxembourg 21 pounds; and West Germany 2 pounds. Value per pound of metal averaged \$159 in 1964 and \$98 in 1965. The import of scrap tripled in 1965 with 4,196 pounds, gross weight, received in comparison with 1,166 pounds in 1964. France supplied 2,250 pounds or 54 percent, followed by the United Kingdom, Netherlands, and Italy.

World Review.—*Belgium.*—Société Générale Métallurgique de Hoboken and the Société Vieille-Montagne de Balen operated refineries relying on germanium in concentrates and germanium dioxide produced as a byproduct of copper-zinc ores of Union Minière du Haut-Katanga in the Republic of the Congo (Léopoldville).

Italy.—Monteponi e Montevecchio Societi per Azioni produces germanium from lead-zinc ores of the Sardinian mines. Capacity is rated at 5,000 kilos annually but output has been on the order of 25 percent of capacity.

Japan.—Five companies reprocess germanium scrap and also refine germanium dioxide imported principally from Belgium. Consumption of germanium in electronic devices has steadily risen.

South-West Africa.—The Tsumeb Corp. Ltd., in recent years, has become the world's largest source of germanium. Associated with the copper-lead-zinc ores of the Tsumeb mine, the germanium is recovered in the smelting of copper and lead in the form of germanium enriched residues and refined to germanium dioxide. The capacity of the germanium plant is reported to be 15,000 kilograms annually. Germanium contained in blister copper is exported principally to West Germany for refining, and germanium in zinc concentrates and as dioxide is exported to the United States and Belgium for processing.

Republic of the Congo (Léopoldville).—The copper-zinc ores of the Prince Léopold mine of Union Minière du Haut-Katanga contain small amounts of germanium that accompanies the copper concentrate. Part of the germanium is subsequently recovered as a concentrate by magnetic separation and in the treatment of flue dust recovered at the Lubumbashi copper smelter. The recovered germanium bearing materials are exported to Belgium for refining. Production reached a peak of 25,000 kilograms in 1960 but output in recent years has been approximately one-half that of the record year amounting to 14,638 kilograms of germanium in 1965.

Technology.—A significant portion of research and development activity in germanium was devoted to engineering improvement in semiconductor reliability and

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capability at very high voltage and very high frequency. The importance of the maximum volt-per-second capability in determining the volt-ampere and power-gain performance with ultra-high frequency has been recognized only recently, and research is being conducted to determine all the factors that may be significant in determining the basic limitations of semiconductor devices. Germanium units appear to be evolving into two broad types: High performance, low-cost units for audio, radio, and high-fidelity applications and high-voltage, high-peak power capability units for television ignition and computer applications. Microelectronic circuitry requirements for military and space applications have further stressed the need for technology improvements in performance, reliability, size, weight, and cost.

Surface protection of germanium devices is an area of special concern in semiconductor application. Simple environmental conditions such as humidity result in variable sensitivity and performance. Extensive research on the electrochemical behavior of oxide films on germanium was reported,[28] and a process for surface pacification was developed to convert the common oxide film on germanium to an extremely stable tetragonal form of germanium dioxide.[29] A new fabrication technique for surface passivated germanium transistors using annular construction and selective metal-etch was also reported.[30] The results of a study on the relationship of current leakage to aging behavior of germanium alloy transistors was published.[31] The recent discovery of the low thermal conductivity of germanium-silicon alloys has revealed that these alloys have high efficiencies for thermoelectric-power generation and a method for the preparation of homogenous samples of these alloys for definitive measurements was described.[32]

The history of investigations and developments in the field of organogermanium chemistry during the period 1959–64 was summarized in a book prepared primarily for students.[33]

U.S. patents were issued for a process of purification of liquid halogenated compounds of semiconductor elements[34] and for producing refined silicon and germanium by a dual cell electrolytic method.[35]

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[28] Boddy, P. J., and W. H. Brattain. Residual Surface Recombination on Germanium Anodes. J. Electrochem. Soc., v. 112, No. 10, October 1965, pp. 1053–1054.
Haq, K. E. Deposition of Germanium Films by Sputtering. J. Electrochem. Soc., v. 112, No. 5, May 1965, pp. 500–502.
Krischer, Christof C., and Robert A. Osteryoung. The Effect of Cathodic Prepolarization on Capacity Curves of Germanium Electrodes. J. Electrochem. Soc., v. 112, No. 9, September 1965, pp. 938–943.
Story, Joseph B. Mechanism of Anodic Germanium Oxide Film Formation. J. Electrochem. Soc., v. 112, No. 11, November 1965, pp. 1107–1111.

[29] Steel. GM Toughens Skins on Germanium Devices. V. 156, No. 21, May 24, 1965, pp. 137–138.

[30] Electronic News. Innovations in Ge Transistors Introduced by Motorola Division. V. 10, No. 484, Apr. 12, 1965, p. 42.

[31] Conrad, George T., Jr., and Donald C. Shook. A Transistor Screening Procedure Using Leakage Current Measurements. J. of Res. of NBS, C; Engineering and Instrumentation, v. 69C, No. 4, October–December 1965, pp. 319–330.

[32] Dismukes, J. P., and L. Ekstrom. Homogeneous Solidification of Ge-Si Alloys. Trans. AIME, v. 233 (Met. Soc.), 1965, pp. 672–680.

[33] Rijkens, F., and G. J. M. Van der Kerk. Investigations in the Field of Organogermanium Chemistry. Organisch Chemisch Instituut T.N.-O., (Netherlands). 1964, p. 162. Chem. and Ind. (London), No. 28, July 10, 1965, p. 1253.

[34] Gauguin, Roland, and Georges Nury (assigned to Pechiney, Compagnie de Produits Chimiques et Electrometallurgiques, Paris, France). Process for the Purification of Halogenerated Volatile Compounds of Germanium and Silicon. U.S. Pat. 3,216,785, Nov. 9, 1965.
———(assigned to Pechiney, Compagnie de Produits Chimiques et Electrometallurgiques, Paris, France). Purification of Halogenated Derivatives of Silicon and Germanium. U.S. Pat. 3,216,784, Nov. 9, 1965.

[35] Monnier, Robert, and Dlawar Barakat (assigned to The General Trustee Co., Inc., Geneva, Switzerland). Dual Cell Refining of Silicon and Germanium. U.S. Pat. 3,219,561, Nov. 23, 1965.

INDIUM [36]

Domestic Production. — Indium metal and chloride were produced at the Perth Amboy, N.J., plant of American Smelting and Refining Company, and the metal was also produced at the Great Falls, Mont., plant of The Anaconda Company for the first time since 1960. The source material for indium production was certain smelter flue dusts and residues in which the trace quantities of indium occurring in zinc minerals were concentrated.

Uses.—Indium was used in electronic devices in a variety of ways, such as soldering lead wires to germanium transistors; a property-modifying component of the intermetallic semiconductor used for germanium transistors; utilization of the magnetorestrictive and photodetective properties of indium arsenide and indium antimonide; and an injection laser using indium phosphide as a semiconductor.

A significant use of indium was in sleeve-type bearings to promote resistance to corrosion and wear. Indium was also used in solders, glass-sealing alloys, and dental alloys.

Prices.—Greater demand for indium, particularly for electronic uses, resulted in price advances of 15 cents and 20 cents per troy ounce, effective May 3 and October 5, respectively. The new quotes were \$2.75 per troy ounce for 30 to 90 troy ounces for stick shapes; in ingot shapes prices were \$2.30 per troy ounce for 100 ounce lots and \$2 per troy ounce for 10,000 and up lots.

Technology.—A patent was granted on a method of preparing high purity indium by dissolution in acid, removal of impurities, and recovery by electrolysis.[37]

Articles were published on the properties of indium containing alloys.[38] Patents were granted for solders containing indium as an important constituent.[39]

Research on the use of indium adhesion to measure surface cleanliness of metals was described.[40] Published papers describe the constitution diagrams, solid solution relationships, and other physical properties determined for indium and indium containing compounds and alloys.[41]

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[36] Prepared by Harold J. Schroeder.

[37] Beau, Raymond (assigned to Societe Anonyme les Produits Semi-Conducteurs, Paris, France). Process for the Manufacture of Indium of High Purity. U.S. Pat. 3,180,812, Apr. 27, 1965.

[38] Corderoy, D. J. H., and R. W. K. Honeycombe. The Deformation Behaviour of Age-Hardened Copper-Indium Alloys. J. Inst. Metals (London), v. 93, Pt. 12, August 1965, pp. 432–437.

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[39] Braun, Japanell D. (assigned to Monsanto Research Corp., St. Louis, Mo.). Sn–Pb–In–Zn Solders for Gold and Gold Alloys. U.S. Pat. 3,226,226, Dec. 28, 1965.

Grobin, Allen W., Jr. (assigned to International Business Machines Corp., New York). Superconductive Solder. U.S. Pat. 3,184,303, May 18, 1965.

[40] Krieger, G. L., and G. J. Wilson. Measuring Surface Cleanliness by Indium Adhesion. Mat. Res. and Standards, v. 5, No. 7, July 1965, pp. 341–348.

[41] Ellinger, F. H., C. C. Land, and K. A. Johnson. The Plutonium-Indium System. Trans. AIME, v. 233 (Met. Soc.), 1965, pp. 1252–1258.

Grierson, R., and R. N. Parkins. Yield Strength of Polycrystalline In_2Bi and $Mg_{17}Al_{12}$. Trans. AIME, v. 233 (Met. Soc.), 1965, pp. 1000–1004.

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Markovac, V., and B. Lovrecek. Studies of the Electrochemical Kinetics of Indium. J. Electrochem. Soc., v. 112, No. 5, May 1965, pp. 520–524.

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RADIUM [42]

No primary radium has been produced in this country for many years, but some secondary radium was reprocessed in 1965. Artificially produced radioisotopes have been substituted for radium in many uses, but radium continued to be important in radiotherapeutic applications. The placing of radium exports in a basket tariff classification expressed in value only added to the difficulty of obtaining information on international trade in radium compounds and radioisotopes.

Legislation and Government Regulations.—The U.S. Atomic Energy Commission (AEC) exercises no direct control over the possession and use of radium, which is a naturally occuring radio element. In 1965 at least 29 States, under radiological health programs, inspected radium users and either licensed or registered its possession and use. The Food and Drug Administration promulgated regulations under the Food, Drug, and Cosmetic Act which set forth conditions under which radioactive materials, such as radium 226, may be used safely in food handling and processing. A U.S.-European Radiation Protection Committee undertook a study of maximum activity limits for radium 226 and two other radioisotopes used in luminescent paints for timepiece dials.

Domestic Production.—The small demand for radium salts is met by primary radium shipped from Belgium or secondary radium reprocessed by one domestic company. Radium salts were distributed by Radium Chemical Co., Inc., New York, for the Belgian company, Union Minière du Haut-Katanga, which processed primary radium from Congolese ores. Canadian Radium & Uranium Division, Canrad Precision Industries, Inc., New York, maintained a small refinery for reclaiming secondary radium. United States Radium Corp., Morristown, N.J., was concerned primarily with luminescent radioisotopes but handled some radium. A. Bruce Edwards, Haverford, Pa., continued as the agent for Atomic Energy of Canada Ltd., which held radium stocks.

Consumption and Uses.—In most applications formerly reserved for radium salts, radioisotopes from nuclear reactors received increased attention despite the need to obtain a license for their use from the AEC or from the various States having such regulatory authority. Radium salts or radon, however, were still important in sealed radiation sources used for the therapeutic treatment of cancer. Other radioisotopes used in radiotherapy included cobalt 60, iridium 192, and cesium 137. If necessary, these isotopes can be prepared with a higher specific activity than radium. Cesium 137 recently has become popular because its half life (30 years) is more acceptable for clinical applications than cobalt 60 with a half life of 5.25 years. Cobalt 60, cesium 137, iridium 192, and thulium 170 were used in industrial radiography. In many cases, antimony 124, americium 241, plutonium 239, and polonium 210 were used as activators in small neutron sources which formerly were made mostly from radium-beryllium combinations. Beta-radiation emitters such as hydrogen 3 (tritium) and krypton 85 activated phosphors in self-luminous light sources which were superior to those containing radium, being more easily visible, less destructive to the phosphor, and less hazardous to use than the alpha-emitting radium. Alpha-radiation emitting americium and polonium were used in place of alpha- and gamma-emitting radium in devices designed to eliminate static electricity in manufacturing processes.

Prices.—During the year Steel, The Metalworking Weekly, ceased quoting prices of $16.00 to $21.50 per milligram for the content of primary radium in its salts, usually as sulfate and sometimes as the bromide. Small gram quantities of reprocessed, less pure material were said to be available at much lower prices.

Foreign Trade.—Imports of radium salts were from Belgium, 83 percent by weight and 84 percent by value; Canada, 15 percent by weight and 14 percent by value; and the United Kingdom, 2 percent by weight and 2 percent by value. Imports decreased 12 percent in quantity and 8 percent in value from those of 1964. Exports of radium, including radium compounds, radium sources, and radon (radium emanation), were recorded by value only under a new statistical classification which includes both stable isotopes and radioisotopes.

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[42] Prepared by John G. Parker.

Technology.—Biogeochemical halos of radium were used as the basis for prospecting for uranium deposits by radiometric methods. Both unburned and ashed plant samples were used in determining alpha activity, indicating the concentration; the accuracy of the technique was verified by uranometric survey, gamma-logging, and exploration drilling.[43]

Barite, synthetic zeolite, and clinoptilite (natural zeolite) were included in a number of inorganic ion-exchange materials used to absorb radium from simulated lime-neutralized uranium-mill waste solutions. The materials were satisfactory for thousands of bed volumes of aqueous feed passing through the ion-exchange column.[44] Sawdust containing amorphous manganese dioxide (MnO_2) sorbed radium quantitatively from solutions; finely ground pyrolusite with 63 percent MnO_2 also was used for this purpose.[45]

Excerpts of discussions at a September 1964 meeting on management of radium and radium substitutes for medical uses were published by the Public Health Service.[46] The need for tighter controls, periodic leak-testing of radium sources, and proper storage procedures was shown.[47] Types of radium sources, suggestions for initial and periodical testing for external contamination of the sources, and their custody and storage were discussed.[48] A new type safe designed principally for storage of radium needles was described.[49]

SCANDIUM [50]

Domestic Production.—Scandium metal and compounds were produced as a byproduct from uranium plant sludge and tungsten (wolframite) concentrates and from euxenite and thortveitite imported from Switzerland and Norway, respectively. Production was higher than in 1964, and sales were made in gram lots up to 10-pound lots. The principal producers or refiners of scandium were Atomergic Chemetals Co., Division of Gallard-Schlesinger Chemical Manufacturing Corp., Carle Place, Long Island, N.Y.; Electronic Space Products, Inc., Los Angeles, Calif.; King Products, Arlington, N.J.; Research Chemicals, Division of Nuclear Corporation of America, Phoenix, Ariz.; Semi-Elements, Inc., Saxonburg, Pa.; and United Minerals and Chemical Corp., New York, N.Y. Other firms that fabricated or reworked scandium material for resale included Dresser Products, Inc., Great Barrington, Mass.; and Semi-Alloys, Inc., Mount Vernon, N.Y.

Uses.—Scandium was used mainly for research work to find some general industrial applications. Studies continued on alloys of scandium with aluminum, tungsten, molybdenum, and titanium. Ultraviolet light on scandium doped with europium yields a bright red fluorescence while scandium doped with terbium gives a bright green. This property may find uses in color-television and cathode-ray tubes. Scandium products were used by various Government research facilities for several classified projects.

The stable isotope, Sc^{45}, the only one found in nature, will form Sc^{46} when irradiated in a nuclear reactor. Sc^{46}, with a half-life of 84.2 days, is highly radioactive, emitting both beta and gamma radiation. It was produced at the Oak Ridge National Laboratory of the AEC and was used for oil-well logging. The isotope, contained in small plastic spheres, is pumped with water into the perimeter wells

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[43] Makarov, M. S. Razrabotka metodiki i opyt primineniia biokhimicheskikh poiskov mestorozhdenii urana v odnom iz raionov Sovetskogo Soiuza [Biogeochemical Prospecting for Uranium Deposits in an Area of the U.S.S.R.]. Voprosy Rudnoi Geofiziki (Moscow, U.S.S.R.), v. 5, 1965, pp. 33–39.

[44] Arnold, W. D., and D. J. Crouse. Radium Removal From Uranium Mill Effluents With Inorganic Ion Exchangers. I&EC Process Design and Development, v. 4, No. 3, July 1965, pp. 333–337.

[45] Tiutrina, A. P., B. P. Zhagin, and V. G. Bakhurov. Udalenie radiia iz zhidkikh otkhodov sorbtsiei na dvuokisi margantsa [Separation of Radium From Liquid Wastes by Sorption on MnO_2]. Atomnaia Energiia (Moscow, U.S.S.R.), v. 18, No. 5, May 1965, pp. 487–491.

[46] Public Health Service. Division of Radiological Health. Medical Uses of Radium and Radium Substitutes. No. 999–RH–16, July 1965, 60 pp.

[47] Gerusky, Thomas M., Joel O. Lubenau, Robert Roskopf, and Jan Lieben. Survey of Radium Sources in Offices of Private Physicians. Public Health Reports, v. 80, No. 1, January 1965, pp. 75–78.

[48] Fields, Theodore. Problems in Handling Radium Accidents and Emergencies. Ch. 5 in Radiation Accidents and Emergencies in Medicine, Research, and Industry. Charles C. Thomas Publishers, Springfield, Ill., 1965, pp. 179–189.

[49] Webster, Edward W., Milford D. Schulz, and E. Theodore Agard. A Compact Radium Safe Employing Gas Sterilization. Am. J. Roentgenol., Radium Therapy Nuclear Medicine, v. 93, January 1965, pp. 183–189.

[50] Prepared by Charles T. Baroch.

of an oilfield. By probing with radiation detectors, permeable strata were located and sealed off where necessary.

Prices.—Scandium oxide, 99.9 percent, was quoted by Research Chemicals at $3.86 per gram in lots of 250 to 454 grams, about 16 percent less than in 1964. Lesser quantities were, per gram, $4.05 for 100 to 249 grams, $4.90 for 25 to 100 grams, and $5.70 for 2 to 24 grams. The company first introduced scandium foil and sheet ranging from 0.003 to 0.060 inch in thickness; prices varied from $18.00 to $70.50 per square inch, based on a theoretical weight of 0.0499 gram per square inch for each 0.001 inch thickness. Scandium metal prices were little changed from 1964.

Koch-Light Laboratories Ltd., Buckinghamshire, England, boosted the purity of its scandium oxide from 99.8 to 99.999 percent and priced it at $98 per 10 grams.[51]

Technology.—In a study of the hyperbasic massifs of the Ural Mountains, it was found that all the principal rock-forming minerals in pyroxenites are carriers of scandium, but the main concentrations were in diopside and hornblende. The Sc_2O_3 contents of the diopsides investigated ranged from 0.01 to 0.02 percent and of hornblende from 0.005 to 0.015 percent. The Sc_2O_3 content of olivine and magnetite was very low, below 0.001 percent. Various methods for extracting the scandium were tried, using acid, bisulfate, and caustic fusion for decomposing the pyroxenites. Caustic fusion at 500° to 600° C gave the best decomposition, and the hydroxide residue was filtered, washed free of alkali, and dissolved in 18 percent hydrochloric acid. Carbonate treatment of this solution produced a precipitate which, after roasting to oxide, contained 5.1 percent Sc_2O_3, and represented 81.2 percent recovery.[52]

Iron sludges produced in some uranium plants and wolframite concentrates are important potential sources of scandium. Laboratory-scale techniques were developed in which the scandium was solubilized in inorganic acid, sulfuric acid being the most economical. After reducing the iron to the ferrous state with sulfur dioxide, the scandium was extracted by solvent extraction using either the alkyl phosphates or the primary amine, JM–T, in kerosine solvent. The scandium-loaded solvent was easily stripped with hydrochloric acid solution, which then had to be purified by a combination of ion exchange, solvent extraction, and chemical precipitation to separate such impurities as uranium, iron, thorium, and titanium. From initial materials containing 0.058 and 0.14 percent scandium, a product analyzing from 99.6 to 99.9 Sc_2O_3 was prepared with extractions of 87 to 97 percent of the scandium.[53]

It is practically impossible to separate scandium by any single method. Residues from decomposition of wolframite concentrates containing 0.3 to 0.4 percent scandium and slags from tin smelting containing 0.05 to 0.6 percent Sc_2O_3, were leached with strong mineral acids, usually hydrochloric acid. The solution was extracted with freshly prepared alkyl hydrogen phosphate (0.85 molar) in kerosine, mixing the aqueous and organic phases for 2 to 5 minutes. The organic phase was washed several times with hydrochloric and sulfuric acid solutions to remove most of the impurity metals. The scandium was then reextracted (stripped) from the organic with concentrated hydrofluoric acid. A white precipitate of scandium fluoride formed which was contaminated with only small amounts of impurities, mainly thorium and iron in the case of the wolframite residues, and calcium, iron, titanium, and zirconium (less than 1 percent) in the case of the tin-smelting slags.[54]

Ion exchange equilibria between the cation exchange resin, Amberlite IR–120, and an aqueous solution containing a small concentration of scandium ions were measured.[55]

Several scandium alloys containing man-

[51] Chemical Week. New Chemicals. V. 96, No. 9, Feb. 27, 1965, p. 12.

[52] Komissarova, L. N., L. F. Borisenko, and V. M. Shatskii. Possibility of Isolating Scandium From Pyroxenite. J. Appl. Chem. of the U.S.S.R., (English transl. of Zhurnal Prikladnoi Khimii [Journal of Applied Chemistry]), v. 38, No. 2, February 1965, pp. 244–247.

[53] Ross, J. R., and C. H. Schack. Recovery of Scandium From Uranium Plant Iron Sludge and From Wolframite Concentrates. BuMines Rept. Inv. 6580, 1965, 22 pp.

[54] Navtanovich, M. L., A. S. Chernyak, and Yu. E. Sutyrin. The Selective Extraction of Scandium With Alkyl Hydrogen Phosphates. J. Appl. Chem. of the U.S.S.R., (English transl. of Zhurnal Prikladnoi Khimii [Journal of Applied Chemistry]), v. 38, No. 2, February 1965, pp. 341–344.

[55] Tateda, Akira. The Cation Exchange Investigation of Scandium Acetate and Sulfate Systems. Bull. Chem. Soc. Japan (Tokyo, Japan), v. 38, February 1965, pp. 165–171.

ganese, iron, cobalt, nickel, copper, and beryllium were investigated. It was found that scandium forms the same compounds as zirconium and hafnium, probably because of the close values of the atomic radii of these three metals.[56] Structure data on ScMg, ScAl, ScGa, $ScIn_3$, ScSi, and ScGe were tabulated.[57] The structural analysis was used to establish the existence of the ternary compounds ScCoAl and ScNiAl.[58]

Calorimetric data for the dissolution of Sc_2O_3 and $ScCl_3$ in hydrochloric acid solution were used to evaluate the standard heat of formation of crystalline $ScCl_3$.[59]

SELENIUM [60]

Production of selenium decreased 42 percent and shipments increased 28 percent. There was an increase in the use of selenium in manufacture of rectifiers.

Total Government-owned inventories on December 31 were 403,702 pounds, 85 percent of the objective. Inventories showed 97,100 pounds in the national strategic stockpile, none in the CCC stockpile, and 306,602 pounds in the supplemental stockpile.

Domestic Production.—Companies reporting selenium production, shipments, and stocks were American Metal Climax, Inc., Carteret, N.J.; American Smelting and Refining Company, Baltimore, Md.; International Smelting & Refining Co., Perth Amboy, N.J.; Kawecki Chemical Co., Boyertown, Pa.; and Kennecott Copper Corp., Magna, Utah. Kawecki Chemical is a manufacturing chemical company. The other four companies produced selenium as a byproduct of the electrolytic refining of copper.

Consumption and Uses.—Selenium was used in electronic applications, xerography, photoluminescent products, photoconductor cells, glass, rubber, alloy steel, as a catalyst in the processing of organic materials, and a small quantity was used as an agent in chromium-plating solutions to improve the quality of chromium plate.

The demand for ferroselenium was commensurate with shipments.

Stocks.—Stocks of selenium reached a record high at producers' plants in the first quarter of the year when they were reported to be 1,324,700 pounds. Stocks declined 23 percent during the remainder of the year.

Prices.—Selenium was quoted at $4.50 per pound for the commercial grade and

[56] Gladyshevskii, E. I., P. I. Kripyakevich, Yu. B. Kuzma, and V. S. Protasov. Binary Compounds of Scandium With Transition Metals and Beryllium. U.S. Dept. of Commerce, Clearinghouse for Federal Scientific and Technical Information, JPRS 28849, 1965, pp. 199–200 (English transl.).

[57] Parthe, D., D. Honke, W. Jeitschko, and O. Schob. Structure Data of New Intermetallic Compounds. Naturwissenschaften (Berlin, Germany), v. 52, No. 7, April 1965, p. 155 (in English).

[58] Teslyuk, M. Y., and V. S. Protasov. [Crystal Structure of Ternary Compounds ScCoAl and ScNiAl.] Dopovidi Akad. Nauk Ukr. RSR (Proceedings of the Academy of Sciences of the Ukrainian SSR), No. 5, 1965, p. 599 (in Ukrainian).

[59] Stuve, J.M. Heat of Formation of Scandium Trichloride. BuMines Rept. Inv. 6705, 1965, 5 pp.

[60] Prepared by Arnold M. Lansche.

Table 7.—Salient selenium statistics

(Thousand pounds of contained selenium)

	1956–60 (average)	1961	1962	1963	1964	1965
United States:						
Production [1]	837	1,022	999	928	929	540
Shipments to consumers	743	787	741	679	646	824
Imports for consumption	190	117	159	339	293	251
Consumption, apparent [2]	933	904	900	1,018	939	1,075
Stock, Dec. 31, producers	401	515	773	1,022	1,305	1,021
Price per pound, commercial grade	$7.60–$9.70	$5.75–$6.25	$5.75–$6.25	$4.50–$5.75	$4.50–$6.00	$4.50–$6.00
World: Production	1,726	2,097	2,095	2,033	2,100	1,740

[r] Revised.
[1] Includes small quantity of secondary selenium for 1956–61.
[2] Measured by shipments plus imports.

Table 8.—Free world production of selenium by countries
(Pounds)

Country	1961	1962	1963	1964	1965 p 1
Australia e	3,000	3,500	3,500	3,500	4,000
Belgium-Luxembourg (exports)	51,808	29,542	54,013	r 87,082	93,034
Canada	430,612	487,066	468,772	r 465,746	504,109
Finland	13,296	11,797	15,417	14,500	12,577
Japan	300,262	309,314	313,494	r 325,926	e 350,000
Mexico	5,642	6,953	6,336	r 9,345	e 9,000
Peru	16,305	18,382	19,790	16,797	18,964
Sweden	213,846	154,322	r 156,527	r 181,540	2 141,094
United States	1,022,000	999,000	928,000	929,000	540,000
Yugoslavia	1,872	3,986	4,120	8,439	e 7,000
Zambia (formerly Northern Rhodesia)	38,292	r 71,453	62,891	57,631	e 60,000
World total	r 2,097,000	r 2,095,000	r 2,033,000	r 2,100,000	1,740,000

e Estimate. p Preliminary. r Revised.
1 Compiled mostly from data available June 1966.
2 Exports.

$6 per pound for the high-purity grade. Ultra-high-purity selenium (99.999+ percent) sold for $13 to $20 per pound; on the basis of contained selenium, ferroselenium was quoted at $4.50 per pound on January 1 and on June 7 the price was increased to $5.

Foreign Trade.—Imports of selenium metal totaled 217,547 pounds; Canada supplied 190,979 pounds, West Germany 6,794 pounds, Japan 10,638 pounds, Peru 4,136 pounds, and the United Kingdom, 5,000 pounds. Imports of selenium dioxide came from Canada—8,369 pounds; West Germany—6,600 pounds; and the United Kingdom—100 pounds. Selenium salts and other selenium compounds imported from Canada totaled 17,691 pounds and from Japan 605 pounds.

World Review.—World production of selenium decreased 17 percent compared with 1964.

Technology.—Patents were issued on a process for recovering selenium from an ore containing uranium;[61] a method of depositing lead selenide from a bath of selenourea, lead acetate, and potassium triiodide;[62] and a process for producing crystalline selenium oxide and tellurium oxide from a material containing elemental sulfur, selenium, and tellurium.[63]

TELLURIUM [64]

The price of commercial grade tellurium was unchanged at $6 per pound for the 4th consecutive year.

Domestic Production.—The primary source of tellurium was as a byproduct of electrolytic copper refining and lead refining. A small quantity was recovered from scrap.

Companies that reported production, shipments, and stocks were American Metal Climax, Inc., Carteret, N.J.; American Smelting and Refining Company, Baltimore, Md.; International Smelting & Refining Co., Perth Amboy, N.J.; Penn Rare Metals, Inc., Revere, Pa.; Phelps Dodge Refining Corp., New York; and United States Smelting, Refining, and Mining Co., East Chicago, Ind. Kennecott Copper Corp. expects to begin producing commercial grade tellurium late in 1966 at a new plant under construction at the Utah Copper Division, Garfield, Utah.

Consumption and Uses.—Tellurium was used in the manufacture of free-machining steels, tellurium-copper alloys, ceramics, chemicals, thermoelectric devices, and in the rubber industry. Shipments of ferrotellurium were insignificant.

Stocks.—Stocks of tellurium at producers' plants increased 31 percent.

61 Hart, James L. (assigned to Phillips Petroleum Co., Bartlesville, Okla.). Flocculation of Selenium From a Basic Medium. U.S. Pat. 3,178,257, Apr. 13, 1965.
62 Johnson, Thomas H. (assigned to Santa Barbara Research Center, Goleta, Calif.). Solutions and Methods for Depositing Lead Selenide. U.S. Pat. 3,178,312, Apr. 13, 1965.
63 Yanagase, Kenjiro (not assigned), 2150 Mukoyama, Fukumamachi, Munakatagun, Fukuoka-ken, Japan. Production of Selenium Oxide, Tellurium Oxide or Mixture Thereof. U.S. Pat. 3,179,497, Apr. 20, 1965.
64 Prepared by Arnold M. Lansche.

Table 9.—Salient tellurium statistics

(Thousand pounds of contained tellurium)

	1956–60 (average)	1961	1962	1963	1964	1965
United States:						
Production, primary and secondary	209	205	264	201	145	195
Shipments to consumers	216	231	233	134	122	146
Stocks, Dec. 31, producers	121	64	87	141	162	212
Imports	8	NA	NA	2	6	18
Price per pound, commercial grade	$1.86–$2.45	$4.00–$5.25	$6.00	$6.00	$6.00	$6.00
World: Production	269	375	396	318	277	337

r Revised. NA Not available.

Prices. — Commercial-grade tellurium (99.7 percent) was quoted at $6 per pound for the entire year. The following prices were in effect during the year: For 99.99 percent grade, $11 to $15 per pound and for 99.999 percent grade, $21 to $30 per pound, depending on quantity. The price of ferrotellurium was $4 to $5 per pound of material.

Foreign Trade.—Imports for consumption of tellurium unwrought metal, waste, and scrap totaled 18,127 pounds, valued at $113,788. Canada supplied 13,875 pounds ($92,224); Peru, 4,200 pounds ($20,550); and the United Kingdom, 52 pounds ($1,014).

World Review.—World production of tellurium was 22 percent more than in 1964.

Table 10.—Free world production of tellurium by countries

(Pounds)

Country	1961	1962	1963	1964	1965 p 1
Canada	77,609	58,725	76,842	r 77,782	86,264
Japan	16,486	23,168	13,256	7,573	20,126
Peru	76,279	50,472	26,634	46,757	36,045
United States	205,000	264,000	201,000	145,000	195,000
Free world total 1	375,400	396,400	317,700	r 277,100	337,400

p Preliminary. r Revised.
1 Compiled mostly from data available June 1966.

Technology.—A phase study of the Nb-Se, Nb-Te, Ta-Se, and Ta-Te systems was reported.[65] These dichalcogenides are of interest to thermoelectricity, superconductivity, and lubrication.

A radiochemical method was developed for the determination of trace quantities of tellurium in nickel alloys.[66] The paper describes the sample irradiation process, separation of the radiochemicals produced, and quantitative measurement of the radioactivity of tellurium precipitated as tellurium dioxide.

A new species of mineral containing selenium, tellurium, and nickel was discovered in Finland.[67] The mineral, named kitkaite, has the chemical formula NiTeSe and is composed of about 30 percent selenium, 48 percent tellurium, and 22 percent nickel.

Equilibrium phase relations in the mineralogically important gold-silver-tellurium system were determined at 290° C, 335°

65 Revolinsky, E., B. E. Brown, D. J. Beerntsen, and C. H. Armitage. The Selenide and Telluride Systems of Niobium and Tantalum. J. Less-Common Metals (Amsterdam, Netherlands), v. 8, No. 1, January 1965, pp. 63–72.

66 Morris, D. F. C., and N. Hill. Radiochemical Methods for the Determination of Trace Elements in Nickel Alloys. Pt. 1, Determination of Tellurium. Metallurgia, v. 71, No. 424, February 1965, pp. 99–102.

67 Hakli, T. A., Y. Vuorelainen, and Th. G. Sahama. Kitkaite (NiTeSe), a New Mineral From Kuusamo, Northeast Finland. Am. Miner., v. 50, Nos. 5 and 6, May–June 1965, pp. 581–586.

C, and 356° C, and alterations in the assemblages were studied from about 50° C to about 800° C.[68]

CdTe and ZnTe melts were studied with special attention directed toward their electrical conductivity and viscosity.[69]

THALLIUM[70]

Domestic Production.—American Smelting and Refining Company, at its Denver, Colo., plant, was the only domestic producer of thallium and thallium sulfate.

Uses.—The largest use of thallium was as the sulfate, a poisonous rodenticide and insecticide. Thallium has a significant use in electronics, such as for thallium-activated sodium iodide crystals in photomultiplier tubes. Other uses of thallium were in low-melting alloys, in optical glass, and in glass seals for the protection of electronic components.

A significant development concerning thallium was the action taken, effective August 1, by the U.S. Department of Agriculture, under authority of the Federal Insecticide, Fungicide, and Pesticide Act, in prohibiting the private use of thallium products in control of insect and rodent pests. The ruling, published July 3 in the Federal Register, permits the use of these products only by qualified personnel in Federal, State, or local governments.

Price.—The price of thallium metal was $7.50 per pound.

Technology.—The heat of formation for $TlBi_2$ was included in reported research.[71]

Patents were granted for the use of thallium as an activator or catalyst for certain photoconductive processes.[72] In another patent, a thallium compound was employed as a catalyst for producing spinnable polyesters.[73]

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[68] Cabri, Louis F. Phase Relations in the Au–Ag–Te System and Their Mineralogical Significance. Econ. Geol. and the Bull. of the Soc. of Econ. Geol., v. 60, No. 8, December 1965, pp. 1569–1606.

[69] Glazov, V. M., and S. N. Chizhevskaya. Study of the Physico-Chemical Properties of Zinc and Cadmium Telluride Melts. Dokl. Akad. Nauk. S.S.S.R. [Proceedings of the Academy of Sciences of the U.S.S.R.], v. 154, No. 1, 1964, pp. 193–196. Met. Abs. (London), v. 32, No. 5, 1965, p. 420.

[70] Prepared by Harold J. Schroeder.

[71] Robinson, P. M., and M. B. Bever. The Heats of Formation of the Intermetallic Compounds in InBi, In_2Bi, and $TlBi_2$. Trans. AIME, v. 233 (Met. Soc.), 1965, pp. 1908–1909.

[72] Mueller, Fritz W. H., and Curt B. Roth (assigned to General Aniline & Film Corp., New York). Photopolymerization of Vinyl Monomers by Means of Thallium Compounds as Catalysts. U.S. Pat. 3,201,255, Aug. 17, 1965.

Wachtel, Anselm (assigned to Westinghouse Electric Corp., East Pittsburgh, Pa.). Thallium-Activated Zinc Sulfide Phosphor. U.S. Pat. 3,210,290, Oct. 5, 1965.

[73] Advani, Ram. (assigned to Firma Hans J. Zimmer Verfahrenstechnik, Frankfurt am Main, West Germany). Preparation of Spinnable Polyesters Using Thallium Catalysts. U.S. Pat. 3,220,982, Nov. 30, 1965.

Minor Nonmetals

By Staff, Division of Minerals

CONTENTS

GREENSAND [1]

Domestic production of greensand (glauconite) increased 15 percent in quantity and 13 percent in value compared with that of 1964. Since only two firms were in operation, statistics on production and sales for the year are not reported in order to avoid disclosure of individual company confidental data. The average annual production for the 5-year period 1961–65 was 4,306 tons valued at $200,200. The material was marketed for use as a soil conditioner and a water softener.

An article of mineralogical interest was published concerning the New Zealand glauconites.[2]

MEERSCHAUM [3]

Since the meerschaum pipe industry began over 200 years ago, the nearly singular use of meerschaum has been for the manufacture of smokers' articles, such as pipes and cigar and cigarette holders. Consumers of meerschaum (the mineral sepiolite) in the United States continued to rely on imports for all their raw material in 1965. There has been no reported domestic production since 1914.

Meerschaum imports for consumption in 1965 totaled 39,407 pounds valued at $27,695. These figures represent an increase of 35 percent in quantity but a decrease of 25 percent in value compared to 1964 totals. The principal supplier was Turkey with 93 percent; the Somali Republic, 5 percent, and France, 2 percent, provided the rest.

Additional quantities of meerschaum were imported as finished articles, mainly smoking pipes. Statistics on finished meerschaum products are not compiled by the Bureau of Mines.

Rich meerschaum deposits near Eskisehir, Turkey, have been the primary source of the world's supply of this material since the middle of the nineteenth century. During the past 10 years, however, deposits in France, Somali Republic, and Tanzania have been developed. Production from Tanzania-Kenya exceeded that of Turkey in 1957. The meerschaum mined from deposits near El Bur in the Mudugh region of the Somali Republic was previously consumed locally, but some of this material entered the world market in 1965.

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[1] Prepared by Richard W. Lewis.

[2] Seed, D. P. The Formation of Vermicular Pellets in New Zealand Glauconites. Amer. Miner. v. 50, Nos. 7 and 8, July–August 1965, pp. 1097–1106.

[3] Prepared by R. C. Briggs.

QUARTZ CRYSTAL

ELECTRONIC-GRADE [4]

Raw quartz crystal consumption decreased 8 percent from last year although the consumption of manufactured quartz increased substantially. Finished crystal unit production decreased very slightly.

Domestic Production.—No domestic production of natural electronic-grade quartz was reported in 1965. At yearend production of manufactured quartz for electronic use was reported by six companies: American Hydrothermal, Inc., Groton, Mass.; P. R. Hoffman Co., Carlisle, Pa.; Sawyer Research Products, Inc., Eastlake, Ohio; Thermal-Kinetic Corp., Tuscon, Ariz.; Transcom Electronics, Inc., Newport, R. I., and Western Electric Co., Inc., North Andover, Mass. Sawyer Research Products, Inc., reported sales of about 50,000 pounds of manufactured quartz. The Western Electric Co. continued to produce quartz for its own use and the use of its affiliated companies.

Consumption and Uses.—Raw quartz crystal consumption for the production of piezoelectric units decreased almost 29,000 pounds from the previous year. Manufactured quartz crystal continued its steady increase, and 50,647 pounds were consumed, an increase of almost 45 percent over that of 1964. Almost 18 million finished quartz crystal units were produced from the 315,000 pounds of raw quartz crystal consumed during the year. The yield of finished quartz crystal from manufactured quartz is at least three times greater than the yield from natural quartz crystal.

The Bureau of Mines received reports in 1965 from 40 crystal cutters, representing 41 consumers in 16 states. Finished piezoelectric units were produced by 38 of the consumers; the others produced only semifinished blanks. Twenty consumers in six States used 90 percent of the total raw quartz crystal consumption. Pennsylvania retained its position as the leading consumer with 49 percent of the total consumption. Massachusetts, Illinois, Missouri, and Kansas followed in the order listed.

Sixty producers, in 20 States, fabricated piezoelectric units. Of these, 23 worked from partially processed quartz crystal blanks and did not consume raw quartz crystal. Forty-five plants in nine States supplied 87 percent of the total output of finished crystal units. Production consisted of 82 percent oscillator plates, and the remainder consisted of filter plates, telephone resonator plates, transducer crystals, and miscellaneous items. Filter plate production rose slightly. Resonator plate production remained essentially unchanged.

Prices.—The price patterns of electronic-grade quartz crystal and lasca remained unchanged from those of previous years.

Foreign Trade.—Imports of electronic and optical-grade quartz crystal valued in excess of $0.50 per pound reached 323,530 pounds valued at $913,081, an increase of 22 percent in quantity and 72 percent in value. The average value was $2.82 per pound. Brazil continued its position as

[4] Prepared by Benjamin Petkof.

Table 1.—Salient electronic- and optical-grade quartz crystal statistics

	1956–60 (average)	1961	1962	1963	1964	1965
Imports of electronic- and optical-grade quartz crystal [1]..thousand pounds	454	854	325	282	r 264	324
Value..thousands	$655	$762	$731	$447	r $532	$913
Consumption of raw electronic-grade quartz crystal [2]..thousand pounds	188	216	291	325	344	315
Production, piezoelectric units, number [3]..thousands	6,444	9,822	11,787	13,614	17,920	17,832

r Revised.
[1] Imports through 1963 are mostly Brazilian pebble valued at $0.35 or more per pound; 1964–65—$0.50 per pound.
[2] For 1956 and subsequent years, data include some reworked scrap quartz crystal.
[3] For 1957–65 includes finished crystal units produced from reprocessed blanks, from raw quartz previously reported as consumption; and from imported blanks; 1957–62 and 1964–65.

the world's major producer and provided almost 96 percent of U.S. imports. The remainder came from Argentina, Japan, Canada, and the United Kingdom. Quartz crystal imports valued at less than $0.50 per pound totaled 858,223 pounds valued at $170,258. Most of the material came from Brazil. This material, which is generally known as lasca, was used for the manufacture of fused quartz and as feed material for the production of manufactured quartz crystal.

Exports of raw quartz, both natural and manufactured, reached 106,701 pounds and was valued at $968,907. About 93 percent of all exports went to Japan, Canada, United Kingdom, Sweden, France, West Germany, Yugoslavia, and Israel.

World Review.—*Brazil.*—In March quartz crystal was discovered at Crystalina, Goiás State, south of Brasilia. The area had been previously known to have quartz crystal deposits and was worked during World War II. News of the find attracted many people to the area for both mining and supplying goods and services to the influx of people.

Technology.—Acoustical and growth properties of rapidly grown manufactured quartz can be affected by chemical additives. Lithium salts increased the "Q" (the reciprocal of the damping factor in elastic vibration) of the manufactured material. Doping growing crystals with lithium has permitted acceptable quartz crystals to be grown more rapidly.[5]

The strength of manufactured quartz crystal decreases when the crystal is raised to high temperatures. Plastic deformation can be produced without causing fracture because the contained water has hydrolyzed the silicon-oxygen bonds. The silanol groups formed become mobile by increasing the temperature to 400° C and align themselves in dislocation under the influence of a small applied shear stress.[6]

STAUROLITE [7]

Staurolite, a complex silicate of iron and aluminum that finds application as sand blast abrasive and as an ingredient in some portland cement formulations, was produced in 1965 only in Florida. The Highland and Trail Ridge plants of E. I. du Pont de Nemours & Co., Inc., separating ilmenite from Clay County sand, recovered staurolite as one of the byproducts. Staurolite sold for abrasives in 1965 was 54 percent less in tonnage and 53 percent less in value than the quantity sold for the same purpose in 1964.

STRONTIUM [8]

For the sixth consecutive year there was no reported domestic production of strontium minerals. Imports for consumption of strontium minerals dropped sharply compared with 1964 totals. The United Kingdom and Mexico continued as the leading foreign suppliers of celestite, although imports from Spain were reported for the first time since 1949. There were no significant new uses for strontium or strontium compounds reported during 1965.

Legislation and Government Programs.—The General Services Administration (GSA) again offered for sale about 12,500 short tons of nonstockpile-grade celestite through bids opened on April 29, 1965. This ore, with a $SrSO_4$ content of about 93 percent, was offered on an "as is" basis from the GSA warehouse in Point Pleasant, W. Va. Most of the material (9,632 tons) came from Spain and the remainder from Mexico. No acceptable bids were received.

Domestic Production.—No domestic production of strontium minerals was reported in 1965. This marks the sixth consecutive year that all strontium minerals needed to meet U.S. requirements came from foreign sources. Celestite was the principal strontium mineral imported. Companies importing celestite and converting it to various strontium compounds included E. I. du Pont de Nemours & Co., Inc., Grasselli, N.J.; Foote Mineral Co., Exton, Pa.; and FMC Corp., Modesto, Calif.

King Laboratories, Inc., Syracuse, N.Y., continued as the only domestic producer

[5] Ballman, Albert A., and David W. Rudd. The Growth of Cultured Quartz. Western Elec. Eng., v. 9, No. 1, January 1965, pp. 3–7.

[6] Griggs, D. T., and J. D. Blacic. Quartz: Anomalous Weakness of Synthetic Crystals. Science, v. 147, No. 3655, Jan. 15, 1965, pp. 292–295.

[7] Prepared by J. Robert Wells.

[8] Prepared by R. C. Briggs.

Table 2.—U.S. imports for consumption of strontium minerals,[1] by countries

Country	1964		1965	
	Short tons	Value	Short tons	Value
Italy	16	$4,200	6	$1,425
Mexico	5,278	66,824	3,224	44,105
Spain	-----	-----	1,629	35,472
United Kingdom	16,323	435,474	4,882	140,125
Total	21,617	506,498	9,741	221,127

[1] Strontianite or mineral strontium carbonate and celestite or mineral strontium sulfate.

of strontium metal. They produced only a minor quantity and consumed most of it themselves.

Consumption and Uses.—The largest quantities of strontium are consumed as compounds. Strontium carbonate and strontium nitrate are the principal compounds manufactured from imported celestite and sold by producers. The ability of strontium to impart a brilliant crimson color to a flame is the reason its salts are used primarily in pyrotechnics, flares, and fireworks. Strontium salts were also used in ceramics, greases, medicines, plastics, and zinc refining.

Strontium metal was used largely in getter alloys to remove traces of gas from vacuum tubes and as a scavenger in metallurgy.

Prices.—Prices of various strontium compounds, as quoted throughout the year in Oil, Paint and Drug Reporter, have remained unchanged since 1955 and were the same as those quoted in previous Minerals Yearbooks.

Foreign Trade.—The quantity of strontium minerals imported during 1965 was considerably less than the comparable 1964 figure. Total value of strontium imports dropped in proportion to quantity because the average unit value was nearly the same. Although the United Kingdom continued as the principal foreign supplier, quantity and value of celestite imports from that country declined 70 and 68 percent, respectively, from those of the previous year. Imports of celestite from Spain were reported for the first time since 1949. Italy supplied the only imported strontium carbonate. Other strontium compounds imported included 5,000 pounds of strontium nitrate and 2,426 pounds of organic strontium salts all from West Germany.

World Review.—Estimated free world production of strontium minerals during 1965 was considerably less than that of 1964. The United Kingdom was once again the free world's principal producer with Mexico a close second. The United States continued as the leading consumer of strontium minerals while the small requirements of most other countries were satisfied by importation of prepared strontium compounds and products.

Technology.—Most of the reported technological advances centered around uses of strontium and strontium compounds rather than the mining or processing of strontium minerals. A method of handling strontium 90 was described in a newly issued patent. The method involves mixing a strontium 90 compound, selected from the group of strontium 90 oxide and strontium 90 carbonate, with lithium fluoride and melting the mixture. Above a melting temperature of 800° C the components react. The reaction product is cooled and dissolved in mineral acid.[9]

Another patent was granted for a process to purify strontium solutions by ion exchange. By this process the strontium values can be extracted from a solution that also contains lanthanide rare-earth metal values, calcium, sodium, cesium, iron, lead, ruthenium, zirconium, and niobium values. After adjusting the pH of the solution to a value between 3.5 and 5, a weak-acid complexing agent added to the solution forms complexes with all metal values except calcium and strontium. The solution is then passed over a cation exchange resin which absorbs the calcium and strontium while the complexed metal values remain in solution. Calcium and

[9] Amos, Lawrence C. (assigned to the U.S. Atomic Energy Commission). Strontium Composition and Process of Making It. U.S. Pat. 3,165,475, Jan. 12, 1965.

strontium values are recovered from the resin.[10]

The first generator in Britain powered by a radio isotope was developed by the United Kingdom Atomic Energy Authority using strontium 90 as the power source. It is reported that small power sources of this type can last for 10 years or more without refueling and require little maintenance.[11]

WOLLASTONITE [12]

Sales of wollastonite in 1965, mostly for the manufacture of ceramics, especially wall tile, floor tile, and glazes, were 2 percent less than in 1964. Although a new producer, American Non-Metallics, Inc., of Sherman Oaks, Calif., reported sale of a minor quantity of wollastonite to tile makers, virtually the entire domestic supply of this material suitable for ceramics use came from the Willsboro mine of Cabot Minerals Division of Cabot Corp. in Essex County, N.Y. Also in New York, a small quantity of wollastonite was mined by Adirondack Development Corp. for experimental use. Other domestic production was limited to that of a finer-grained material quarried by two companies in California for building stone.

Prices quoted for wollastonite in Oil, Paint and Drug Reporter without change from October 1960 through December 1965 were as follows: Fine, paint-grade, bags, carlots, works, $41 per ton; less than carlots, ex warehouse, $51 per ton; medium, paint-grade, bags, carlots, works, $29 per ton; less than carlots, ex warehouse, $39 per ton.

Technology.—A journal article listing advantages from addition of wollastonite to ceramic body mixtures stated that "For both the whitewares and the wall tile producer . . . a pure grade of wollastonite is an essential ingredient if rapid firing is to be successful." In this same connection the author cited production of high-strength unglazed biscuit tile with only 17 minutes of firing time.[13] The third Cabot-Ferro Seminar, held at Lake Placid, N.Y., dealt especially with kilns designed for rapid firing of wollastonite-containing tile mixtures.[14] A description was published of a Mexican establishment that currently turns out about 200,000 floor and wall tile per day. The operating company, whose formulations combine wollastonite mined in Mexico with clay and talc imported from the United States, plans soon to double its present plant capacity and to install a fast-firing kiln system.[15]

Wollastonite was an ingredient in two special paint formulations covered by recent patents.[16] A Canadian patent was given for a nonshrinking and nonhardening bituminous adhesive mixture of which wollastonite is an essential component.[17] Also patented in 1965 was an application of wollastonite in the forming of cores for aluminum alloy casting.[18]

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[10] Wheelwright, E. J., J. A. Bray, F. P. Roberts, and R. L. Moore (assigned to the U.S. Atomic Energy Commission). Purification of Strontium Solutions by Ion Exchange. U.S. Pat. 3,173,757, Mar. 16, 1965.

[11] Metal Bulletin (London). Bismuth Telluride Potential. No. 4997, May 14, 1965, p. 26.

[12] Prepared by J. Robert Wells.

[13] Carpenter, Scott. Wollastonite, Yes, No, or Maybe! Ceramic News, v. 14, No. 4, April 1965, pp. 8–9.

[14] Svec, J. J. Why the Tile Industry is Going to Fast Firing. Ceramic Industry, v. 85, No. 2, August 1965, pp. 56–58, 72–73.

[15] Svec, J. J. Ladrillera Monterrey Produces 5½ Million Tile per Month. Ceramic Industry, v. 85, No. 6, December 1965, pp. 85, 95.

[16] Vukasovich, M. S., H. L. Johns, and E. Wainer (assigned to Horizons, Inc., Cleveland, Ohio). Coating Composition. U.S. Pat. 3,167,-439, Jan. 26, 1965.

Vugasovich, M. S., H. L. Johns, and E. Wainer (assigned to Horizons, Inc., Cleveland, Ohio.) Coating Composition. U.S. Pat. 3,179,527, Apr. 20, 1965.

[17] Morrow, F. C., and L. F. Bramble (assigned to Gulf States Asphalt Co., Inc.). Canadian Pat. 710,228, May 25, 1965.

[18] Ingles, T. A. (assigned to Doulton & Co., Ltd.). British Pat. 1,005,136, Sept. 22, 1965.

INDEX

The index consists of two parts: A commodity index and a company index. Because nearly all commodity chapters in Minerals Yearbook, volume I, follow a standard outline (Introductory Summary, Domestic Production, Consumption and Uses, Stocks, Prices (and specifications), Foreign Trade, World Review, World Reserves, and Technology), references to such data have been omitted under the various headings.

Readers seeking information on mine production for States, Territories, or possessions should refer to tables in the Statistical Summary chapter, starting on page 95. These tables show the commodities produced in each area, thus guiding the reader to the appropriate commodity chapters. For complete area information, however, the reader should refer to volume III.

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