Minerals yearbook: Metals and minerals 1977. Year 1977, Volume 1 1977

Bureau of Mines
Washington, D. C.: Bureau of Mines : United States Government Printing Office, 1977

https://digital.library.wisc.edu/1711.dl/PPYAWXJZXOESO8L

Minerals Yearbook

1977

Volume I

METALS AND MINERALS

Prepared by staff of the

BUREAU OF MINES

UNITED STATES DEPARTMENT OF THE INTERIOR • Cecil D. Andrus, Secretary

BUREAU OF MINES

As the Nation's principal conservation agency, the Department of the Interior has basic responsibilities to protect and conserve our land and water, energy and minerals, fish and wildlife, and park and recreation areas, and for the wise use of all those resources. The Department also has a major responsibility for American Indian reservation communities and for the people who live in Island Territories under U.S. administration.

U.S. GOVERNMENT PRINTING OFFICE

WASHINGTON : 1980

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402

Foreword

The Federal Government, through the Minerals Yearbook and its predecessor volumes, has reported annually on mineral industry activities for 96 years. This edition discusses the performance of the worldwide mineral industry during 1977. In addition to statistical data, the volumes provide background information to assist in interpreting the year's developments. Content of the individual volumes follows:

Volume I, Metals and Minerals, contains chapters on virtually all metallic and nonmetallic mineral commodities important to the domestic economy. In addition, it includes a general review chapter on the mineral industries, a chapter on mining and quarrying trends, and a statistical summary.

Volume II, Area Reports: Domestic, contains chapters on the mineral industry of each of the 50 States, the U.S. island possessions in the Pacific Ocean and the Caribbean Sea, and the Commonwealth of Puerto Rico. This volume also has a statistical summary, identical to that in Volume I.

Volume III, Area Reports: International, contains the latest available mineral data on more than 130 foreign countries and discusses the importance of minerals to the economies of these nations. A separate chapter reviews the international minerals industry in general and its relationship to the world economy.

The Bureau of Mines continually strives to improve the value of its publications to its users. Therefore, the constructive comments and suggestions of readers of the Yearbook will be welcomed.

Director

Acknowledgments

Volume I, Metals and Minerals, of the Minerals Yearbook presents data on more than 90 nonfuel mineral commodities that were obtained as a result of the mineral information gathering activities of the Bureau of Mines.

The collection, compilation, and analysis of data on the domestic minerals industries were performed by the staffs of the Sections of Ferrous Metals, Nonferrous Metals, and Nonmetallic Minerals, Division of Production/Consumption Data Collection and Interpretation and the Branch of Economic Analysis, Division of Analytic Studies. Statistical data were compiled from information supplied by mineral producers, processors, and users in response to production and consumption canvasses, and their voluntary response is gratefully appreciated. The information obtained from individual firms by means of confidential surveys has been grouped to provide statistical aggregates. Data on individual firms are presented only if available from published or other nonconfidential sources or when permission of the companies has been granted. Other material appearing in this volume was obtained from the trade and technical press, industry contacts, and numerous other sources.

Statistics on U.S. imports and exports, world production, and foreign country trade were compiled in the Branch of Foreign Data. U.S. foreign trade data were obtained from reports of the Bureau of the Census, U.S. Department of Commerce. World production and international trade data came from numerous sources, including reports from the Foreign Service, U.S. Department of State.

The Branch of Publication Support Services, Division of Publication provided general guidance on the preparation and coordination of the chapters in this volume and reviewed the manuscripts to insure statistical consistency among the tables, figures, and text, between this volume and other volumes, and between this edition and those of former years.

Acknowledgment is also particularly made of the splendid cooperation of the business press, trade associations, scientific journals, international organizations, and other Federal agencies that supplied information.

The Bureau of Mines has been assisted in collecting mine production data and supporting information by numerous cooperating State agencies. These organizations are listed in the acknowledgments to Volume II.

Albert E. Schreck, *Editor-in-Chief*

Contents

Review of the Mineral Industries

By Barry W. Klein,[1] Steven C. Greene,[1] and Kenneth P. Hanks[1]

The performance of the U.S. economy in 1977 was similar to that in 1976 which, in turn, had been a considerable improvement over 1974-75. In 1977 real gross national product (GNP) showed a similar, but somewhat slower, growth pattern compared with 1976. Real GNP increased sharply in the first quarter of the year followed by smaller increases for the remaining three quarters. With only two exceptions, the monthly unemployment rate declined or remained steady throughout 1977, falling to a low for the year in December. The inflation rate in 1977 was slightly higher than in 1976, but the rate still remained far below that of 1974-75.

Total U.S. output as measured by GNP in current dollars rose 10.8% in 1977. Real GNP in constant 1972 dollars increased 4.9%, and inflation, as measured by the implicit price deflator, rose 5.6%. In real terms, gross private domestic investment for residential structures increased 19.3% in 1977, only slightly below the 22.9% rise in 1976; State and local government expenditures increased 1.1% in 1977; and personal consumption expenditures for services rose 4.5%.

The unemployment rate continued to decline for the second straight year, falling to 7% in 1977 compared with 7.7% in 1976. The unemployment rate, except for February and August, declined or remained steady throughout the year. Therefore, the drop in the unemployment rate during 1977 was more than the 7% yearly average might otherwise indicate because the December rate of 6.4% was the low for the year.

The Consumer Price Index (CPI) rose 6.5% in 1977, slightly above the 5.8% increase in 1976. Food prices rose 6.3% in 1977, (about double the growth in 1976). Prices of all nonfood commodities increased 5.4%. The Wholesale Price Index rose 6.1% in 1977 compared with 4.6% in 1976. Farm products and processed foods and feed increased 3.1% (farm products alone increased 0.7%) and industrial commodities rose 7%. As previously stated, in 1977 the implicit price deflator increased 5.6%.

In 1977, as in recent years, the Federal Reserve Board (FRB) followed a monetary policy with the objective of promoting financial conditions that would further economic growth. In carrying out this policy, the FRB tried to avoid excessive expansion of money and credit that would tend to increase inflationary pressures. The money supply M1, defined as currency plus demand deposits, rose 8.0% in 1977, up from 6.2% in 1976. M2, defined as M1 plus time and savings deposits, grew 9.3% in 1977, down from 11.4% in 1976.

Fiscal policy in 1977 was intended to increase the growth in real output through additional Federal spending and tax cuts, thereby resulting in reduced unemployment. Owing to the time lag before the fiscal policy of the new Administration was implemented, the new measures had no effect until the beginning of the summer. Thus for the first quarter of 1977, fiscal policy was contractive because of slow growth in Federal spending coupled with a sharp increase in revenues. Fiscal policy was more expansive for the balance of the year, however, as expenditures returned to their usual growth levels and the stimulative measures started taking effect. The stimulus package enacted included approval of public works, public service employment, and other employment and training programs as well as passage of the Tax Reduction and Simplification Act of 1977 in late May, one provision of which was an increase in the personal standard deduction.

U.S. imports exceeded exports by $26.5 billion in 1977. Exports of manufactured goods were $3.6 billion higher than imports of manufactures. The trade balance deficit was largely attributable to $44.4 billion worth of petroleum imports. The value of crude nonfuel mineral imports was $3.0 billion and that of exports was $1.1 billion.

In 1977, the Federal Government continued some activities and initiated others that affected the mineral sector. The Government continued in its efforts to control inflation. Mineral-related legislation enacted in 1977 was in areas such as public lands, the environment, water resources, taxation, health and safety, and import duties.

The research program of the Bureau of Mines in 1977 was designed to promote the effective utilization of our mineral resources, insuring adequate mineral supplies without objectionable environmental, social, and economic effects. In August 1977, the Department of Energy (DOE) was established and the Bureau functions of coal production technology, fuel data collection and analysis, and coal preparation research were transferred to DOE effective October 1, 1977.

The mining industry in 1977 continued to face relatively high inflation coupled with rising operating costs. Metal mining firms, in addition, had to contend with labor and market problems. The value of metal production declined in 1977, largely as a result of strike activity in both the copper and iron ore industries and depressed copper prices for much of the year.

The world economy showed little growth in real GNP after the first quarter of 1977. Progress was made in controlling inflation, but rates remained high by historical standards. In many countries, unemployment rates were higher than they had been at the trough of the 1974-75 recession.

SOURCES AND USES

ALL MINERALS

Production.—In 1977 the production of domestic raw minerals, excluding fuels, rose almost 5% in value compared with 1976, to $17.5 billion. The production value of metals declined 4.5% to $5.8 billion, but this was more than offset by a 10.2% rise in nonmetals to $11.7 billion. In constant 1967 dollars, the value of total raw nonfuel mineral output increased less than 1% to $8.6 billion, metals declined 8.9%, and nonmetals rose 5.8%. Returning to a current dollar basis, crude nonfuel mineral exports increased 10.2% to $1.1 billion, and raw nonfuel mineral imports rose 4.3% to $3.0 billion.

The Bureau of Mines indexes of physical volume of nonfuel mineral production (1967=100) were mixed in 1977 compared with 1976. The overall index rose 0.7% to 115.8 index points in 1977. The index for the average of all metals declined 9% and the index for the average of all nonmetallic minerals rose 5.8%. Within the metals group, the ferrous metals index dropped 21%, the largest decline of any production index, and the index for all nonferrous metals declined 2.7%. The base metal index decreased 6.0%, the index for monetary metals rose 8.7%, and the other nonferrous metals index increased 11.8%. As components of the nonmetals sector, the construction index rose 6.1%, the index for chemicals increased 5.2%, and the index for other nonmetals rose 3.0%.

The FRB index of industrial production (1967=100) was 137.1 points for all industries in 1977, an increase of 5.6% compared with 1976. The average index for all mining rose 3.2% to 117.8 index points. The metal mining index declined significantly, by 14.2% to 105.4 index points. The stone and earth minerals index rose 5.6% to 124.9 points. The average index for crude oil and natural gas extraction increased 5.4% to 118 index points and the bituminous coal production index rose 0.8%, reaching 120.8 index points.

The FRB production index for all mining by month was 112.8 index points in January. The all mining index vacillated during most of 1977, reaching a high of 122.8 points in June and finishing in December at 113.4 points, only a little above where it had started the year. The coal index was 95.3 points in January and, despite a few intermediate declines, reached a high of 141.4 points in October. It decreased only slightly to 140.6 points in November, but then fell sharply to 74.6 points in December, reflecting the United Mine Workers coal strike. The oil and gas extraction index was

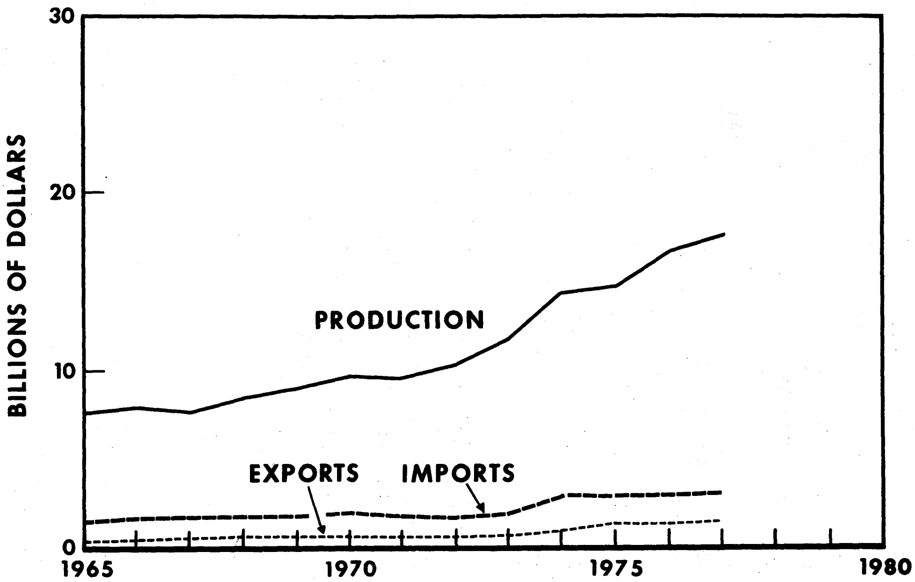


Figure 1.—Value of raw nonfuel mineral production, exports, and imports.

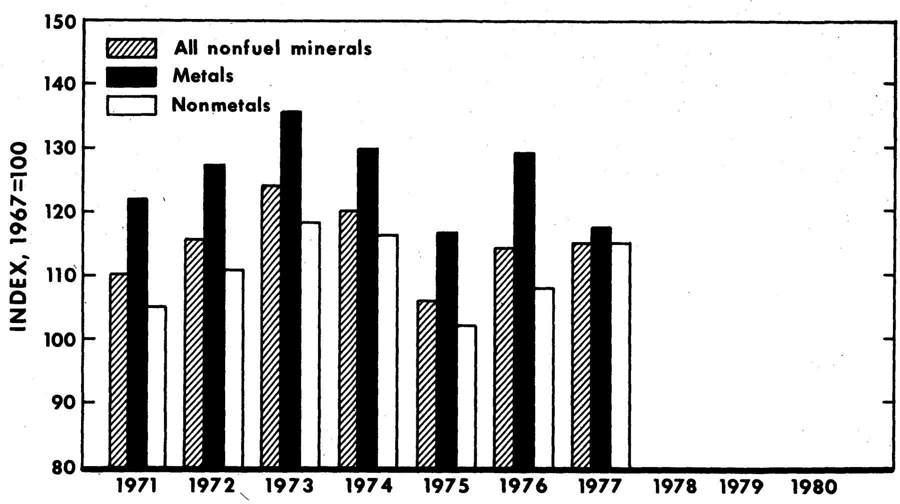


Figure 2.—Indexes of physical volume of nonfuel mineral production in the United States, by group.

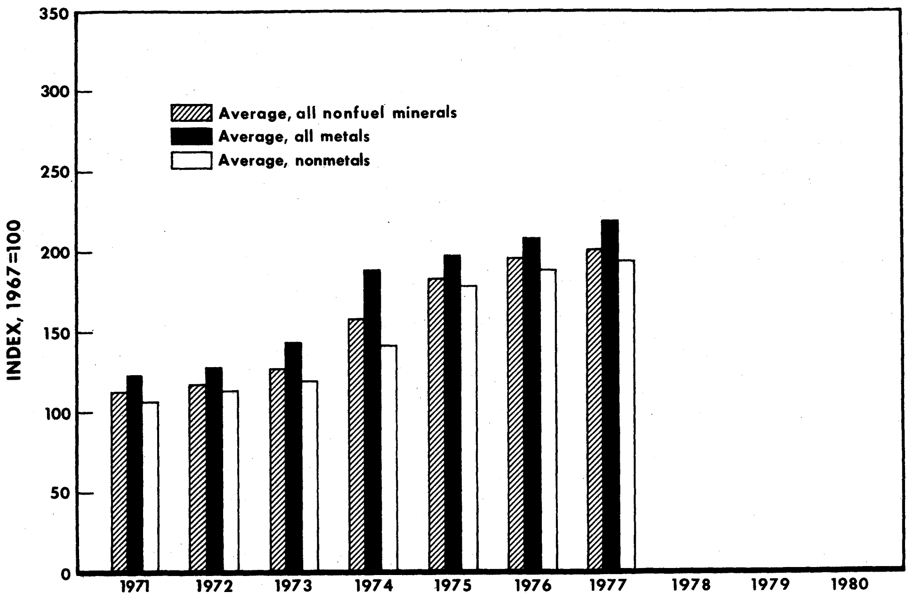


Figure 3.—Indexes of implicit unit value of nonfuel minerals.

112 index points in January and, similar to all mining, reached a high of 121.3 points in June. It closed in December at 118.4 points. The metal mining index was 130.6 in January, reached a high of 133.8 points in March, declined to a low of 70 in August, and then increased for the remainder of 1977, closing at 104.3 in December. The stone and earth mineral index was 121.6 in January, vacillated during most of 1977, climbing to a high of 128.1 in October, and finished at 126.5 points in December.

The net supply for selected nonfuel minerals was almost equally divided between increases and decreases in 1977. This pattern held true for the ferrous metals. Iron ore showed the largest decline in the ferrous category, falling 24.6%. Pig iron decreased 6.1%, but steel rose 2%. Other declines were: Cobalt, 20.5%; manganese ore, 13.7%; and nickel, 9.4%. Ferrous metal increases in descending order were tungsten at 23.8%, chromite at 16.6%, and molybdenum at 11.1%. The pattern was similarly mixed for the nonferrous metals. Gold showed the largest decline of any mineral, resulting in a negative net supply, which means that stocks (in this case Government stocks) were drawn down. Cadmium decreased 17.5%, followed by zinc at 8.4%, and mercury at 7.2%. Copper, titanium concentrate and slag, and platinum-group metals decreased in the range of 3.4% to 3.9%. Most nonmetallic minerals increased in net supply in 1977, led by mica which rose 25%, the largest increase of any mineral. Other nonmetallic mineral increases in descending order were: Barite, 14.3%; gypsum, 13.4%; marketable potash, 9.1%; fluorspar, 5.4%; talc and pyrophyllite, 4%; and sulfur, 1.7%. Asbestos, phosphate rock, and salt declined 7.4%, 5.6%, and 1.5%, respectively.

Stocks and Government Stockpiles.—Yearend stocks of crude nonfuel minerals at primary producers as illustrated by Bureau of Mines indexes (1967=100) showed a mixed pattern in 1977 compared with 1976. The overall index declined 0.7%, the crude metals index increased 2.9%, and the crude nonmetals index decreased 3.1%. Within the metals sector, the iron ore index rose 0.9%, the other ferrous index declined 3.3%, and the nonferrous index rose 36.6%. Stocks at mineral manufacturer, consumer, and dealer locations at yearend as illustrated by Bureau indexes declined for all but one category in 1977. The overall index for manufacturers' stocks declined 3.1%, the metals index decreased 3%, and the nonmetals index dropped 8.3%. Within the metals sector, the iron index decreased 19.8%, the largest decline of any processed mineral stock, the other ferrous index dropped

12.6%, the base nonferrous index rose 10.5%, and the other nonferrous index remained unchanged.

The seasonally adjusted book value of product inventories rose for two of the three selected mineral processing industries during 1977. Stone, clay, and glass products rose 6.6% to $4,469 million as of December 31, 1977. Total primary metals inventories increased slightly, 0.2% to $17,370 million. Within this category, product inventories of blast furnaces and steel mills declined 3.9% to $9,782 million and those of all other primary metals rose 6.1% to $7,588 million. The total seasonally adjusted book value of inventories for selected nonfuel mineral processing industries increased 1.5% to $21,839 million.

Strategic and critical minerals in the U.S. stockpile as of yearend 1977 that had high market values included antimony, bauxite, chromium, cobalt, industrial diamond, fluorspar, lead, manganese, platinum-group metals, silver, tin, titanium, tungsten, and zinc.

Exports.—The total value of selected minerals and mineral products, excluding fuels, exported declined 1.9% in 1977, compared with the corresponding 1976 figure. Largely responsible for the decrease were declines in all but two of the iron and steel export components, with scrap showing the greatest percentage decline at 35.0%. Crude and scrap nonferrous metal exports rose in value for all categories, with thorium ores and concentrates increasing the most at 170%. Sulfur and unroasted iron pyrites showed the largest percentage change, 21.0%, and showed the only decline among the crude nonmetallic mineral exports. Chemical export values were evenly divided between advances and declines. Percentage changes for the three manufactured nonmetallic minerals were small with two showing higher export values. Exports of most manufactured metals rose in value, with "other" base metals increasing by $37.7 million or about 24%. Copper was one of the two manufactured metal exports that fell in value, declining $86.1 million or about 31%.

The geographical distribution pattern, based on value, for the majority of selected mineral exports was similar in 1977 to that in 1976. Some notable exceptions follow. The distribution of U.S. exports of iron and steel scrap shifted away from noncentrally planned Europe, which declined from 48% to 31%, to noncentrally planned Asia, which rose from 34% to 54%. In the case of uranium and thorium ores and concentrates, the share of exports to noncentrally planned Europe continued to decrease, declining from 86% to 55% while that to North America continued to rise, increasing from 14% to 45%. The distribution of exports of lime, cement, and fabricated building materials except glass and clay began shifting away from both North America, which declined from 61% to 50%, and noncentrally planned Europe, which declined from 20% to 12%, to noncentrally planned Asia, which increased from 11% to 32%. The share of exports of iron and steel ingots and other primary forms shifted away from both North America, which declined from 56% to 37%, and noncentrally planned Europe, which declined from 15% to 5%, to both South America, which increased from 17% to 33%, and noncentrally planned Asia, which rose from 11% to 24%. The change in the pattern of iron and steel hoop and strip exports was a shift away from noncentrally planned Europe, which decreased from 48% to 26%, and to both North America, which rose from 32% to 43%, and South America, which rose from 9% to 17%. The share of zinc and zinc alloy exports to noncentrally planned Europe declined from 47% to 24% and those to North America increased from 31% to 49%. The distribution of exports of uranium and thorium and their alloys shifted away from North America, which decreased from 59% to 45%, to noncentrally planned Asia, which rose from 4% to 27%.

Imports.—The total value of selected minerals and mineral products, excluding fuels, imported in 1977 increased 11.5%. A significant rise in value of nonfuel mineral imports was largely attributable to increases in all iron and steel categories except pig iron, shot, ferroalloys, and iron ore and concentrates. All crude nonmetallic mineral imports rose in value, with crude fertilizers showing the greatest percentage gain at 76.4%, largely reflecting a relatively low base figure. Among the crude and scrap metals, thorium ores and concentrates showed the only gain — more than double that of 1976, but remaining under $1 million. Chemical imports were evenly divided between advances and declines and imports of the three manufactured nonmetallic minerals increased, with clay and refractory construction materials rising the most by 55%. Import values for all but one manufactured metal rose in 1977. Lead and its alloys were 2 1/2 times as large while zinc and its alloys declined about 25%.

The general geographic distribution pattern for most nonfuel mineral imports, based on value, was similar in 1977 to that in 1976. There were, however, some notable exceptions. The distribution of U.S. imports of crude phosphate and apatite shifted away from North America, which declined from 98% to 45%, to the African continent, which rose from zero to 55%. The change in the pattern of imports of copper ores and concentrates was a shift away from North America, which declined from 68% to 43%, to noncentrally planned Asia, which increased from 21% to 43%. The distribution of imports of nickel waste and scrap shifted away from North America, which declined from 71% to 52%, to Western Europe, which rose from 25% to 46%. The share of imports of lead waste and scrap shifted away from South America, which declined from 44% to zero, to both Western Europe, which increased from zero to 32%, and North America, which rose from 37% to 68%. The distribution of imports of zinc waste and scrap shifted away from North America, which declined from 80% to 25%, to Western Europe, which increased from 19% to 74%. The change in the pattern of columbium imports was a shift away from South America, which decreased from 39% to 17%, to several other areas, the largest increase of which was for North America which rose from 32% to 44%. The share of imports of tin waste and scrap shifted away from Western Europe, which declined from 82% to 2%, primarily to both South America which rose from zero to 47%, and noncentrally planned Asia which rose from zero to 26%.

Consumption.—In 1977, consumption of major mineral products was about evenly divided between those that increased and those that decreased compared with 1976 consumption which increased for most products over the previous year. Ferrous metals displayed a mixed pattern. Steel showed the largest increase at 11.4% and columbium the largest decrease at 20.4%. Vanadium consumption dropped 18%; manganese ore, 15.1%; iron ore, 8.1%; nickel, 4.9%; and chromite, 0.6%. Other ferrous metal increases were: Molybdenum, 8.1%; tungsten, 6.2%; and cobalt, 0.6%. About two-thirds of the selected nonferrous metals showed decreases in consumption. Silver for coinage fell sharply, declining 93.1%. Cadmium consumption decreased 24.5% and both silver for industry and arts and primary antimony declined 9.9%. Other nonferrous metal decreases were: Titanium, 8.6%; mercury, 5.6%; tin, 3.2%; zinc, 1.9%; and platinum-group metals, 0.7%. Among nonferrous metals that rose, uranium (U_3O_8 for enrichment) showed the largest increase at 20.6%, followed by refined copper at 9.7%, aluminum at 7%, lead at 6.2%, and gold for industry and arts at 4.5%. Two-thirds of the selected nonmetallic minerals showed increases in consumption in 1977. Talc rose 23.6%, the largest nonmetallic increase, followed by barite which rose 14.5%. Phosphate rock, cement, and gypsum increased from 10.4% to 13.4%. Other increases were: Potash, 8.4%; sulfur, 6.5%; stone, 5.9%; clays, 2%; and sand and gravel, 1.5%. Among those nonmetallics that declined were mica at 17.4%, fluorspar at 8.7%, asbestos at 7.4%, lime and salt decreased 1.4% and 1.3%, respectively.

EMPLOYMENT AND PRODUCTIVITY

Employment.—Employment increased in all selected mining and mineral manufacturing industries except for metal mining, primary nonferrous metals, and mining machinery in 1977. All mining, including fuels employment rose 3.9%, and within this group nonmetallic mining, except fuels employment increased 1.7%, and metal mining declined 3.2%. In the metal mining category, iron ores employment dropped 20.8% and copper ores decreased 3.0%.

All manufacturing employment increased 3.4% in 1977. Within manufacturing, blast furnaces and steel mills employment rose negligibly, primary nonferrous metals decreased 2.1%, chemical and fertilizer minerals rose 0.4%, and hydraulic cement rose 0.3%.

Hours and Earnings.—Average hourly earnings increased 7.4% to $6.94 for all mining, including fuels, in 1977. Hours worked for all mining increased 2.4% resulting in weekly earnings 10.0% higher than those in 1976. For metal mining, average hourly earnings rose 8.3% to $7.32. Weekly hours rose 1.7% in metal mining and weekly earnings increased 10.1%. Within the metal mining industry, hourly earnings rose 6.5% for the iron ore industry, but weekly hours declined less than 1%. Copper ore average hourly earnings increased 6.8%, but because weekly hours decreased 3.0%, weekly earnings rose only 3.6%. In the nonmetallic minerals, except fuels category, hourly earnings increased 8.0% and coupled with an increase in hours worked of about 1%, resulted in an increase in weekly earnings of 9.0%.

For all manufacturing, the average hourly earnings increased 8.6% to $5.67, weekly hours rose 0.5%, and weekly earnings were 9.2% above those in 1976. Blast furnaces and steel mills again showed the highest hourly wages and shortest workweek of the manufacturing industries considered. Hourly earnings in this industry increased 10.3% to $8.59 and hours worked rose a slight 0.5% resulting in an increase in weekly earnings of 10.8%. In the primary nonferrous metals industry, hourly earnings increased 11.7%, weekly hours declined 0.5%, and resultant weekly earnings rose 11.1%. Hydraulic cement showed an increase in hourly earnings of 8.8%, a rise in weekly hours of 1.2%, and an increase in weekly earnings of 10.1%.

Wages and Salaries.—Total wages and salaries grew to $983.6 billion in 1977, an increase of 10.5% which was almost the same as the previous year's increase. In the mining sector the increase was 15% to $14 billion, and in the manufacturing sector total wages rose 12% to $266.3 billion. Average earnings per full-time employee in all industries for 1977 increased 6.6% to $12,372. Average earnings per employee for both mining and manufacturing rose slightly over 8% to $17,352 and $13,892, respectively.

Labor Turnover Rates.—The accession rate (hires and rehires) for all manufacturing rose 2.6% in 1977. Of the selected mineral industries, copper ores experienced the largest decline at 41.2% in 1977, after showing the largest increase in 1976. There was a 3.7% decline in the iron ores accession rate, and for metal mining as a whole there was a 9.4% decline. The accession rate dropped 12.5% for blast furnaces and steel mills, 28.0% for primary nonferrous metals, and 13.3% for hydraulic cement.

All of the selected mineral industries showed either increases or no change in total separation rates and the manufacturing sector showed no change. The separation rate rose 40.7% for iron ores, 22.2% for copper ores, and 24.1% for metal mining as a whole. Primary nonferrous metals, blast furnaces and steel mills, and hydraulic cement separation rates declined by 5.6%, 3.2%, and 3.7%, respectively.

The layoff rate rose for all but one of the selected mineral industries in 1977. Iron ores showed the largest layoff increase, rising 110%; copper ores rose 27.2%; and metal mining as a whole climbed 50%. In the manufacturing sector, the layoff rate for primary nonferrous metals showed no change, for blast furnaces and steel mills it declined 11.1%, and for hydraulic cement it fell 17.6%.

Productivity.—Indexes of labor productivity for copper and iron all declined in 1977. Indexes for copper ore output per employee decreased 7.2%; per production worker, 4.5%; and per production worker-hour, 4.9%. For recoverable copper metal, the corresponding indexes declined 4.5%, 5.5%, and 1.8%, respectively. Indexes of iron ore output per employee decreased 11.8%; per production worker, 5.7%; and per production worker-hour, 5.0%. For usable iron ore mined, the output per employee fell 13.1%, output per production worker declined 6.4%, and output per production worker-hour declined 6.5%.

PRICES AND COSTS

Index of Average Unit Mine Value.—The index of average unit mine value (1967=100) is designed to reflect the unit values of mine production. All but two of the component indexes showed increases in 1977. The overall average unit mine value index increased slightly over 5%, with the metals index rising 7.2% and the nonmetals index increasing 4.2%. The ferrous metals index and the other nonferrous metals index each rose 10.5%. The index for all nonferrous metals increased 2.9%, the base nonferrous metals index declined 1.5%, and the monetary metals index rose 13%, the largest increase of any category. Within the nonmetals category, the construction index rose 7.3%, the chemical index declined 5.3%, and the other nonmetals index rose 4.9%.

Index of Implicit Unit Value.—The index of implicit unit value (1967=100) is designed to reflect the unit values of the minerals included in the index of the physical volume of mineral production. The implicit unit value index in 1977 yields results similar to those of the average unit mine value index which is to be expected since both show changes in the relative prices of commodities. The overall average of the implicit unit value index for nonfuel minerals rose about 4% to 202.6 index points. The metals index increased less than 5% and the nonmetals index rose about 4%. Within the metals group, the ferrous metals index increased 9.4% and the nonferrous metals index rose 3.8%. The base nonferrous metals index declined less than 1%, the monetary metals index rose 11.3%, and the other nonferrous metals index rose 14.9%, the largest increase of any index. Within the nonmetals category, the construction index rose 7.2%, the chemical index declined 4.0%, and the other nonmetals index rose 4.3%.

Prices.—In 1977 wholesale price indexes for selected metals and minerals showed a similar pattern to that in 1976 with most indexes increasing. The index for all commodities rose 6.0% to 194.2 index points and the index for all commodities other than farm and food increased 7% to 195.1 points. The metals and metal products index rose 6.6% to 209 index points. Within this category, those indexes showing large changes (10% or more) were: Lead, pig, common, up 33.5%; aluminum, primary, buyers, up 16.4%; and iron and steel scrap, down 10.8%. The nonmetallic mineral products index increased 7.5% to 200.4 index points. Within this category, those indexes showing large changes were: Gypsum products, up 18.8%; insulation materials, up 10.8%; and phosphate rock, down 12%.

Principal Metal Mining Expenses.—The index of principal metal mining expenses (1967=100) was up sharply in 1977, increasing 11.2% to 218 index points. The fuel component continued to show the largest increase, rising 13.5% to 302 index points. The other components showed the following increases in descending order, electrical energy, 12% to 233 index points; labor, 11.2% to 218 points; and supplies, 7.4% to 202 points. Supplies was the only component increasing less than the overall index.

Costs.—Iron ore and copper indexes of relative costs and productivity (1967=100) increased in 1977, with one exception. All three iron ore indexes showed increases: The index of labor costs per unit of output rose 13.4%, the index of value of product per production-worker-period increased 1%, and the index of labor costs per dollar of product rose 4.5%. For copper, the index of labor costs per unit of output rose 8.4%, the index of value of product per production-worker-period declined 4.9%, and the index of labor costs per dollar of product increased 12.3%.

Price indexes for mining construction and materials handling machinery and equipment (1967=100) showed increases in 1977 similar to those in 1976. The index for mixers, pavers, spreaders, etc. rose about 9%; the indexes for mining machinery and equipment, and tractors other than farm each rose 8%; and the indexes for construction machinery and equipment, and scrapers and graders each increased about 7%. The index for power cranes, excavators, and equipment showed the smallest increase at 6%.

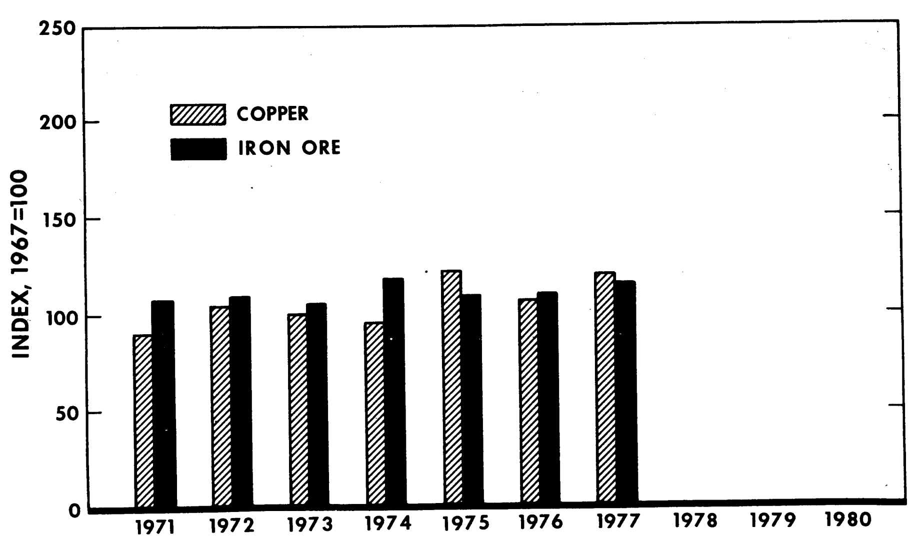


Figure 4.—Index of labor cost per dollar of product.

INCOME AND INVESTMENT

National Income Generated.—National income originating in all industries increased 11.5% to $1,555 billion in 1977. Income originating in the mining sector rose 14.4% to $23.2 billion. Income in nonmetallic minerals, except fuels, remained at $2.3 billion; and that in metal mining rose 8.8% to $2.1 billion. Income originating in the manufacturing sector increased 12.7% to $408.9 billion.

Profits and Dividends.—The annual average profit rate on shareholders' equity for all manufacturing industries rose a negligible amount to 14.2% in 1977. All but one of the selected mineral manufacturing industries showed declining profit rates. The primary metals profit rate decreased by 3.6 percentage points to 4.9%, a significant decline. Largely contributing to this decline was the sharp drop in the iron and steel profit rate which decreased by 5.5 percentage points to 3.5%. Nonferrous metals, on the other hand, decreased a negligible amount to a rate of 7.2%. The profit rate for stone, clay, and glass products increased by 1.5 percentage points to 13.4% and that for chemicals and allied products fell a negligible amount to 15.1%.

Total dividends for all manufacturing increased 17.1% to $26,650 million. While total dividends rose for all selected mineral manufacturing industries, the metals showed only small gains. Total dividends for primary metals increased 3.4% to $1,226 million, with iron and steel increasing 3.8% to $802 million, and nonferrous metals rising 2.2% to $423 million. Stone, clay, and glass products dividends rose 17.5% to $517 million and dividends for chemicals and allied products increased 16.2% to $3,643 million.

The total number of industrial and commercial failures in 1977 was significantly less than in 1976 which, in turn, was significantly less than in 1975. Current liabilities associated with these failures rose slightly in 1977 over those in 1976. The number of failures declined 17.8% to 7,919 and their liabilities rose 3.3% to $3.1 billion. Failures in the mining sector declined from 37 in 1976 to 30 in 1977 and corresponding current liabilities dropped from $106 million in 1976 to $42 million in 1977, a 60% decline. In the manufacturing sector, the number of failures declined for the second year in a row, falling 15.4%, but their current liabilities rose 20%.

New Plant and Equipment.—Expenditures for new plant and equipment rose for the mining (including fuels) industry and for all but one of the selected mineral manufacturing industries in 1977. Expenditures by firms in the mining industry increased 12.5% to $4.5 billion; those by all manufacturing firms rose 14.6% to $60.16 billion. Petroleum industry expenditures jumped 19.4% to $13.87 billion. Expenditures by the stone, clay, and glass products industry rose 15.7% to $1.99 billion; those by the primary nonferrous industry increased 3.7% to $2.24 billion; those by the chemicals and allied products industry rose 2.2% to $6.83 billion; and those by the primary iron and steel industry declined 9.7% to $3.44 billion.

Plant and equipment expenditures of foreign affiliates of U.S. companies declined 11.8% for mining and smelting, and increased 9.5% for manufacturing in 1977. Canada accounted for nearly half the total mining and smelting expenditures of $808 million, despite Canada's 20% decline. Most of the remaining mining and smelting expenditures were in the all other areas category which increased 50%, while those in Latin America declined 61.5%. Manufacturing investments totaled $12,561 million in 1977. Investments in Europe rose 6.7% and continued to account for more than half of the total. Manufacturing investments in Canada increased 21.4% and those in the all other areas category rose 16.8%.

Issues of Mining Securities.—Gross proceeds from all corporate primary security offerings in 1977 were $52.1 billion in 1977, a negligible decline from those of 1976. The share of these proceeds from each type of security offering changed little from 1976, with bonds at 77%, common stock at 16%, and preferred stock at 7%. Proceeds from offerings in the extractive industries continued to increase sharply in 1977, rising 51% to $2.7 billion. Fifty percent were from bonds, 49% from common stock, and 1% from preferred stock. In manufacturing, proceeds from offerings decreased 11% to $13.8 billion. These were distributed as follows: Bonds, 91%; common stock, 5%; and preferred stock, 4%.

Foreign Investment.—Direct private investment by U.S. companies in foreign mining was $7.1 billion in 1977, the same as in 1976. Two-thirds of these investments continued to be made in the developed countries which in 1977 amounted to $4.8 billion; two-thirds of the developed countries' share, or $3.2 billion, was invested in Canada; slightly over one-fourth, or $1.3 billion, was invested in Australia. Seventy percent of the $2.3 billion investment in developing countries, or $1.6 billion, was invested in Latin America.

TRANSPORTATION

The total quantity of major nonfuel minerals and mineral products transported by rail and domestic waterways (excludes imports and exports) in 1976 (latest data available) was 682 million short tons. Minerals and mineral products excluding fuels accounted for almost one-third of all commodities transported by rail and one-fourth of those transported by water. Sixty-four percent of minerals excluding fuels were transported by rail.

The quantity of nonfuel minerals transported by rail was 435.6 million short tons. Of this total, 51% consisted of five commodities: Iron ores and concentrates, phosphate rock, steel works and rolling mill products, sand and gravel, and crushed stone. These five largest commodities and the majority of other nonfuel minerals declined; all but one of the commodities that gained in 1976 showed relatively low tonnage.

The nonfuel minerals tonnage carried by water was 246.5 million short tons. Three commodities—iron ores and concentrates, sand and gravel, and limestone flux—accounted for two-thirds of this tonnage. Despite the slight decline in the overall tonnage, those commodities that increased in volume out numbered those that declined by almost two to one.

RESEARCH ACTIVITIES

Bureau of Mines.—The Bureau of Mines research program emphasizes efficient use of our mineral resources to insure adequate mineral supplies without objectionable environmental, social, and economic effects. The Bureau conducts scientific and engineering investigations to improve the recovery of minerals from domestic deposits, to improve the economics of recycling scrap mineral materials, to achieve more efficient utilization of mineral products by extending their lifespan, and to find industrial uses for mineral wastes and thus improve the environment. Bureau research concentrated on the following areas: Mining (including health and safety and explosives), metallurgy, secondary resource recovery and pollution abatement, economics, and helium. In August 1977, the Bureau functions of coal production technology, fuel data collection and analysis, and coal preparation research were transferred to the newly created Department of Energy.

Bureau of Mines funding obligations for mining and mineral research and development were $101.9 million during fiscal year 1977, a 22.4% decline from 1976. Funds for applied research fell by one-third to $48.3 million. Basic research funds were five times as large in 1977 as in 1976, reaching $4 million. Funds for development declined 14.5% to $49.6 million. For fiscal year 1978, obligations were estimated at $114.0 million, an increase of 11.9%. Fiscal year 1978 funds were estimated to increase 0.2% to $48.4 million for applied research, to rise 115% to $8.6 million for basic research, and to increase 14.9% to $57.0 million for development.

Bureau of Mines funding obligations for total research decreased 29% to $52.3 million during fiscal year 1977. Funds for engineering sciences declined 35% to $44 million, those for physical sciences rose 106% to $3.7 million, those for mathematical sciences increased 3% to $1.65 million, and those for environmental sciences increased 21% to $2.9 million. Obligations for total research during fiscal year 1978 were estimated to rise 9.0% to $57.0 million. Funds for engineering sciences were estimated to decline 3.9% to $42.3 million, those for physical sciences were estimated to drop 5.4% to $3.5 million, those for mathematical sciences were estimated to increase 75.8% to $2.9 million, and those for environmental sciences were estimated to increase 141.4% to $7.0 million.

Economic Analysis.—In 1977 the Bureau of Mines economic research program continued the study of economic conditions affecting the mineral industries and, in turn, the effect of the mineral sector on the national and international economies. The purpose of the research was to provide decisionmakers with information and up-to-date analyses of the economic situation, alternative courses of action, and the impact of choosing any of the alternatives. The economic analysis program attempted to create general methodology necessary for such analysis as well as information relevant to problem solving in the field of mineral economics. Major long-term research projects included the study and forecasting of demand, supply, and productivity; international trade; mineral taxation; financial analysis; a weekly price report on major minerals; input-output analysis; mineral transportation; mining and land use; waste recycling; and measures of the role of minerals in the U.S. economy. Some of the short-term projects undertaken in 1977 were the following: Review of a macroeconomic model prepared for an interagency stockpile study; review of a Massachusetts Institute of Technology report on ocean mining; analysis comparing revenues accruing to the Federal Government under a proposed coal lease with those that would accrue under provisions of the Coal Leasing Act Amendments; economic analysis of tungsten in response to a request from the Department of State; estimate of linear and quadratic functional relationship of steel shipments to population; analysis of domestic coal transport costs; reports of cold weather impacts on domestic minerals transport; completion of a final report on the Bureau of Mines information system using copper as a prototype commodity; in conjunction with the Law of the Sea Conference in New York, supplied background data on forecasting and provided additional analysis on future nickel demand; prepared data and background information for the Federal Energy Administration on the status of price controls on minerals and mineral fuels; participated in a Conference on Commodity Supply Policies sponsored by the Experimental Technology Incentive Program (ETIP), Department of Commerce and then summarized and forwarded the Bureau's comments to ETIP; estimated a statistical linear function relating world phosphate rock production to world population; and evaluated contract proposals related to the development of an operational summary index for measuring both the critical nature of minerals to the United States, and the U.S. vulnerability to reductions in minerals availability.

Helium.—The Bureau of Mines conducts a helium program under the Helium Act of 1960 to stimulate individual enterprise in production and distribution; encourage conservation; and to continue research on all phases of production, transportation, and use.

The atmosphere contains an unlimited supply of helium, but recovery is currently feasible economically only from natural gas, primarily fuel gas. The Bureau extracted 444 million cubic feet of helium from natural gas at its Keyes, Okla. plant in 1977. Unsold helium is transported by pipeline to underground storage at the Bureau's Cliffside field near Amarillo, Tex. At yearend 1977, storage of helium plus helium contained in natural gas amounted to 43.5 billion cubic feet. Mixtures of stored helium and native gas produced from Cliffside are transported by pipeline to the Bureau's Exell, Tex. plant for processing. The Bureau has contracts with several firms for which it stores and redelivers privately produced helium.

LEGISLATION AND GOVERNMENT PROGRAMS

In December 1977, as a result of previous communication with Members of Congress, President Carter directed that an interagency nonfuel mineral policy review be undertaken. The President appointed Secretary of the Interior Cecil Andrus as Chairman of the Cabinet-level committee created to conduct this review. The study was directed to address problems of domestic and international supply and demand among nonfuel minerals, examine Federal actions affecting the health of the U.S. mining industry, and submit policy options and recommendations to the President.

Legislation affecting the mineral sector and approved during the First Session of the 95th Congress covered areas such as taxes, energy, the environment, water, public lands, health and safety, surface mining, and import duties. Some of the more important laws passed are described below.

The Tax Reduction and Simplification Act (Public Law 95-30) has several provisions affecting the minerals sector as well as business in general, such as extending through yearend 1978 the reduction in the corporate tax rate on the first $50,000 of taxable income, providing for highly complex new jobs credit in 1977-78, and reducing exclusion of income for individuals working abroad to $15,000. Public Law 95-2 authorized the President to allocate gas supplies to any interstate pipeline where needed to serve residential consumers, small commercial consumers, or end-users that are vital to health, safety, or the protection of property. Among Public Law 95-217's amendments to the Federal Water Pollution Control Act were the following: Specified best management practices for discharge of dredged or fill material into navigable waters; set July 1, 1984 as time limit for industrial point sources to install best available control technology for certain pollutants, and as late as July 1, 1987 for other pollutants. Amendments to the Clean Air Act (Public Law 95-95) affecting the mineral industry included the following: Authorized issuance to primary nonferrous smelters requiring the use of continuous and supplemental controls for sulfur dioxide emissions unless such controls would be so costly as to necessitate permanent or prolonged shutdown of operations; established penalties from noncomplying stationary sources of pollution equal to economic benefit of noncompliance; required the Environmental Protection Agency (EPA) to review available information on radioactive pollutants, cadmium, arsenic, and polycyclic organic matter and determine whether emissions will cause or contribute to air pollution which may reasonably be anticipated to endanger public health, and if so, EPA must promulgate standards. Public Law 95-164 transferred the Mining Enforcement and Safety Administration from the Department of the Interior to the Department of Labor, renaming it the Mine Safety and Health Administration; made an amended version of the Coal Health and Safety Act applicable to all mining. Public Law 95-91 established the Department of Energy. Among the functions transferred to DOE were some of the Secretary of the Interior dealing with Federal land leases, including establishment of production rates for those leases, and the Bureau of Mines functions of coal production technology, fuel data collection and analysis, and coal preparation research. The Surface Mining Control and Reclamation Act of 1977 (Public Law 95-87) was primarily concerned with surface coal mines, but could be applied to the reclamation of abandoned metal and nonmetal mines and also provided for the study of the regulation of metal and nonmetal surface mines. Public Law 95-12 amended the United Nations Participation Act of 1945 to halt the importation of Rhodesian chromium. Public Law 95-37 extended for 2 years, until September 30, 1979, the Defense Production Act. A listing of mineral-related Federal legislation signed into law during 1977 follows:

Public Law	Mineral-related Federal legislation in 1977	Date signed
	ENERGY	
95-2	To authorize the President to declare a temporary gas emergency, and to make allocations toward meeting requirements for high-priority uses.	Feb. 2
95-91	To establish a Department of Energy in the Federal Government to direct a coordinated national energy policy.	Aug. 4
	ENVIRONMENTAL QUALITY	
95-95	The Clean Air Act Amendments of 1977.	Aug. 7
95-217	The Clean Water Act of 1977.	Dec. 27
	WATER RESOURCES	
95-41	To amend the Water Resources Planning Act of 1965.	June 6
95-84	To fund the Saline Water Conservation Program and other water research programs for fiscal years 1978-79.	Aug. 2
95-96	To appropriate for public works for water and power development and energy research for fiscal year 1978.	Aug. 7
	PUBLIC LANDS AND LAND USE	
95-42	To amend the Land and Water Conservation Fund Act of 1965.	June 10
95-87	To establish an Office of Strip Mining Reclamation and Enforcement in the Department of the Interior for administering programs related thereto.	Aug. 3
95-150	To provide for a study of certain lands (in Montana) to determine their suitability for designation as wilderness areas.	Nov. 1
95-178	To amend the Alaska Native Claims Settlement Act with regard to selections in the withdrawal for certain lands.	Nov. 15
95-192	To further the conservation, protection, and enhancement of the Nation's land, water, and related resources.	Nov. 18

Public Law	Mineral-related Federal legislation in 1977	Date signed
	OTHER	
95-12	To halt the importation of Rhodesian chromium through amendment of the United Nations Participation Act of 1945.	Mar. 18
95-30	The Tax Reduction and Simplification Act.	May 23
95-37	To extend the Defense Production Act 2 years to September 30, 1979.	June 1
95-161	To suspend the import duty on synthetic tantalum-columbium concentrate until June 30, 1980.	Nov. 8
95-164	To promote health and safety in the mining industry.	Nov. 9
95-212	To fund State cooperative programs under the Endangered Species Act through fiscal years 1978-80.	Dec. 19

The acquisition cost of strategic and critical materials in the national stockpile as of December 31, 1977, was $2.5 billion with a market value of $7.1 billion. The acquisition cost of materials in the supplemental stockpile was $1.1 billion with a market value of $1.9 billion. Corresponding Defense Production Act (DPA) stockpile figures were $0.2 billion and $0.1 billion, respectively. The total acquisition cost of these materials was $3.7 billion with a current market value of $9.2 billion. During fiscal year 1977 (October 1976-September 1977), disposals from the national and supplemental stockpiles totaled $66.6 million. Disposals from the DPA inventory and other inventories were $7.1 million and $2.7 million, respectively, bringing grand total disposals to $76.4 million. Commodities with the greatest sales value included tin at $26 million, tungsten ores and concentrates at $32.7 million (including both the national and supplemental stockpiles and DPA inventory), and industrial diamonds at $6.0 million.

WORLD REVIEW

World Economy.—The economies of the major industrial countries—Canada France, the Federal Republic of Germany, Italy, Japan, and the United Kingdom—virtually stagnated after the first quarter of 1977. Growth in real GNP for these countries averaged an estimated 3% in 1977, and for most other countries in the Organization for Economic Cooperation and Development (OECD), growth rates were even lower. Progress was made in controlling inflation in five of the six major foreign industrial countries, although rates remained high by historical standards. Unemployment rates in many countries were higher than they had been at the trough of the 1974-75 recession. The volume of trade worldwide was estimated to have increased only 4% in 1977.

Real GNP in 1977 increased 5.1% for Japan, 2.7% for Canada, and 2.4% for the Federal Republic of Germany. Real gross domestic product rose 3% in France, 1.7% in Italy, and 0.1% in the United Kingdom. Contributing to the small increase in demand was slow growth in business fixed investment, with the possible exception of Canada. The low growth in real economic activity was due in part to restrictive policies that were adopted by a number of countries as a means of lowering inflation. Consumer prices rose at a slower rate in 1977 than in 1976 for all of the countries except Canada. In Italy and Japan the inflation rate dropped 6 or more percentage points, while in France, the Federal Republic of Germany, and the United Kingdom, the decline in inflation was less, but nevertheless significant. Canada, which had low inflation in 1976 relative to other major countries, experienced an inflation rate of almost 10% in 1977.

World Production.—The United Nations (UN) indexes of world mineral industry production (1970=100) for the extractive industries increased 4 index points to 124 in 1977. The metal mining index remained unchanged at 106 index points. Indexes for the mineral processing industries showed increases of 2 points to 123 for base metals and 7 points to 142 for nonmetallic mineral products. Overall industrial production as measured by the UN index increased 7 points to 142 in 1977.

World Trade.—The value of world export trade in all commodities increased 13.4% to $988.8 billion in 1976 (latest data available). The value of mineral commodities entering world trade rose 13.5% to $287.8 billion. Internationally traded metals increased 4.6% in value to $81.9 billion; iron and steel showed the only decrease of any mineral category, declining 2.4% to $44.7 billion; nonferrous metals rose 18.8% to $21.5 billion; and all ores, concentrates, and scrap increased 9.7% to $15.8 billion. Crude nonmetal exports rose 1.6% in value to $6.3 billion. The value of mineral fuels entering world trade increased 18% to $199.6 billion.

World Prices.—Mineral commodity export price indexes (1970=100) were higher in 1977 for all sectors. Metal ores rose by 5 index points to 214, fuels by 58 points to 674, and all crude minerals by 44 index points to 554. Total minerals export prices rose 4.3% in developed areas and 9.2% in developing areas. Nonferrous base metal prices increased 6.6% in developed areas and 5.8% in developing areas.

[1]Economist, Division of Economic Analysis.

Table 1.—Value of U.S. production, exports, and imports of unprocessed nonfuel mineral raw materials, by major mineral group

(Million dollars)

Mineral group	1971	1972	1973	1974	1975	1976	1977
VALUE OF PRODUCTION							
All minerals, except fuels	9,461	10,124	11,775	14,140	r14,761	r16,702	17,511
Metals	3,403	3,642	4,362	5,501	5,191	6,086	5,810
Nonmetals	6,058	6,482	7,413	8,639	r9,570	r10,616	11,701
VALUE OF PRODUCTION, IN CONSTANT 1967 DOLLARS[1]							
All minerals, except fuels	8,388	8,623	9,289	9,051	r8,007	r8,574	8,643
Metals	2,742	2,861	3,070	2,956	2,640	r2,912	2,652
Nonmetals	5,646	5,762	6,219	6,095	r5,367	r5,662	5,991
VALUE OF EXPORTS							
All minerals, except fuels	418	399	533	876	1,117	1,022	1,126
Metals	192	247	253	343	372	380	464
Nonmetals	226	152	280	533	745	642	662
VALUE OF IMPORTS							
All minerals, except fuels	1,620	1,634	1,849	r2,916	r2,833	r2,844	2,966
Metals	1,047	988	1,081	1,758	1,618	r1,607	1,513
Nonmetals	573	646	768	1,158	1,215	r1,237	1,453

rRevised.
[1]Current values are deflated by indexes of implicit unit value (1967=100) shown in a later table.

Note: Detailed commodity data are shown in later tables of this chapter and in the Statistical Summary chapter.

Table 2.—Indexes of the physical volume of nonfuel mineral production

(1967=100)

Mineral group	1971	1972	1973	1974	1975	1976	1977p
All minerals, except fuels	110.4	115.9	124.3	121.2	107.2	115.0	115.8
All metals	122.3	127.5	136.8	130.4	117.5	129.8	118.0
Ferrous metals	96.9	98.4	116.0	108.3	96.2	99.8	78.8
Nonferrous metals	143.0	151.1	153.6	148.4	134.8	154.0	149.8
Base	151.0	162.8	166.5	159.3	142.7	158.0	148.5
Monetary	110.6	102.7	94.5	86.9	86.2	85.1	92.5
Other	115.5	112.6	114.8	122.8	119.2	175.2	195.8
All nonmetals	105.2	111.0	119.0	117.2	102.8	108.6	114.9
Construction	106.2	111.7	120.8	115.2	99.5	105.0	111.4
Chemical	101.9	108.7	112.2	121.3	112.2	117.3	123.4
Other	105.4	112.2	122.7	128.6	109.4	123.4	127.1

pPreliminary.

Table 3.—Industrial production indexes of the Federal Reserve Board, for selected sectors

(1967=100)

Selected sectors	1972	1973	1974	1975	1976	1977
Total index	119.7	129.8	129.3	117.8	129.8	137.1
Durable manufacturing	113.7	127.1	125.7	109.3	140.9	129.5
Mining, including fuels	113.1	114.7	115.3	112.8	114.2	117.8
Anthracite	55.3	54.9	50.9	50.1	51.9	50.8
Bituminous coal	108.1	106.8	108.7	116.0	119.9	120.8
Oil and gas extraction	113.6	113.7	114.4	113.3	112.0	118.0
Crude oil	107.3	104.4	[r]99.7	[r]94.9	92.2	92.4
Natural gas	[r]125.3	125.9	[r]120.7	[r]111.0	109.5	110.4
Oil and gas drilling	129.6	146.5	189.3	222.8	230.1	279.3
Metal mining	[r]118.8	[r]130.2	[r]125.6	115.8	122.8	105.4
Iron ore	95.1	112.6	110.4	105.4	105.4	74.3
Nonferrous ores	139.9	146.0	139.2	125.1	138.3	133.3
Copper ore	171.0	179.8	167.0	147.0	167.2	158.1
Lead, zinc ores	117.3	113.9	120.2	111.0	108.5	103.3
Stone and earth minerals	[r]113.2	[r]119.2	[r]121.5	107.0	118.3	124.9
Clay, glass, stone products	[r]120.8	[r]133.5	[r]133.1	117.9	137.1	124.9
Cement	117.9	125.9	115.6	98.3	103.0	112.1
Structural clay products	108.4	120.7	115.7	99.5	111.6	114.4
Inorganic chemicals, nec	107.8	110.8	112.6	112.9	123.6	126.5
Fertilizer materials	118.3	121.9	129.9	125.3	133.3	142.6
ERDA[1] nuclear materials	97.3	107.5	104.0	135.4	160.1	153.8
Primary metals	[r]112.1	[r]126.7	[r]123.1	96.4	108.9	110.2
Basic steel and mill products	107.0	122.9	121.6	96.8	105.6	102.1
Pig iron	101.8	115.6	109.5	91.5	98.5	92.7
Raw steel	105.5	120.6	119.9	94.7	104.4	103.7
Coke and products	93.5	99.6	95.3	88.7	90.1	83.0
Equipment steel	99.4	110.8	113.5	99.8	111.8	113.2
Construction steel	85.7	101.1	104.6	77.8	71.5	68.3
Iron and steel foundries	107.1	[r]120.1	[r]113.0	[r]91.9	102.5	108.0
Nonferrous metals and products	121.1	134.5	129.0	97.5	115.9	122.4
Primary nonferrous metals	129.2	136.3	136.9	111.8	123.0	124.3
Copper	160.7	160.5	139.3	123.0	138.1	127.7
Aluminum	125.8	138.6	150.1	118.8	129.7	138.3
Secondary nonferrous metals	128.2	142.3	139.4	115.3	142.5	148.5
Nonferrous products	126.3	142.8	131.0	94.4	123.2	130.1
Copper mill products	122.6	133.0	113.7	82.4	112.3	111.1
Aluminum mill products	143.7	168.9	164.3	113.5	145.5	158.2
Nonferrous foundries	100.9	110.8	96.7	77.3	99.5	106.2
Building and mining equipment	121.0	136.5	159.7	168.3	177.7	202.5

[r]Revised.
[1]Energy Research and Development Administration.

Source: Board of Governors of the Federal Reserve System, Industrial Production, 1976 Revision; Statistical Release, Dec. 14, 1977 and Oct. 17, 1978.

Table 4.—Industrial production indexes of the Federal Reserve Board, for mining industries

(1967=100, seasonally adjusted)

	Mining including fuels	Metal mining	Iron ore	Nonferrous ores	Copper ores	Lead, zinc ores	Stone, earth minerals
1976:[r]	114.2	122.8	105.4	138.3	167.2	108.5	118.3
January	113.2	116.8	113.2	126.6	149.4	109.2	117.1
February	113.6	121.1	118.2	129.5	151.2	114.3	119.9
March	113.8	121.6	112.0	131.4	154.8	113.2	119.3
April	112.6	122.6	112.4	134.7	159.2	111.1	117.5
May	113.8	121.6	97.7	136.5	164.2	111.6	116.7
June	114.6	120.6	102.5	132.5	154.6	108.3	116.5
July	112.7	124.2	93.1	147.2	180.8	104.5	116.5
August	114.0	124.5	97.9	153.6	194.3	102.4	118.8
September	115.5	123.2	98.1	146.1	181.3	105.4	119.2
October	116.1	126.1	105.2	147.6	184.0	104.4	200.0
November	115.3	124.5	114.1	140.2	170.5	108.2	120.8
December	115.4	126.8	119.5	138.4	167.9	109.1	118.0
1977:	117.8	105.4	74.3	133.3	158.1	103.3	124.9
January	112.8	130.6	121.3	145.0	182.7	101.6	121.6
February	116.3	128.5	123.3	138.4	169.6	110.2	124.9
March	120.6	133.8	121.0	146.2	184.1	109.6	126.1
April	119.2	126.1	113.0	140.6	172.0	111.6	124.0
May	119.5	120.5	90.4	142.1	176.1	103.8	123.0
June	122.8	121.3	98.1	138.6	165.6	104.7	122.5
July	119.8	101.9	89.0	104.4	103.3	86.2	126.7
August	115.4	70.0	23.7	121.7	133.9	105.3	125.0
September	118.0	71.4	23.5	120.9	135.1	98.0	126.7
October	119.6	80.0	24.4	132.1	153.7	99.0	128.1
November	118.8	84.8	28.9	133.2	156.2	103.2	127.2
December	113.4	104.3	75.6	130.3	151.2	106.1	126.5

[r]Revised.

Source: Board of Governors of the Federal Reserve System. Industrial Production Indexes 1976, September 1977; Statistical Release, Feb. 15, Oct. 15, Dec. 15, 1978.

Table 5.—U.S. net supply, and world production of selected mineral products

Commodity, mineral content measured	U.S. mine production	Old scrap	Exports	Imports	U.S. net supply	World mine production
Iron ore, thousand long tons:						
1975	78,900	--	2,500	46,700	123,100	887,389
1976	80,000	--	2,900	44,400	121,500	881,028
1977	55,800	--	2,100	37,900	91,600	840,000
Pig iron, thousand short tons:						
1975	79,700	--	60	500	80,140	528,298
1976	86,800	--	58	400	87,142	551,193
1977	81,500	--	51	400	81,849	542,696
Steel, thousand short tons:						
1975	[1]116,600	--	4,000	12,500	125,100	710,106
1976	[1]128,000	--	3,700	[r]15,000	139,300	747,103
1977	[1]125,300	--	3,100	19,900	142,100	741,648
Chromite, thousand short tons:						
1975	[2]418	--	[3]184	1,252	1,486	9,071
1976	[r] [2]311	--	[3]209	1,275	1,377	9,492
1977	[2]517	--	[3]248	1,336	1,605	10,804
Cobalt, short tons:						
1975	[2]3,173	--	884	3,304	5,593	34,000
1976	[2]3,349	--	876	8,244	10,717	31,197
1977	[2]74	--	446	8,774	8,402	32,611
Manganese ore, thousand short tons:						
1975	[2]624	--	205	1,574	1,993	27,175
1976	[2]681	--	128	1,317	1,870	27,153
1977	[2]821	--	138	931	1,614	24,267
Molybdenum ore and concentrate, thousand pounds:						
1975	105,980	--	62,611	2,567	45,936	176,713
1976	113,233	--	62,474	2,093	52,852	191,736
1977	122,408	--	65,666	1,976	58,718	205,921
Nickel, thousand short tons:						
1975	[4]17	8	[5]30	161	156	891
1976	[4]16	6	[r] [5]47	188	163	905
1977	[4]14	6	[5]39	167	148	852
Tungsten, thousand pounds:						
1975	5,588	--	[e]1,316	6,570	10,842	84,508
1976	5,830	--	[e]1,729	5,301	9,402	91,767
1977	6,008	--	[e]1,284	6,919	11,643	93,630
Aluminum, thousand short tons:						
1975	[6]3,879	283	440	550	4,272	13,387
1976	[6]4,251	341	484	749	4,857	13,771
1977	[6]4,539	413	411	836	5,377	15,049
Antimony, short tons:						
1975	886	16,020	340	18,706	35,272	77,114
1976	283	17,657	341	21,770	39,369	76,576
1977	610	26,540	742	13,335	39,743	78,977
Cadmium, short tons:						
1975	2,193	--	198	2,618	4,613	[5]16,793
1976	2,256	--	252	3,411	5,415	[5]18,180
1977	2,204	--	118	2,570	4,656	[5]18,898
Copper, thousand short tons:						
1975	1,413	369	10	271	2,043	8,386
1976	1,606	419	18	470	2,477	8,258
1977	1,504	452	24	437	2,369	9,094
Gold, thousand troy ounces:						
1975	1,052	2,696	3,496	2,662	2,914	38,476
1976	1,048	2,504	3,531	2,656	2,673	39,089
1977	1,100	2,454	8,671	4,454	-663	38,966
Lead, thousand short tons:						
1975	621	564	71	146	1,260	3,783
1976	610	622	53	[r]236	1,415	3,677
1977	592	702	95	364	1,563	3,759
Mercury, thousand flasks:						
1975	7	8	([7])	44	59	252
1976	23	3	[8]1	44	69	240
1977	28	7	[8]1	29	63	199
Platinum group, thousand troy ounces:						
1975	19	270	660	1,820	1,449	5,714
1976	6	215	512	2,667	2,376	5,979
1977	6	195	427	2,510	2,284	6,386
Silver, thousand troy ounces:						
1975	34,938	49,600	32,626	66,540	118,452	297,882
1976	34,328	50,200	14,596	72,700	142,632	304,899
1977	38,166	47,900	22,394	79,147	142,819	325,475
Tin, thousand metric tons:						
1975	[6]6	16	[3]4	51	69	[6]222
1976	[6]6	16	[3]2	51	71	[6]228
1977	[6]7	19	[3]5	54	75	[6]231

See footnotes at end of table.

Table 5.—U.S. net supply, and world production of selected mineral products —Continued

Commodity, mineral content measured	U.S. mine production	Old scrap	Exports	Imports	U.S. net supply	World mine production
Titanium concentrate, slag, thousand short tons:						
1975	717	--	3	559	1,273	4,447
1976	652	--	5	622	1,269	4,909
1977	639	--	23	609	1,225	4,903
Zinc, thousand short tons:						
1975	469	77	7	525	1,064	6,448
1976	485	95	4	812	1,388	6,358
1977	450	91	(7)	700	1,241	6,683
Asbestos, thousand short tons:						
1975	99	--	36	539	602	4,563
1976	115	--	47	658	726	5,623
1977	102	--	37	607	672	5,879
Barite, thousand short tons:						
1975	1,318	--	57	634	1,895	5,419
1976	1,234	--	41	905	2,098	5,666
1977	1,494	--	50	955	2,399	5,892
Fluorspar, thousand short tons:						
1975	377	--	1	1,050	1,426	4,986
1976	611	--	5	895	1,501	4,932
1977	613	--	7	976	1,582	5,158
Gypsum, thousand short tons:						
1975	9,751	--	75	5,448	15,124	65,279
1976	11,980	--	284	6,231	17,927	69,175
1977	13,390	--	143	7,074	20,321	72,164
Mica, short tons:						
1975	134,584	--	6,055	8,325	136,854	[1]227,936
1976	[r]140,714	--	8,465	4,598	136,847	[1]240,298
1977	175,880	--	8,768	3,897	171,009	[1]283,282
Phosphate rock, million metric tons:[9]						
1975	44	--	11	(7)	33	107
1976	45	--	9	(7)	36	107
1977	47	--	13	(7)	34	116
Potash, K_2O, thousand short tons:						
1975	2,501	--	779	3,797	5,519	[r]27,352
1976	2,400	--	945	4,594	6,049	26,876
1977	2,457	--	932	5,076	6,601	28,550
Salt, thousand short tons:						
1975	41,710	--	1,332	3,215	43,593	178,207
1976	43,801	--	1,007	4,352	47,146	185,324
1977	42,922	--	1,008	4,529	46,443	187,292
Sulfur, thousand long tons:						
1975	11,259	--	1,352	1,897	11,804	[r]49,877
1976	10,707	--	1,270	1,727	11,164	49,741
1977	10,558	--	1,178	1,977	11,357	51,671
Talc, pyrophyllite, thousand short tons:						
1975	965	--	158	23	830	5,366
1976	1,062	--	212	20	870	5,946
1977	1,205	--	322	22	905	6,331

[e]Estimate. [r]Revised.
[1]Production.
[2]Deliveries from stockpile. No production.
[3]Includes reexports.
[4]Mine shipments.
[5]Gross weight.
[6]Refinery or smelter production.
[7]Less than 1/2 unit.
[8]Marketable production.
[9]Phosphate rock is not in mineral content, but instead is marketable phosphate rock.

Note: Net supply, is calculated as the sum of the first, second, and fourth columns, minus the third column. World figures for 1977 are preliminary. The 1977 yearbook commodity chapters were the most up-to-date sources used.

Table 6.—Shipments and orders in primary metal industries

(Million dollars, seasonally adjusted)

	Shipments		Net new orders		Unfilled orders, end of period	
	Blast furnaces and steel mills	Other primary metals	Blast furnaces and steel mills	Other primary metals	Blast furnaces and steel mills	Other primary metals
1973	35,260	36,767	39,913	38,729	9,884	4,960
1974	47,424	46,249	49,036	48,197	13,751	6,947
1975	40,210	38,749	35,779	36,013	9,287	5,455
1976	45,137	43,689	45,846	44,200	9,993	6,011
1977	49,960	48,424	51,820	49,252	11,873	6,787
1977:						
January	3,457	3,523	4,054	3,933	10,580	6,078
February	3,831	3,943	4,068	3,906	10,939	6,102
March	4,539	4,308	4,304	4,343	10,977	6,145
April	4,282	4,348	3,906	3,998	10,851	6,039
May	4,384	4,277	5,089	3,990	11,696	5,977
June	4,735	4,335	3,945	4,014	11,171	6,034
July	3,882	3,601	4,316	3,995	11,239	6,103
August	4,154	3,837	4,382	4,194	11,347	6,287
September	4,350	4,194	4,513	4,179	11,489	6,398
October	4,197	4,157	4,140	3,954	11,385	6,348
November	4,102	3,992	4,747	4,154	11,837	6,475
December	4,047	3,909	4,356	4,592	11,873	6,787

Source: U.S. Department of Commerce, Bureau of Economic Analysis. Survey of Current Business. V. 58, No. 3, March 1978, pp. S5-S7.

Table 7.—Indexes of mineral stocks held at yearend

(1967 = 100)

Mineral group	1971	1972	1973	1974	1975	1976	1977[p]
CRUDE MINERAL STOCKS HELD BY PRODUCERS							
Crude minerals, except fuels	148	141	110	98	126	141	140
Metal ores	147	143	95	76	91	102	105
Iron ore	136	113	84	73	95	108	109
Other ferrous	275	428	208	130	104	90	87
Nonferrous	101	78	63	53	55	71	97
Nonmetal crude minerals	149	138	129	125	171	191	185
MINERAL STOCKS HELD BY MANUFACTURERS, CONSUMERS, AND DEALERS[1]							
Minerals, except fuels	115	108	98	116	131	130	126
Metals	117	108	98	117	134	132	128
Iron	99	88	79	79	93	101	81
Other ferrous	135	135	99	102	132	111	97
Base nonferrous	114	99	89	131	153	152	168
Other nonferrous	130	126	117	140	155	148	148
Nonmetals	88	94	91	100	91	84	77

[p]Preliminary.
[1]Revised aluminum series as of 1971, affecting the total and subtotal categories as well as other nonferrous metals.

Note: The data include various grades of minerals and stages of processing, if available and where applicable, for a representative number of minerals only.

Table 8.—Stocks of selected products at end of period

	Stone, clay, glass products	Blast furnaces and steel mills	Other primary metals	Iron ore at mines, yards, docks (thousand long tons)	Refined copper	Producers' lead, ore, bullion[2]	Slab zinc at smelter
	Million dollars[1]				Thousand short tons		
1973	2,813	4,672	4,684	59.9	157	158	20.8
1974	3,721	5,747	6,114	57.7	374	187	22.9
1975	3,848	8,483	7,044	69.1	538	191	75.7
1976	4,194	10,179	7,150	75.0	651	181	88.8
1977	4,469	9,782	7,588	59.4	649	185	65.8
1977:							
January	4,248	10,148	7,049	73.5	647	170	90.5
February	4,234	10,154	7,122	72.2	668	173	84.2
March	4,142	10,232	7,091	70.1	666	162	58.9
April	4,193	10,215	7,117	68.5	662	163	67.9
May	4,258	10,444	7,140	67.7	679	158	78.9
June	4,251	10,500	7,145	68.5	683	157	77.3
July	4,321	10,591	7,228	69.7	656	163	74.9
August	4,314	10,519	7,240	67.2	598	183	64.7
September	4,348	10,323	7,317	65.9	582	193	59.7
October	4,415	10,355	7,429	63.5	577	190	60.3
November	4,562	10,100	7,481	60.7	614	188	65.3
December	4,469	9,782	7,588	59.4	649	185	65.8

[1]Months are seasonally adjusted.
[2]Also lead in process. All data in lead content.

Source: U.S. Department of Commerce, Bureau of Economic Analysis. Survey of Current Business. February 1974, 1975; March 1976, 1977, 1978.

Table 9.—Value of U.S. exports and imports of selected mineral products

(Million dollars)

Products by SITC code[1] (Nos. 271-689)	Exports 1975	Exports 1976	Exports 1977	Imports 1975	Imports 1976	Imports 1977
Fertilizers, crude	464.0	329.2	364.3	27.7	12.7	22.4
Stone, sand and gravel	37.8	46.6	47.5	27.0	28.9	32.7
Sulfur and unroasted iron pyrites	69.7	60.4	47.7	71.0	59.6	65.3
Natural abrasives and industrial diamond	58.5	62.7	72.1	54.5	63.0	83.3
Other crude minerals	261.6	293.3	319.3	262.1	301.9	312.1
Iron ore, concentrates	60.1	82.2	62.8	860.5	980.3	950.8
Nonferrous base metal ore, concentrates	240.2	260.0	332.4	772.6	892.6	847.3
Nonferrous metal scrap	222.0	238.9	267.3	160.7	221.2	180.3
Silver, platinum-group metal ore, concentrate	52.3	44.5	55.9	134.4	109.1	59.3
Uranium and thorium ores, concentrate[2]	1.8	24.4	65.9	.5	.4	.9
Inorganic chemicals, elements, oxides	608.2	643.9	630.5	724.9	804.4	1,011.9
Other inorganic chemicals	337.8	365.7	415.3	107.3	128.7	140.1
Radioactive materials[2]	315.2	466.7	550.1	195.5	659.1	506.0
Tar, chemicals from coal, petroleum, gas	59.3	74.8	71.6	14.1	11.4	11.0
Lime, cement, fabricated building materials	55.7	54.7	52.7	116.7	113.9	157.0
Clay, refractory construction materials	136.3	138.3	142.8	66.2	81.6	126.5
Other mineral manufactures	166.1	203.0	217.2	83.2	97.4	119.2
Iron and steel:						
Scrap	779.3	634.5	412.7	31.8	42.8	46.8
Pig, shot, ferroalloys	73.8	73.2	52.9	557.0	535.7	527.8
Ingot	63.3	46.6	42.7	69.5	52.8	61.8
Bar, rod, angle, section	181.0	153.2	140.5	941.5	863.6	1,143.5
Plate and sheet	328.3	337.5	272.0	1,727.5	1,915.1	1,143.5
Hoop and strip	62.3	100.8	70.4	67.4	72.4	85.4
Rails and track construction material	70.6	61.6	39.4	29.7	19.0	40.7
Wire, except wire rod	25.3	36.2	39.8	231.6	214.1	287.2
Tube, pipe, fittings	1,411.9	776.5	677.0	1,040.2	819.8	973.9
Rough cast, forgings	240.6	318.5	325.8	30.9	21.0	27.7
Silver, platinum-group metals	222.9	96.7	91.1	517.7	559.5	565.6
Metals and their alloys:						
Copper	332.6	281.7	195.6	418.6	776.8	807.6
Nickel	117.9	158.1	161.2	464.3	526.3	543.4
Aluminum	433.2	466.4	480.3	410.6	549.9	762.5
Lead	12.0	5.3	8.4	47.5	63.5	157.9
Zinc	17.3	11.2	8.0	283.9	502.9	373.5
Tin	12.3	4.6	8.7	315.7	329.7	458.5
Uranium, thorium	.2	.1	.1	([3])	.1	.3

See footnotes at end of table.

Table 9.—Value of U.S. exports and imports of selected mineral products —Continued

(Million dollars)

Products by SITC code[1] (Nos. 271-689)	Exports			Imports		
	1975	1976	1977	1975	1976	1977
Metals and their alloys —Continued						
Other base metals	164.0	158.5	196.2	122.0	185.5	213.5
Total	7,695	7,110	6,938	10,986	12,617	12,847

[1]Standard International Trade Classification.
[2]Starting with 1977, uranium data are included in radioactive materials, instead of with thorium ores.
[3]Less than 1/2 unit.

Source: U.S. Department of Commerce, Bureau of the Census. U.S. Exports, Commodity and Country, FT 410; U.S. Imports, General and Consumption, FT 246.

Table 10.—Value of U.S. exports of selected mineral products in 1977, by destination area

(Million dollars)

Products by SITC code[1] (Nos. 271-689)	America		Europe		Asia	Africa	Oceania
	North	South	West	East			
Fertilizers, crude	73.8	19.7	124.2	36.1	110.5	([2])	([2])
Stone, sand and gravel	37.1	1.5	4.6	([2])	3.7	0.2	0.3
Sulfur and unroasted iron pyrites	1.3	4.5	40.6	([2])	([2])	([2])	1.3
Natural abrasives and industrial diamond	8.7	2.6	47.4	.1	10.1	.8	2.5
Other crude minerals	87.0	20.1	132.6	1.2	65.2	5.8	7.5
Iron ore, concentrates	62.6	([2])	([2])	--	.1	([2])	--
Nonferrous base metal ore, concentrate	20.9	17.4	228.9	10.5	52.0	1.2	1.4
Nonferrous metal scrap	39.4	10.3	89.8	.8	125.8	.8	.4
Uranium and thorium ores, concentrate	29.7	--	36.2	--	--	--	--
Inorganic chemical elements, oxides	187.8	122.6	113.7	9.1	120.1	38.7	38.4
Other inorganic chemicals	150.6	62.5	96.7	1.2	72.0	15.1	14.6
Radioactive materials	12.5	2.5	337.3	.3	195.2	.3	1.8
Tar, chemicals from coal, petroleum, gas	8.5	3.9	48.6	([2])	8.2	.6	1.9
Lime, cement, fabricated building material	26.4	2.1	6.1	.2	16.8	.7	.4
Clay, refractory construction material	74.1	21.4	19.5	3.5	14.4	6.4	3.5
Other mineral manufactures	88.6	13.9	59.0	2.3	41.6	5.7	6.2
Iron and steel:							
Scrap	49.6	8.5	126.5	.9	222.0	4.3	.9
Pig, shot, ferroalloys	29.6	5.9	6.4	.6	6.8	.7	2.8
Ingot	16.0	14.2	2.3	([2])	10.1	.1	([2])
Bar, rod, angle, section	73.3	35.4	13.1	.5	13.0	2.7	2.6
Plate and sheet	119.0	45.3	37.4	9.0	44.3	12.8	4.3
Hoop and strip	30.5	11.9	18.5	.4	4.9	1.8	2.3
Rails and track construction material	21.4	11.1	.8	([2])	5.6	.5	.1
Wire, except insulated electric	18.1	2.2	7.3	([2])	2.7	9.2	.2
Tube, pipe, fittings	224.8	74.0	93.2	24.7	180.7	69.4	9.8
Rough cast, forgings	292.7	4.4	21.3	.7	4.3	.3	2.0
Silver, platinum-group metals	10.5	1.8	29.3	([2])	48.9	([2])	.6
Metals and their alloys:							
Copper	63.3	10.0	95.3	3.2	20.1	2.3	1.3
Nickel	41.7	7.7	101.5	.1	7.2	.6	2.3
Aluminum	203.1	62.2	129.2	1.8	56.0	16.5	6.2
Lead	3.4	.7	3.0	([2])	1.1	.1	.1
Zinc	3.9	.7	1.9	([2])	.9	.4	.3
Tin	5.1	2.2	.7	--	.6	([2])	.1
Uranium, thorium	.1	([2])	([2])	--	([2])	--	([2])
Other base metals	37.4	16.4	98.5	2.6	35.4	2.4	3.4

[1]Standard International Trade Classification.
[2]Less than 1/2 unit.

Note: Eastern Europe includes Albania, Bulgaria, Czechoslovakia, German Democratic Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, the U.S.S.R., and Yugoslavia. Not shown are $8.7 million in exports to centrally planned Asian countries.

Source: U.S. Department of Commerce, Bureau of the Census.

Table 11.—Value of U.S. imports of selected mineral products in 1977 by area of origin

(Million dollars)

Products by SITC code[1] (Nos. 27130-56130)	America		Europe		Asia	Africa	Oceania
	North	South	West	East			
Crude phosphate and apatite	2.7	([2])	--	--	--	3.4	--
Gypsum and gypsum cement	21.8	--	0.1	--	0.2	--	--
Sulfur	63.8	0.9	.1	--	.3	--	--
Emery, pumice, corundum	.1	([2])	3.2	--	.1	.2	--
Graphite, natural	1.8	.1	1.1	0.6	1.6	1.2	--
Magnesia	([2])	--	11.4	([2])	2.0	([2])	0.2
Salt	24.6	.2	1.8	--	([2])	--	--
Asbestos	131.4	--	([2])	1.9	([2])	12.1	--
Mica	([2])	.5	([2])	--	1.2	.1	--
Fluorspar	33.8	([2])	12.4	--	.5	13.7	--
Barium sulfate, carbonate	3.6	5.5	5.6	--	1.3	2.3	--
Talc	.4	--	1.0	--	.7	--	--
Iron and steel scrap	134.1	--	4.7	--	.2	--	--
Ores and concentrates:							
Iron	695.5	215.2	4.0	1.1	([2])	36.1	5.8
Copper	20.7	4.3	([2])	--	20.7	([2])	2.8
Bauxite	242.1	75.6	.4	--	([2])	44.0	([2])
Lead	22.4	3.4	--	--	--	--	8.9
Zinc	32.4	4.6	.3	--	1.3	--	1.0
Tin	--	60.4	--	--	.4	([2])	--
Manganese	3.3	11.9	--	--	--	39.8	1.7
Chrome, ore only	--	.3	20.3	11.1	8.6	25.9	--
Tungsten	21.7	18.5	2.4	--	6.6	1.4	1.1
Tantalum, molybdenum, vanadium	7.6	1.4	1.8	--	.9	1.6	.4
Titanium	2.5	1.8	1.6	--	--	--	11.2
Zirconium, ore only	.2	--	--	--	--	([2])	11.2
Antimony ores and needles	3.2	1.6	.1	--	--	2.4	--
Beryllium	--	.3	([2])	--	([2])	--	([2])
Columbium	3.0	1.2	.3	--	.6	1.3	--
Platinum-group metals[3]	9.5	1.0	7.3	--	--	.3	.4
Uranium, thorium	--	--	--	--	.4	--	.5
Waste and scrap:							
Copper	30.0	([2])	1.8	--	.4	--	--
Nickel	3.4	([2])	3.0	--	.1	--	([2])
Aluminum	28.4	.3	7.4	27.0	([2])	--	--
Magnesium	.2	--	3.2	--	.2	.2	([2])
Lead	1.2	--	.6	--	([2])	--	--
Zinc	.5	([2])	1.6	--	([2])	--	--
Tin	.2	.4	([2])	--	.2	([2])	--
Mercury, except alloys	.7	--	1.0	.3	--	1.1	([2])
Alumina	111.2	54.4	22.8	--	7.2	--	318.8
Potassic fertilizer	347.3	.3	8.8	1.4	8.1	--	--

[1]Standard International Trade Classification.
[2]Less than 1/2 unit.
[3]Also includes scrap and waste.

Note: Eastern Europe includes Albania, Bulgaria, Czechoslovakia, German Democratic Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, the U.S.S.R., and Yugoslavia. Not shown are imports (in millions) of $5.3 from centrally planned Asian countries, consisting of tungsten ores, $4.3; graphite, $0.7; and columbium ores, $0.4.

Source: U.S. Department of Commerce, Bureau of the Census.

Table 12.—U.S. consumption of selected mineral products, and projections of consumption to year 2000

Commodity, mineral content measured		1973	1974	1975	1976	1977	2000
Iron ore	thousand short tons	92,500	90,800	77,200	79,900	73,400	129,000
Steel	do	142,500	138,400	104,100	115,000	128,100	188,000
Chromite	do	1,387	1,447	881	1,006	1,000	1,240
Cobalt	short tons	9,371	9,431	6,394	8,241	8,289	20,200
Columbium	do	5,598	7,193	4,231	6,003	4,777	23,600
Manganese ore (35% or more Mn)	thousand short tons	2,140	1,880	1,819	1,601	1,359	2,130
Molybdenum	thousand pounds	57,049	63,476	51,743	50,448	54,557	188,000
Nickel	thousand short tons	198	208	146	163	155	580
Tungsten	thousand pounds	15,386	16,298	14,012	16,107	17,100	58,000
Vanadium	short tons	8,549	8,453	7,858	9,779	8,019	33,000
Aluminum	thousand short tons	5,825	5,428	3,904	r5,113	5,472	20,000
Antimony, primary	short tons	20,613	18,041	12,987	15,337	13,823	48,000
Cadmium	do	6,267	6,050	3,368	5,932	4,480	12,700
Copper, refined	thousand short tons	2,437	2,194	1,535	1,992	2,185	5,100
Gold (industry, arts)	thousand troy ounces	6,729	4,651	3,993	4,648	4,859	8,500
Lead	thousand short tons	1,541	1,599	1,297	1,490	1,582	2,330
Mercury	flasks	54,283	59,479	50,838	r64,870	61,259	102,000
Platinum-group metals	thousand troy ounces	1,834	1,981	1,309	1,603	1,592	3,058
Silver (industry, arts)	million troy ounces	196	176	158	171	154	310
Silver (coinage)	thousand troy ounces	920	1,017	2,740	1,315	91	NA
Tin	thousand metric tons	76	66	56	63	61	62
Titanium concentrate	thousand short tons	1,366	1,402	1,127	1,264	1,155	1,414
Uranium, U_3O_8[1]	short tons	6,900	8,000	8,100	10,700	12,900	68,000
Zinc	thousand short tons	1,932	1,673	1,232	r1,537	1,508	2,200
Asbestos	do	883	846	608	726	672	1,038
Barite	do	1,820	1,835	1,952	2,139	2,449	NA
Cement	million short tons	90	83	70	74	82	130
Clays	thousand short tons	64,814	61,087	49,388	r52,389	53,468	174,000
Fluorspar	do	1,352	1,525	1,245	1,273	1,162	NA
Gypsum	million short tons	21,156	19,291	15,124	17,927	20,321	37,900
Mica	thousand pounds	6,443	7,160	5,369	5,559	4,592	NA
Lime	thousand short tons	21,090	21,606	19,133	20,229	19,947	43,120
Phosphate rock[2]	thousand metric tons	28,328	31,491	31,022	31,131	34,365	50,600
Potash	thousand short tons	9,641	10,538	8,671	r10,517	11,406	12,000
Salt	do	46,508	49,373	42,913	47,536	46,933	136,400
Sand and gravel	million short tons	984	979	789	885	898	1,150
Stone	do	1,060	1,044	901	902	955	1,600
Sulfur	thousand long tons	10,235	10,818	10,603	10,768	11,473	30,000
Talc	thousand short tons	1,189	1,064	931	901	1,114	NA

rRevised. NA Not available.

[1]For enrichment.
[2]Phosphate rock is not in mineral content, but instead is marketable phosphate rock.

Table 13.—Employment, turnover rates, hours, and earnings in selected industries

(Employment in thousands, turnover per hundred)

	1972	1973	1974	1975	1976	1977
All mining, including fuels						
All employees	628	642	697	752	779	809
Production workers	475	486	530	571	592	615
Accessions	3.8	4.1	4.5	3.8	3.9	4.0
Separations	3.8	3.9	3.9	3.4	3.6	3.6
Weekly hours	42.6	42.6	41.9	41.9	42.4	43.4
Hourly earnings	$4.44	$4.74	$5.23	$5.95	$6.46	$6.94
Metal mining						
All employees	82.7	87.4	95.4	93.5	94.1	91.1
Production workers	65.8	69.4	75.8	73.0	72.7	68.8
Accessions	3.3	3.7	3.6	2.7	3.2	2.9
Separations	3.4	3.3	3.2	3.2	2.9	3.6
New hires	2.3	3.1	3.0	2.0	2.1	2.1
Quits	1.7	2.0	2.0	1.4	1.4	1.5
Layoffs	.8	.3	.3	1.0	.8	1.2
Weekly hours	41.4	41.7	41.5	40.7	41.0	41.7
Hourly earnings	$4.56	$4.83	$5.44	$6.13	$6.76	$7.32
Iron ore mining						
All employees	22.0	23.6	23.8	23.5	24.5	19.4
Production workers	17.7	19.1	19.5	19.0	19.8	14.7
Accessions	2.9	2.7	2.6	2.3	2.7	2.6
Separations	3.2	2.1	2.1	2.7	2.7	3.8
New hires	.9	1.7	1.8	1.2	1.5	1.4
Quits	.7	.8	.9	.7	.6	.6
Layoffs	1.7	.5	.4	1.3	1.0	2.1
Weekly hours	40.9	41.9	43.1	41.9	41.5	41.2
Hourly earnings	$4.60	$4.88	$5.52	$6.29	$7.03	$7.49
Copper ore mining						
All employees	37.4	40.3	43.7	39.0	36.7	35.6
Production workers	29.8	32.2	34.6	30.0	28.1	27.1
Accessions	3.2	3.9	3.2	1.8	3.4	2.0
Separations	2.8	3.4	3.1	3.1	2.7	3.3
New hires	2.5	3.2	2.6	1.0	1.6	1.1
Quits	1.7	2.1	1.9	.9	.9	1.0
Layoffs	.2	.1	.3	1.4	1.1	1.4
Weekly hours	42.0	42.0	40.9	39.7	39.8	38.6
Hourly earnings	$4.66	$4.89	$5.54	$6.37	$7.04	$7.52
Nonmetallic minerals, except fuels						
All employees	116.2	118.6	121.8	116.7	114.6	116.5
Production workers	93.4	95.2	97.6	92.2	90.4	92.2
Accessions	3.8	4.9	4.6	3.6	3.4	3.9
Separations	3.9	4.4	4.4	3.9	3.5	3.8
New hires	3.0	3.8	3.7	2.4	2.2	2.5
Quits	2.1	2.6	2.4	1.4	1.4	1.6
Layoffs	1.1	1.0	1.3	1.8	1.5	1.6
Weekly hours	44.7	45.5	45.0	43.5	44.2	44.6
Hourly earnings	$3.94	$4.21	$4.50	$4.94	$5.36	$5.79
Crushed and broken stone						
All employees	42.8	43.5	44.3	41.0	39.5	40.0
Production workers	35.6	36.1	36.5	33.4	32.4	33.2
Accessions	3.8	5.2	4.9	3.6	3.5	4.5
Separations	4.2	4.9	4.8	4.3	3.5	4.5
New hires	2.8	3.9	3.7	2.2	2.0	2.4
Quits	2.0	2.9	2.4	1.2	1.2	1.5
Layoffs	1.5	1.3	1.7	2.4	1.7	2.4
Weekly hours	45.4	46.5	46.3	43.8	44.7	44.8
Hourly earnings	$3.93	$4.20	$4.48	$4.83	$5.19	$5.66
Sand and gravel						
All employees	37.3	38.4	37.6	34.9	34.0	34.5
Accessions	4.4	4.9	3.9	4.3	4.5	5.0
Separations	4.4	4.3	4.2	4.6	4.7	4.7
New hires	3.5	3.6	3.0	2.7	2.6	3.0
Quits	2.3	2.4	1.9	1.6	1.6	1.9
Layoffs	1.5	1.3	1.6	2.4	2.5	2.1
Manufacturing						
All employees	19,151	20,154	20,077	18,323	18,997	19,647
Production workers	14,046	14,838	14,637	13,043	13,638	14,110
Accessions	4.5	4.8	4.2	3.7	3.9	4.0
Separations	4.3	4.7	4.9	4.2	3.8	3.8
Weekly hours	40.5	40.7	40.0	39.5	40.1	40.3
Hourly earnings	$3.82	$4.09	$4.43	$4.83	$5.22	$5.67
Chemical, fertilizer minerals						
All employees	18.6	19.1	20.9	22.7	23.1	23.2
Hydraulic cement						
All employees	31.9	32.4	33.2	31.2	30.5	30.6
Production workers	24.9	25.4	26.1	24.4	24.1	24.2
Accessions	1.6	1.7	1.5	2.9	3.0	2.6
Separations	1.6	1.6	2.2	4.0	2.7	2.6

See footnotes at end of table.

Table 13.—Employment, turnover rates, hours, and earnings in selected industries —Continued

(Employment in thousands, turnover per hundred)

	1972	1973	1974	1975	1976	1977
Hydraulic cement —Continued						
New hires	1.2	1.3	1.2	.7	.9	1.1
Quits	.6	.7	.7	.4	.5	.6
Layoffs	.5	.3	.9	3.1	1.7	1.4
Weekly hours	41.9	42.4	42.3	41.6	41.9	42.4
Hourly earnings	$5.15	$5.51	$5.92	$6.36	$7.24	$7.88
Blast furnaces and steel mills						
All employees	488.3	519.0	521.4	468.7	469.0	469.6
Production workers	390.4	417.4	418.3	367.9	369.2	368.4
Accessions	3.1	2.5	2.0	2.8	3.2	2.8
Separations	2.2	2.2	2.3	4.1	3.1	3.0
New hires	.9	1.7	1.1	.3	.7	.7
Quits	.6	.9	.7	.2	.3	.4
Layoffs	.7	.4	.7	2.9	1.8	1.6
Weekly hours	40.4	41.5	41.2	39.4	40.1	40.3
Hourly earnings	$5.16	$5.61	$6.41	$7.13	$7.79	$8.59
Primary nonferrous metals						
All employees	62.6	66.3	71.8	66.3	66.2	64.8
Production workers	49.6	52.3	56.5	51.1	51.3	49.7
Accessions	2.1	2.2	2.2	1.4	2.5	1.8
Separations	2.1	2.1	1.9	2.9	1.8	1.7
New hires	1.2	1.7	1.9	.6	1.2	1.1
Quits	.9	1.0	1.0	.5	.6	.6
Layoffs	.5	.3	.3	1.7	.5	.5
Weekly hours	41.9	42.1	42.1	40.9	41.9	41.7
Hourly earnings	$4.59	$4.97	$5.62	$6.25	$6.86	$7.66
Primary aluminum						
All employees	27.5	30.0	33.6	29.3	30.7	32.3
Production workers	22.5	24.4	27.3	23.2	24.8	26.0
Weekly hours	42.0	42.2	42.5	41.3	41.8	41.4
Hourly earnings	$4.95	$5.38	$6.06	$6.64	$7.26	$8.23
Mining machinery						
All employees	23.6	24.9	27.5	31.8	34.1	33.8
Production workers	15.5	16.2	18.2	21.1	22.0	21.7
Weekly hours	41.2	41.5	42.4	41.2	39.8	40.5
Hourly earnings	$4.22	$4.56	$4.93	$5.45	$5.86	$6.42

Note: All data were revised to 1977 benchmark levels and recoded to the 1972 Standard Industrial Classification as explained in the October 1978 issue of "Employment and Earnings." Hours and earnings data are for production workers. Some categories for sand and gravel, chemical, fertilizer minerals, primary aluminum, and mining machinery are not available.

Source: U.S. Department of Labor, Bureau of Labor Statistics. Employment and Earnings, United States, 1972-78, Bulletin 1312-11 (M).

Table 14.—National income, wages and salaries by industry and earnings by employee

		1972	1973	1974	1975	1976	1977
National income by industry:							
All industries	billions	$957	$1,073	$1,152	r$1,245	r$1,394	$1,555
Manufacturing	do	252	284	298	312	r363	409
Mining, including fuels	millions	8,700	10,149	15,539	r18,149	r20,267	23,179
Metal mining	do	1,073	1,489	1,596	r1,635	r1,900	2,067
Nonmetallic minerals, except fuels	do	1,571	1,883	2,074	r2,211	r2,261	2,340
Total wages and salaries paid:							
All industries	billions	633.8	701.2	764.1	r805.9	r890.1	983.6
Manufacturing	do	r175.2	r196.2	211.4	211.0	r237.5	266.3
Mining, including fuels	millions	6,625	7,290	8,827	r10,823	r12,200	14,055
Metal mining	do	918	1,012	1,196	1,317	1,462	1,566
Nonmetallic minerals, except fuels	do	1,101	1,218	1,349	1,405	1,512	1,649
Average annual earnings:							
All industries		8,760	9,290	9,991	r10,835	r11,602	12,372
Manufacturing		9,449	10,027	10,847	r11,903	r12,838	13,892
Mining, including fuels		10,790	11,683	12,905	r14,765	r16,053	17,352
Metal mining		10,675	11,500	12,458	14,161	15,720	17,022
Nonmetallic minerals, except fuels		9,919	10,591	11,432	12,325	13,381	14,593

r Revised.

Source: U.S. Department of Commerce, Bureau of Economic Analysis. Survey of Current Business, July 1976-78.

Table 15.—Indexes of mining expenses, and productivity in copper and iron ore mining

(1967=100)

Category of expense or productivity	1972	1973	1974	1975	1976	1977p
MINING EXPENSES						
All principal expenses	123	133	168	189	198	218
Labor	126	135	172	190	196	218
Supplies	120	128	157	177	188	202
Fuel	119	146	208	245	266	302
Electric power	122	129	163	193	208	233
PRODUCTIVITY						
Copper (recoverable metal):						
Labor costs per unit of output	138	154	190	202	190	206
Labor costs per dollar of product	104	100	95	121	106	119
Product value per production-worker period	136	150	178	160	203	193
Copper ore mined:						
Per employee	124	127	121	124	139	129
Per production worker	119	121	117	123	134	128
Per production worker-hour	118	118	118	129	143	136
Recoverable copper metal mined:						
Per employee	107	105	92	92	110	105
Per production worker	104	100	89	92	110	104
Per production worker-hour	102	97	89	96	113	111
Iron ore (recoverable metal):						
Labor costs per unit of output	115	118	155	180	201	228
Labor costs per dollar of product	109	105	118	109	110	115
Product value per production-worker period	126	134	143	177	196	198
Crude iron ore mined:						
Per employee	119	127	121	117	119	105
Per production worker	122	129	122	120	122	115
Per production worker-hour	124	127	118	117	119	113
Usable iron ore mined:						
Per employee	r114	r120	r111	107	107	93
Per production worker	r117	r122	r113	109	109	102
Per production worker-hour	r119	r120	r109	107	107	100

rRevised. pPreliminary.

Note: Indexes pertaining to mining expenses and recoverable metals were computed from U.S. Bureau of Labor Statistics data found in "Wholesale Price Indexes" and "Employment and Earnings."

Source: U.S. Department of Labor, Bureau of Labor Statistics. Productivity Indexes for Selected Industries.

Table 16.—Indexes of value of minerals produced

(1967=100)

Mineral group	1971	1972	1973	1974	1975	1976	1977[p]
IMPLICIT UNIT VALUE							
All minerals, except fuels	112.8	117.5	126.8	156.7	184.3	194.8	202.6
All metals	124.1	127.3	142.1	187.8	196.6	209.0	219.1
Ferrous metals	115.6	119.5	123.7	157.5	204.2	232.2	254.0
Nonferrous metals	128.7	131.4	153.3	205.8	192.3	196.8	204.2
Base	130.1	130.6	151.0	202.4	176.9	187.6	186.3
Monetary	107.9	136.2	212.2	369.4	356.5	312.2	347.6
Other	132.0	136.4	141.3	156.3	225.1	210.3	241.6
All nonmetals	107.3	112.5	119.2	141.8	178.3	187.5	195.3
Construction	112.8	120.6	127.0	146.5	169.9	184.1	197.4
Chemical	86.9	84.6	90.2	126.6	204.6	196.6	188.7
Other	115.2	119.8	128.0	145.0	169.5	190.2	198.3
AVERAGE UNIT MINE VALUE							
All minerals, except fuels	110.8	116.3	124.7	154.1	185.7	197.1	207.2
All metals	121.5	125.5	139.6	184.6	206.6	222.0	238.0
Ferrous metals	115.9	120.2	125.5	159.5	207.3	235.6	260.3
Nonferrous metals	127.8	131.5	155.5	212.8	205.8	206.7	212.7
Base	129.9	130.7	151.1	205.7	181.5	191.5	188.7
Monetary	108.8	138.1	222.3	380.2	373.5	319.4	361.1
Other	130.0	131.2	136.7	150.1	211.6	206.2	227.8
All nonmetals	106.9	113.0	119.4	143.1	178.2	188.1	196.0
Construction	112.7	120.8	127.2	147.2	170.6	184.8	198.3
Chemical	86.2	85.2	91.1	128.5	204.1	198.0	187.5
Other	115.7	123.4	132.5	148.7	172.2	192.0	201.4

[p]Preliminary.

Note: These indexes measure price changes between the given years and base year, 1967. The first index is calculated by dividing the Bureau of Mines Index of Value figures (not published) by the Index of Physical Volume of Mineral Production. The second index uses an actual or estimated mine value in all cases where a refinery or mill value was reported in the Bureau survey figures used in the first index. Weights are of the given year in the first index, and of the base year in the second index.

Table 17.—Wholesale price indexes of selected products

(1967=100)

Product	1972	1973	1974	1975	1976	1977
All commodities	119	135	160	175	183	194
Metal, metal products	124	133	172	186	196	209
Nonmetallic mineral products	126	130	153	174	186	200
Iron ore	103	107	123	154	171	186
Iron and steel	128	136	179	201	216	230
Iron and steel scrap	122	188	353	246	259	231
Semifinished steel products	131	134	169	207	223	240
Finished steel products	130	134	170	197	209	229
Pig iron, ferroalloys	125	129	188	265	262	256
Nonferrous metals	117	135	187	172	182	195
Primary aluminum	97	102	151	160	177	206
Lead, common pig	110	117	159	154	164	219
Zinc, prime western slab	123	147	249	270	261	240
Nonferrous scrap	103	148	198	128	155	162
Concrete ingredients	127	131	149	172	187	199
Sand and gravel, crushed stone	122	125	135	151	161	171
Gypsum products	115	121	138	144	154	183
Building lime	122	127	153	186	205	220
Insulation material	137	137	156	196	213	236
Fertilizer material	74	77	124	199	164	160
Phosphate rock	80	80	184	429	375	330
Potash	100	106	133	167	167	156
Coal	194	218	332	386	369	389
Coke	156	167	248	331	347	379
Gas fuels	114	127	162	217	287	388
Petroleum products	109	129	223	258	277	308
Electric power	122	129	163	193	208	233
Industrial chemicals	101	103	152	207	219	224
Lumber	159	205	207	192	233	277
Explosives	115	120	147	178	187	194
Construction machinery and equipment	126	131	152	185	199	214
Mining machinery and equipment	117	121	144	184	212	229
Cranes and excavators	126	130	152	184	201	214
Scrapers and graders	124	136	160	196	211	226
Mixers and pavers	126	130	145	161	169	183
Tractors other than farm	127	132	155	188	203	219

Source: U.S. Department of Labor, Bureau of Labor Statistics. Wholesale Prices and Price Indexes, Supplements 1973-78.

Table 18.—Annual profits on equity, and dividends paid in selected industries

Industry	Average annual profits after tax, on owners' equity (percent)			Dividends paid (million dollars)		
	1975	1976	1977	1975	1976	1977
Primary metals	8.6	8.5	4.9	1,188	1,186	1,226
Iron and steel	10.9	9.0	3.5	746	773	802
Nonferrous metals	5.0	7.4	7.2	442	414	423
Stone, clay, glass products	8.3	11.9	13.4	413	440	517
Chemicals and allied products	15.2	15.5	15.1	2,768	3,136	3,643
All manufacturing	11.6	13.9	14.2	19,968	22,763	26,650

Note: 1976 data have been revised to reflect the reclassification of companies by industry in early 1977.

Source: Federal Trade Commission. Quarterly Financial Report for Manufacturing, Mining and Trade Corporations. 1st and 4th Quarters 1977, tables 4, A-1, B-1, D-1.

Table 19.—Failure statistics and liabilities in mining and manufacturing

Industry		1971	1972	1973	1974	1975	1976	1977
Mining, including fuels:								
Failures	number	38	44	32	9	26	37	30
Current liabilities	millions	$15	$12	$24	$10	$9	$106	$42
Manufacturing:								
Failures	thousands	1.9	1.5	1.4	1.5	1.6	1.3	1.1
Current liabilities	billions	$.7	$.8	$.7	$.8	$1.0	$1.0	$1.2
All industries:								
Failures	thousands	10.3	9.6	9.3	9.9	11.4	9.6	7.9
Current liabilities	billions	$1.9	$2.0	$2.3	$3.1	$4.4	$3.0	$3.1

Source: Dun and Bradstreet, Inc., Business Economics Division. Monthly Failure Report.

Table 20.—Investment in plant and equipment in selected industries

(Billion dollars)

Industry	1971	1972	1973	1974	1975	1976	1977
All mining, including fuels	2.16	2.42	2.74	3.18	3.79	4.00	4.50
All manufacturing	29.99	31.35	38.01	46.01	47.95	52.48	60.16
Primary iron and steel	1.37	1.24	1.38	2.12	3.79	3.81	3.44
Primary nonferrous metals	1.08	1.18	1.67	2.33	2.28	2.16	2.24
Stone, clay and glass products	.85	1.20	1.49	1.44	1.42	1.72	1.99
Chemicals and allied products	3.44	3.45	4.46	5.69	6.25	6.68	6.83
Petroleum	5.85	5.25	5.45	8.00	10.51	11.62	13.87

Source: U.S. Department of Commerce, Bureau of Economic Analysis. Survey of Current Business, March 1972-78.

Table 21.—Investment in plant and equipment by foreign affiliates of U.S. companies

(Million dollars)

Industry and year	Canada	Latin America	Europe	Other areas	Total
Mining and smelting:					
1970	411	477	15	484	1,387
1971	827	209	5	424	1,465
1972	593	147	6	421	1,167
1973	554	185	11	351	1,101
1974	427	270	9	374	1,080
1975	534	317	6	316	1,173
1976	490	192	13	221	916
1977	391	74	11	332	808
Manufacturing:					
1970	1,159	669	3,614	1,081	6,523
1971	1,153	648	4,260	1,045	7,106
1972	1,504	840	4,082	708	7,134
1973	1,814	1,043	5,357	1,033	9,247
1974	2,677	1,217	6,374	1,358	11,626
1975	2,094	1,356	6,500	1,292	11,242
1976	2,165	1,615	6,547	1,140	11,467
1977	2,629	1,615	6,985	1,332	12,561

Source: U.S. Department of Commerce, Bureau of Economic Analysis. Survey of Current Business. September 1976-77.

Table 22.—Proceeds from primary security offerings

(Million dollars)

Industry and year	Bonds	Preferred stocks	Common stocks	Total
Extractive, including fuels:				
1972	706	3	1,301	2,010
1973	232	10	831	1,073
1974	258	--	723	980
1975	685	75	871	1,631
1976	1,023	140	606	1,771
1977	1,343	25	1,307	2,674
Manufacturing:				
1972	4,821	202	1,607	6,629
1973	4,241	107	537	4,885
1974	9,881	115	430	10,426
1975	17,097	537	1,134	18,767
1976	13,243	344	1,893	15,479
1977	12,510	541	724	13,776
Total corporate:				
1972	28,896	3,367	9,694	41,957
1973	22,251	3,383	7,800	33,434
1974	31,567	2,254	4,050	37,871
1975	41,740	3,458	7,426	52,624
1976	41,069	2,789	8,305	52,161
1977	40,050	3,878	8,135	52,062

Note: Proceeds include new issues of securities exceeding $100,000 in value maturing in more than 1 year.

Source: U.S. Securities and Exchange Commission. Statistical Bulletin, v. 37, No. 4, April 1978, pp. 13-14.

Table 23.—Income from, and investment position in foreign affiliates engaged in mining and smelting, by geographical area

(Million dollars)

Selected major areas	Total income consisting of		Yearend investment position
	Interest, dividends, unincorporated earnings	Reinvested earnings of incorporated affiliates	
1974			
All countries	680	187	5,790
Canada	125	84	2,794
Australia	129	58	952
Latin America	281	40	1,131
Argentina	(1)	5	50
Brazil	W	10	94
Chile	4	1	25
Mexico	10	23	83
Peru	68	1	412
1975			
All countries	448	238	6,548
Canada	99	150	3,053
Australia	189	43	1,055
Latin America	94	32	1,476
Brazil	W	19	130
Mexico	6	10	80
Peru	- 17	W	700
1976			
All countries	591	338	7,060
Canada	126	127	3,200
Australia	225	126	1,238
Latin America	233	42	1,601
Brazil	10	14	140
Chile	(1)	- 2	5
Jamaica	64	(1)	302
Mexico	5	4	89
1977			
All countries	632	180	7,066
Canada	160	72	3,212
Australia	229	77	1,255

See footnotes at end of table.

Table 23.—Income from, and investment position in foreign affiliates engaged in mining and smelting, by geographical area —Continued

(Million dollars)

Selected major areas	Total income consisting of: Interest, dividends, unincorporated earnings	Total income consisting of: Reinvested earnings of incorporated affiliates	Yearend investment position
1977 —Continued			
New Zealand and South Africa, Republic of	4	12	294
Latin America	194	24	1,579
Mexico	3	5	97
Other African countries	41	W	544
Other Asian and Pacific countries	W	W	132

W Withheld to avoid disclosing company proprietary data.
[1]Less than 1/2 unit.

Source: U.S. Department of Commerce, Bureau of Economic Analysis. Survey of Current Business, August 1976-78.

Table 24.—Mineral freight originating on rail and water carriers

(Million short tons)

Commodities, except fuels	Rail 1974	Rail 1975	Rail 1976	Water 1974	Water 1975	Water 1976
Bauxite	6.7	5.2	5.7	0.6	0.4	0.4
Copper ores	10.8	6.6	8.4	--	(1)	(1)
Iron ores and concentrates	103.1	89.6	77.7	79.9	69.3	73.6
Lead and zinc ores	2.1	1.7	1.9	NA	NA	NA
Manganese ores	1.1	.8	.8	1.2	1.1	.9
Other ores	2.7	2.5	2.4	.6	.7	.9
Steel works, rolling mill products	56.0	41.0	38.5	11.3	8.7	8.4
Iron and steel castings	3.0	2.2	2.1	--	--	--
Nonferrous metals and primary smelting products	7.4	5.1	5.8	.7	.5	.7
Other primary metal products	4.0	3.1	3.1	--	--	--
Iron and steel scrap	38.9	28.9	26.2	2.3	1.6	2.1
Nonferrous metal scrap	.4	2.1	2.0	.1	(1)	.2
Abrasives and asbestos	32.3	27.5	27.2	--	--	--
Cement	17.7	15.4	16.2	9.9	8.3	8.5
Clay	3.3	2.6	3.0	1.7	1.5	1.8
Fertilizer	19.6	18.5	15.9	6.1	6.0	6.6
Gypsum	2.0	1.5	1.7	.7	.6	1.0
Limestone, agricultural and lime	8.8	7.4	6.2	.7	.5	.7
Limestone, flux	11.7	9.1	7.9	36.3	29.1	29.6
Phosphate rock	41.9	42.2	39.0	8.5	9.4	8.7
Sand and gravel	48.3	39.8	36.0	76.4	67.9	61.2
Stone, crushed	45.7	38.8	31.4	--	--	--
Sulfur	5.1	4.8	4.1	8.8	8.1	3.7
Other nonmetallic minerals	11.0	10.2	8.7	7.1	6.6	6.9
Total	483.6	406.6	371.7	252.9	220.4	216.1
Other processed nonfuel minerals	(2)	(2)	63.9	(2)	(2)	30.4
Grand total	(2)	(2)	435.6	(2)	(2)	246.5

NA Not available.
[1]Less than 1/2 unit.
[2]Not computed prior to 1976.

Source: Interstate Commerce Commission, Bureau of Accounts. Freight Commodity Statistics, Class I Railroads in the United States, 1975-76. Department of the Army, Corps of Engineers. Waterborne Commerce of the United States, Part 5. National Summaries, table 2, 1975-76.

Table 25.—Metallurgy and materials research funds obligated by fiscal year

(Million dollars)

Federal agency	1976 research		1977 research		1978 research		
	Basic	Applied	Basic	Applied	Basic	Applied	Total
Department of Defense	29.7	80.3	33.7	76.2	37.1	79.6	116.8
Energy Research and Development Administration	40.2	13.2	56.9	15.6	63.2	18.1	81.3
National Aeronautics and Space Administration	7.3	34.7	4.7	62.8	5.3	103.6	108.9
Bureau of Mines	.1	43.4	.1	41.8	.1	40.9	41.0
National Science Foundation	16.7	2.1	17.4	1.2	14.5	1.2	15.7
Department of Commerce	1.0	1.2	1.1	1.3	.9	1.1	2.0
Other	(1)	.1	(1)	.5	(1)	.5	.6
Total[2]	95.0	175.5	113.9	199.4	121.1	245.1	366.3

[1]Less than 1/2 unit.
[2]Data may not add to totals because of independent rounding.

Source: National Science Foundation. Federal Funds for Research, Development and Other Scientific Activities, Fiscal Years 1976-78, v. 26, Detailed Statistical Tables, Appendices C-D. NSF 77-317, July 1978, tables C-24, C-25, C-43, C-44, C-62, C-63.

Table 26.—Mining and mineral research and development funds obligated by Bureau of Mines, by fiscal year

(Million dollars)

	1972	1973	1974	1975	1976	T. Qtr.	1977	1978[e]
Applied research	32.8	34.6	24.9	51.0	72.5	24.3	48.3	48.4
Basic research	7.8	6.9	5.6	1.9	.8	.2	4.0	8.6
Development	30.2	36.0	35.6	48.7	58.0	20.3	49.6	57.0
Total research	40.6	41.5	30.5	52.9	73.3	24.5	52.3	57.0
Total research and development	70.8	77.5	66.1	101.6	131.3	44.8	101.9	114.0
Research science:								
Engineering	28.7	30.5	23.9	47.7	67.5	23.0	44.0	42.3
Physical	10.5	9.3	5.3	1.9	1.8	.5	3.7	3.5
Mathematical	.5	.6	.5	1.3	1.6	.4	1.6	2.9
Environmental	.9	1.1	.8	2.0	2.4	.6	2.9	7.0

[e]Estimate.

Fiscal year 1976: 7/1/75-6/30/76.
Transition quarter: 7/1/76-9/30/76.
Fiscal year 1977: 10/1/76-9/30/77.
Fiscal year 1978: 10/1/77-9/30/78.

Table 27.—Strategic and critical materials stockpile at yearend

(Million dollars)

Inventories	Acquisition cost			Approximate market value		
	1975	1976	1977	1975	1976	1977
National stockpile	2,554.8	2,479.2	2,501.1	5,258.9	6,013.9	7,121.8
Supplemental stockpile	1,095.1	1,076.1	1,058.5	1,947.9	1,899.9	1,893.2
Defense Production Act	310.4	297.1	161.3	225.9	246.7	137.8
Total on hand[1]	3,960.2	3,852.3	3,721.0	7,432.7	8,160.4	9,152.8
Total less unshipped sales	NA	NA	NA	6,320.3	6,410.1	8,786.4

NA Not available.
[1]Data may not add to totals because of independent rounding.

Source: General Services Administration, Office of Finance. Status of Defense Materials Inventories, Dec. 31, 1977.

Table 28.—Sales commitments of mineral commodities from stockpile in fiscal year 1977

Commodity		Quantity	Sales value
NATIONAL AND SUPPLEMENTAL STOCKPILE INVENTORIES			
Asbestos, amosite	short tons	121	$45,884
Cobalt	pounds	-31,364	-161,215
Diamonds, industrial, bort	carats	2,600,975	5,990,733
Diamond tools	pieces	15,396	64,979
Magnesium	short tons	500	885,000
Manganese, battery grade, natural ore	short dry tons	3,368	164,200
Mica, muscovite film	pounds	67,337	212,546
Mica, muscovite splittings	do	970,564	608,430
Mica, phlogopite splittings	do	232,181	143,672
Quartz crystals	do	63,225	726,389
Rare earths oxide	short dry tons	2,574	1,063,790
Talc, steatite	short tons	527	2,498
Talc, steatite, block and lump	do	4	1,075
Thorium nitrate	pounds	22,000	49,500
Tin	long tons	2,353	25,974,768
Tungsten ores and concentrates	pounds	2,922,679	25,661,434
Total		--	61,433,683
DEFENSE PRODUCTION ACT INVENTORY			
Manganese, metallurgical grade	short dry tons	72,016	1,807,744
Mica, muscovite film	pounds	4,569	17,201
Tungsten ores and concentrates	do	540,801	5,229,577
Total		--	7,054,522
OTHER			
Lithium	pounds	3,456,275	2,578,075
Mercury	flasks	1,200	149,319
Total		--	2,727,394
Grand total		--	71,215,599

Source: General Services Administration, Federal Preparedness Agency. Stockpile Report to the Congress, October 1976-March 1977, April-September 1977.

Table 29.—United Nations indexes of mineral industry production by area of world

(1970=100)

Industry sector and geographical area	1973	1974	1975	1976	1977
EXTRACTIVE INDUSTRIES					
Metals:					
Market economy countries	104	104	97	101	101
Developed[1]	100	100	93	95	94
United States and Canada	103	104	95	100	96
Europe	104	106	98	96	90
European Economic Community[2]	90	88	83	78	71
European Free Trade Association[3]	112	119	105	105	95
Australia and New Zealand	102	102	104	100	110
Developing	110	111	103	110	112
Latin America	109	118	108	117	124
Asia	103	95	97	100	100
Centrally planned (Europe)[4]	118	119	122	123	124
World	107	108	103	106	106
Total extractive industry: (see note)					
Market economy countries	112	112	106	112	116
Developed[1]	104	104	101	103	106
United States and Canada	105	104	103	104	107
Europe	100	99	95	98	100
European Economic Community[2]	100	97	93	96	97
European Free Trade Association[3]	110	111	102	103	96
Australia and New Zealand	136	144	144	144	152
Developing	123	125	114	126	131
Latin America	105	108	102	105	109
Asia	145	148	135	152	156
Centrally planned (Europe)[4]	118	124	132	138	142
World	114	116	114	120	124

See footnotes at end of table.

Table 29.—United Nations indexes of mineral industry production by area of world —Continued

(1970=100)

Industry sector and geographical area	1973	1974	1975	1976	1977
PROCESSING INDUSTRIES					
Base metals:					
Market economy countries	117	120	102	111	112
Developed[1]	117	118	99	108	107
United States and Canada	117	115	92	102	103
Europe	112	117	100	107	105
European Economic Community[2]	109	112	93	101	98
European Free Trade Association[3]	113	116	102	105	103
Australia and New Zealand	107	111	109	105	101
Developing	121	136	142	153	161
Latin America	128	145	148	152	162
Asia	105	121	136	164	169
Centrally planned (Europe)[4]	128	126	135	146	151
World	118	121	112	121	123
Nonmetallic mineral products:					
Market economy countries	122	121	114	124	131
Developed[1]	121	118	109	119	124
United States and Canada	123	120	111	125	133
Europe	118	118	109	116	119
European Economic Community[2]	116	116	106	113	115
European Free Trade Association[3]	117	119	103	104	107
Australia and New Zealand	122	114	116	122	123
Developing	131	139	149	162	176
Latin America	135	143	151	161	170
Asia	125	135	148	170	197
Centrally planned (Europe)[4]	125	135	144	152	159
World	124	126	126	135	142
OVERALL INDUSTRIAL PRODUCTION (see note)					
Market economy countries	120	121	115	125	130
Developed[1]	119	119	112	121	126
United States and Canada	120	119	111	123	129
Europe	116	118	111	119	122
European Economic Community[2]	114	115	108	116	118
European Free Trade Association[3]	115	119	112	114	116
Australia and New Zealand	115	116	117	120	121
Developing	128	135	137	148	157
Latin America	131	141	138	146	150
Asia	123	139	142	158	173
Centrally planned (Europe)[4]	129	140	152	163	175
World	122	126	125	135	142

[1]Includes nations shown plus Israel, Japan, and the Republic of South Africa.

[2]Belgium, Denmark, France, Ireland, Italy, Luxembourg, the Netherlands, the United Kingdom, and the Federal Republic of Germany.

[3]Austria, Norway, Portugal, Sweden, and Switzerland.

[4]Bulgaria, Czechoslovakia, German Democratic Republic, Hungary, Poland, Romania, and the U.S.S.R.

Note: The world category does not include Albania, the People's Republic of China, Mongolia, North Korea, and Vietnam. Data for the extractive industries of coal, crude petroleum, and natural gas; and for the processing industries of chemicals, petroleum, and coal products are included in the respective subtotal and total figures. Data for these excluded fuel categories, including all quarterly data for 1977 for this table, are presented in volume III of the 1977 Yearbook.

Source: United Nations Monthly Bulletin of Statistics. August 1978, pp. 14-27.

Table 30.—Value of world export trade in major mineral commodities and indexes of prices

Commodity group	1972	1973	1974	1975	1976	1977
VALUE OF WORLD EXPORTS (BILLION DOLLARS)						
All commodities	r413.5	r574.6	r838.2	r872.2	988.8	NA
Total minerals	r84.6	r124.7	r265.0	r253.5	287.8	NA
Total metals	39.8	r57.8	r86.8	r78.3	81.9	NA
Metal ores, concentrates, scrap	7.7	11.0	r15.6	14.4	15.8	NA
Iron and steel	20.1	28.5	46.4	45.8	44.7	NA
Nonferrous metals	11.9	r18.3	r24.8	r18.1	21.5	NA
Total nonmetals, crude	r3.0	3.8	r5.8	r6.2	6.3	NA
Mineral fuels	r41.8	r63.0	r172.4	r169.1	199.6	NA
INDEXES OF EXPORT PRICES (1970=100)						
All crude minerals	131	173	473	494	510	554
Metal ores	107	130	175	206	209	214
Fuels	140	189	577	588	616	674
Developed areas:						
Total minerals	118	150	274	301	302	315
Nonferrous base metals	89	119	149	125	137	146
Developing areas:						
Total minerals	136	182	555	571	595	650
Nonferrous base metals	82	127	160	109	121	128

rRevised. NA Not available.

Source: United Nations Monthly Bulletin of Statistics. March 1978, p. 162; and June 1978, pp. 32-34.

Mining and Quarrying Trends in the Metal and Nonmetal Industries

By Franklin D. Cooper[1]

The value of nonfuel raw mineral production in the United States for 1977 increased over that of 1976 by 5%, from $16.7 billion to $17.5 billion. Metals declined by 5% from $6.1 billion to $5.8 billion, chiefly because of strikes in the iron ore industry and a depressed copper market. Subsidization of mining industries in some foreign countries accounted in part for the excess of copper and some other metals on world markets. Weak metal markets and continued slowdowns in the world economy were the main reasons of the virtual absence of new mine projects.

Increasing domestic governmental involvement affecting mineral industry activities, such as pricing controls, public land withdrawals, and the Surface Mining Control and Reclamation Act, effective August 3, continued to be controversial and to be criticized by various segments of the industry.

Large capital outlay and the long lead time to attain production from a new facility were also of concern. Because of increasing costs and depletion of higher-grade reserves, the mining industry relied heavily on technology to develop more efficient mining and processing methods.

The use of raise- and shaft-boring was popular, compared with former development practices, because less completion time was required. Mine ventilation was improved and less maintenance was needed after the boring was completed. Four U.S. companies produced raise-boring machines, one of which could produce a 350,000-foot-pound torque and a 2-million-pound thrust. One manufacturer patented a "taper-lock" removable stem to eliminate the replacement of entire boring heads up to 20 feet in diameter when only the stem is broken.

Although pneumatic drill rigs dominated in most underground mines, hydraulic percussion drills with one single moving part gained favor because of faster penetration and less noise while requiring less energy and maintenance.

A twin-boom tunneling jumbo equipped with a dry dust collector met the strict requirements of environmental inspectors in an underground limestone mine.

The Bureau's continuous spiral drill-and-blast concept, when tested in the White Pine Copper mine, indicated advance rates four times that of conventional drill-and-blast methods.

Explosives manufacturers introduced a new plastic connector, the Safe-T-Tube, to prevent premature detonation of detonating cord. Two new explosives were made available for underground blasting.

Diesel-powered haulage continued to increase in noncoal underground mines.

A roof-support system using 14- to 18-foot-long fiberglass beams permitted a continuous mining operation, as demonstrated in a Pennsylvania mine, to advance 20 feet farther than with steel beams previously used. The Bureau of Mines developed an improved method for anchoring roof bolts, using a cartridge containing quick-setting portland-gypsum cement and microencapsulated water.

Tungsten-halogen lighting was initially introduced in underground mines as were two new designs of roof bolts.

In the surface mining sector, trends in new equipment were diversified. A 16-cubic-yard hydraulic-type shovel was being tested by Reserve Mining Co. Ten of these units were reportedly sold to the U.S.S.R. However, for sizes larger than 11.5 cubic yards, cable operated shovels, according to operators' statistics, tend to be more reliable, have a longer life, and are cheaper to operate. A new small walking dragline capable of using a 10- to 16-cubic-yard bucket on a 140- to 200-foot boom was introduced. The modular design of the machine permitted it to be assembled in 124 hours, using an experienced 6-worker crew. Disassembly required 76 hours by the same crew. A new front-end-loader weighing system was introduced that recorded single and cumulative load weights for inventory control and productivity measurements. Two new 6-ton-capacity load-haul-dump (LHD) machines were introduced. One featured two loading buckets; the other had a 21,000-pound breakout force.

Drilling and blasting practices continued to change because of increasing governmental regulations limiting noise and surface vibration. In a joint effort with the Engineering Contractors' Association of South Florida, the Bureau of Mines developed an explosive-loading technique that can eliminate the often dangerous "kelly-bar" stem loading method.

More rotary drilling was used in open pits as higher benches, wider spacing, and large-diameter holes became more commonplace.

Bulldozers continued to increase in size. Three new machines were introduced. Rated horsepower ranged from 620 to 720, or about 15% higher than for previous models. One manufacturer introduced a track-type tractor with shock-proof sprockets that support the tractor, above the track roller frames.

For practical reasons, most U.S. mine haulage trucks remained below 200-ton capacity. Reasons usually given were: Over 200-tons, electric-wheel trucks require tires that are not readily available; the trucks have high initial and operating costs; and they require special conditions to realize maximum efficiency. A new 100-ton rear-dump truck with an all-hydraulic braking system was undergoing preproduction testing. The truck was said to be readily teamed with front-end loaders and loading shovels currently in use.

In operations handling large tonnages, the greater depth and steeper grades in some pits increased the expense of truck haulage. It was found advantageous in Duval Corp.'s Sierrita mine to replace 12 trucks by a $30.6 million conveyor haulage system. To provide continuous ore flow by preventing bridging problems in Duval's 6,540-ton-per-hour system, each of two 60-inch-diameter gyratory crushers was provided with a boom-mounted, 20,000-foot-pound hydraulic hammer delivering 400 to 500 blows per minute.

Growing use of computers was made for mine planning and production and haulage-truck assignments.

Progress in beneficiation and processing was highlighted by; automation of crushing and grinding circuits, process control using radioisotopic probes, onstream particle measurements, 1,000-cubic-foot flotation cells, new flotation reagents, smaller dimensioned but more efficient thickeners, and new ion exchange resins for absorption of precious and noble metals.

One company used a steel reinforced polyurethane medium to eliminate vibrating screen blinding.

Because of improved engineering and construction procedures, earth-bottom thickeners were increasingly used in porphyry-copper operations and for countercurrent decantation.

A spiral, inductive magnetic separation technique was developed that could produce a single-stage iron ore concentrate having the same metal content as normally recovered in two drum-type separators.

The Bureau of Mines developed economic methods for producing concentrates containing 28% to 31% P_2O_5 at 60% to 70% recovery from complex western phosphate rock.

The use of analog loop instrumentation increased the productivity of a uranium mill from 1,800 tons per day to 2,700 and a similar control system monitored the grinding circuit of a lead-zinc mill.

In one plant a controller, in conjunction with sensors evaluating the reflectance and scattering of 2,950-nanometer-wave-length light, kept the moisture content of green iron ore pellets at the required level.

Autogenous and semiautogenous grinding units continued to increase in number. A new mill liner system, with a reputed 15% to 20% reduction of energy consumption, was introduced. This system has liners of square cross section instead of the conventional wave pattern.

Magnitude of the Mining Industry.—The number of metal and nonmetal mines decreased from 15,279 in 1976 to 14,784 in 1977. Eight additional metal mines were added and 503 nonmetal mines discontinued operations.

In 1977, 25 of nonfuel mines produced more than 10 million tons of crude ore, the same as in 1976. The principal commodities produced in these mines were copper (11 mines), phosphate rock (7), iron ore (4), stone (1), sand and gravel (1), and other (1). Heading the list of metal mines in output of crude copper ore were the Utah Copper mine of Kennecott Copper Corp. and the Sierrita mine of Duval Sierrita Corp. The Minntac mine of United States Steel Corp. and the Peter Mitchell mine of Reserve Mining Co. were the leading iron ore producers, while the largest producer of molybdenum ore was Climax Molybdenum Co., a division of AMAX, Inc. The leading producers of crude nonmetal ore were three Florida phosphate rock mines - Suwanee of Occidental Petroleum Corp., and the Noralyn and Kingsford mines of International Minerals & Chemicals Corp.

The Utah Copper mine of Kennecott Copper Corp. was the leading metal mine in total materials handled, followed by the Sierrita mine of Duval Sierrita Corp. The Kingsford and Noralyn phosphate mines were the leading nonmetal mines in total materials handled.

The 25 leading metal mines, on the basis of crude ore produced, included copper (11), iron ore (9), and titanium (2), while phosphate rock (17) and stone (7) comprised the majority of the 25 largest nonmetal crude ore producers.

Materials Handled.—The U.S. mineral-producing industry, excluding fuels, handled a total of 4.3 billion tons of crude ore and waste, a decrease of 2% compared with that of 1976. Of the total materials handled, crude ore comprised 64%. In 1977, total materials handled decreased 300 million tons for metal mines and increased 200 million tons for nonmetal mines, compared with those of 1976. The largest decrease in metals occurred in copper mining; in nonmetal mining the largest increase was in phosphate rock.

The amount of waste handled in 1977 totaled 1,520 million tons compared with 1,510 million tons in 1972, and 1,030 million tons in 1967.

In 1977, more than 100 million tons of materials were handled in each of 9 States, compared with 10 States in 1976. Arizona was the leading State followed by Florida and New Mexico. These three States handled 29% of the U.S. total.

Value of Principal Mineral Products.—The values shown in table 4 represent crude ore treated or, in the case of some nonmetals, crude ore shipped.

The average value for all commodities including byproducts increased 2% compared with that of 1976. Of the metal commodities and byproducts, approximately 60% showed an increase in value and the average value increased 10%. The metals showing the greatest increases were silver, mercury, and lead with zinc showing the greatest decrease. For the nonmetal commodities including byproducts, 56% showed an increase in average value. The overall average of the nonmetals increased 5% compared with that of 1976. Among the nonmetals, talc, soapstone, and pyrophyllite, pumice, natural sodium carbonate showed the largest increases in average value, with barite showing the largest decrease.

Byproducts were responsible for increasing the average value of all but five of the metal mine products and all but five of the nonmetal products, as shown in table 4. The largest addition to average value by byproducts occurred in ores of fluorspar, 30%, and gypsum, 22%.

The value of byproducts in 1977 from underground metal mine ores averaged 7% of the total value of ores from which they were produced, while byproduct value averaged 8% of the total value of surface mined metal ores. Byproducts from all nonmetal mines, excluding stone, and sand and gravel, contributed about 2% of the total value of the nonmetal ores.

Ratio of Treated Ore to Marketable Product.—The number of tons of crude ore treated to obtain a unit of marketable product in the metals, varied from a high of 826 for uranium to a low of 0.1 for silver. For most nonmetals, the ratio generally is 1:1.

Comparison of Production From Surface and Underground Mines.—In 1977, surface mines produced 94% of the total ore and accounted for 96% of the total materials handled by the U.S. mineral industry, the same as in 1972. The respective figures for 1967 were 94% and 95%.

Crude iron ore (31%) and copper ore (47%) comprised 78% of the total crude ores produced in metal mines. Iron ore and copper mining together accounted for 76% of the total materials moved in 1977 in surface metal mines.

In nonmetal surface mining, phosphate rock (20%), sand and gravel (36%), and crushed and broken stone (39%), accounted for approximately 95% of all nonmetal materials handled in 1977.

The production of 9 metallic crude ores and 18 nonmetal ores came entirely from surface mines. Underground mines accounted for all production of potassium salts, and natural sodium carbonate.

Exploration and Development.—Total reported footage for development work performed in the United States in 1977 increased 151% while the total reported exploration footage increased 46% compared with 1976. Metal mine exploration work increased 54% while nonmetal exploration work decreased 60%.

Metal mining accounted for 84% of the total development footage and 99% of the exploration footage. The major portion of the metals development footage was in uranium, copper, and zinc. The majority of the nonmetals development footage was in phosphate rock and fluorspar.

Exploration drilling and trenching for uranium, gold, and bauxite accounted for 91% of the metals exploration footage. Exploration drilling and trenching for fluorspar and phosphate rock accounted for 71% of the total nonmetals exploration footage.

Of the total reported exploration footage of 21.2 million feet, the distribution was: Uranium, 67%; bauxite, 3%; lead, 2%; and zinc, 2%. Drilling and trenching for copper, molybdenum, tungsten, iron ore, and silver totaled 817,000 feet.

Of the total 162 million short tons of ores and wastes handled in mine development projects, 92% came from stripping. Of this total, uranium, 42%; iron ore, 31%; and copper, 7% accounted for most of the materials produced in development work. Leading States on the basis of materials produced in development work were: Wyoming, 40%; Minnesota, 19%; and Michigan, 11%.

U.S. mineral exploration in 1977 resulted in only a few announcements of new discoveries, some of which resulted from exploration started 3 to 10 years earlier. New exploration-related equipment resulted from modifications of the past art rather than major technological breakthroughs. Some large mining firms seriously examined the cost and usefulness of their exploration programs.

On a regional basis, Alaska, Arizona, Wisconsin, Michigan, and Maine had the most active exploration programs during 1977.

Exploration companies spent approximately $40 million in Alaska. Many of the more than 13,000 new claims recorded in the State were in the Delong Mountains of the Brooks Range.

In the contiguous United States the southern extension of the "Viburnum trend "in Missouri, and the Tennessee-Kentucky zinc district were explored by base metal mining companies. A significant discovery of massive sulfide was made near Ashland, Maine.

West of the Mississippi River, a large porphyry copper deposit was found at Francisco Grande, Ariz. A deposit of porphyry-type molybdenum was found in southern Utah. Estimates of molybdenite mineralization near Crested Butte, Colo., were raised to 165 million tons. An aeromagnetic survey of Idaho's Coeur d'Alene District indicated the existence of a deeply buried intrusion east of Mullan. Underground workings were completed to permit diamond drilling beneath the Twin Buttes open pit copper mine in Arizona. Fifteen major shafts totaling 8,100 feet of depth were completed at a uranium operation near Uravan, Colo.

Most uranium exploration was designed to locate lateral and vertical extensions of ore in Wyoming, Colorado Plateau, Ambrosia Lake, and the Texas Coastal Plain. There was also an intense interest in "porphyry" uranium deposits in conglomerates in the North Central States, in Triassic basins in the East and Southwest, and in the Nevada-Oregon intermontane basins. No major discoveries of interest were reported from these areas.

The largest expenditures for exploration in 1977 included those by the U.S. Department of Energy, Exxon Co. U.S.A., Wyoming Mineral Corp., Gulf Mineral Resources Co., Kerr-McGee Corp., the Tennessee Valley Authority, Getty Oil Co., and a West German consortium. Many smaller groups spent sums in the $1 to $3 million range.

Governmental and private industry exploration programs for uranium exploration amounted to $258 million, but overall it was not a very productive year.

No breakthroughs in ore-finding techniques were announced in 1977. Newmont Mining Corp. advocated the use of a ground search system, called electromagnetic-pulse (EMP), for massive sulfide exploration. The developer of this instrument stated that the practical limit of the system is near and that few additional advances can be expected.

Landsat imagery data and its interpretation was used on ore bodies that lie at, or near, lineament intersections.

Despite its relatively high cost, side-looking-radar was proven to be useful for rapid structural interpretations in thickly forested or deeply weathered terrain.

An improved drill hole logging system, using neutron-activation analysis, was announced. Core drilling may be unnecessary because sufficient data may be obtained by lowering the instrument through a percussion- or rotary-drilled borehole for quick results onsite.

A process was developed at Stanford University to efficiently sort particles as small as 1.7 millimeters and to detect fluorescent minerals. Photometric sorting was used elsewhere on gold, uranium, and copper ores.

Major diamond drilling contractors estimated that the average depth of drill holes for base metals was increasing about 5% annually.

Many base metals exploration groups switched emphasis from general exploration to exploration for massive sulfides.

There was some shift to exploration on private lands, particularly in the Eastern States in areas not under control of the U.S. Forest Service.

Explosives.—Apparent consumption of industrial explosives in the United States during 1977 increased 11.4% compared with that of 1976 to a record high of 3.7 billion pounds. This is the third successive year that the total surpassed 3 billion pounds. Bulk blasting agent consumption rose 15%, water gels and slurries declined 6.5%, permissible explosives rose 9.5%, and other high explosives declined 7.2% compared with 1976.

Nearly two-thirds (65.4%) of the total weight of explosives and blasting agents was used in coal mining. This total consisted of 95.4% of all permissible explosives and 62.5% of cylindrically packaged blasting agents and bulk blasting agents consumed. Quarrying, (33.9%) and construction, (27.6%) consumed the majority of all other high explosives. Metal mining used the majority (48.8%) of the water gels and slurries.

Seven States, namely Kentucky, Pennsylvania, Alabama, Ohio, Virginia, West Virginia, and Arizona, consumed 58.8% of all explosives and blasting agents used in the United States in 1977.

The apparent differences in 1977 consumption shown in tables 17-18, compared with prior years, are due to a change in category classification made by the Institute of Makers of Explosives (IME). In the change, processed blasting agents were added to the cylindrically packaged blasting agent category and the other processed blasting agent category now includes only unprocessed ammonium nitrate.

More detailed explosives information is published in the annual Explosive issue of Mineral Industry Surveys, prepared by the Division of Nonmetallic Minerals, Bureau of Mines.

---

[1]Physical scientist, Division of Ferrous Metals.

Table 1.—Material handled at surface and underground mines in the United States, by type

(Million short tons)

Type and year	Surface			Underground			All mines[1]		
	Crude ore	Waste	Total[1]	Crude ore	Waste	Total[1]	Crude ore	Waste	Total
Metals:									
1972	491	1,080	1,570	86	5	91	576	1,080	1,660
1973	574	1,280	1,860	82	9	91	655	1,290	1,950
1974	547	1,210	1,760	80	11	91	627	1,220	1,850
1975	535	1,170	1,700	74	13	87	609	1,180	1,790
1976	573	1,250	1,820	73	15	87	646	1,260	1,910
1977	490	1,030	1,530	74	12	87	564	1,050	1,610
Nonmetals:									
1972	2,020	415	2,430	77	5	82	2,100	420	2,520
1973	2,240	418	2,650	82	1	83	2,320	419	2,740
1974	2,220	418	2,640	82	5	87	2,300	423	2,720
1975	1,910	372	2,290	79	6	84	1,990	378	2,370
1976	2,000	393	2,390	80	6	86	2,080	399	2,480
1977	2,120	472	2,590	80	6	86	2,200	478	2,680
Total metals and nonmetals:[1]									
1972	2,500	1,500	4,000	163	10	173	2,670	1,510	4,180
1973	2,810	1,700	4,510	163	11	174	2,970	1,710	4,680
1974	2,760	1,630	4,390	162	16	178	2,930	1,650	4,570
1975	2,450	1,540	3,990	153	18	171	2,600	1,560	4,160
1976	2,570	1,640	4,210	153	21	174	2,720	1,660	4,390
1977	2,610	1,510	4,120	155	18	173	2,760	1,520	4,290

[1]Data may not add to totals shown because of independent rounding.

Table 2.—Material handled at surface and underground mines in 1977, by commodity[1]

(Thousand short tons)

Commodity	Surface			Underground			All mines[2]		
	Crude ore	Waste	Total[2]	Crude ore	Waste	Total[2]	Crude ore	Waste	Total
METALS									
Bauxite	3,980	15,200	19,100	--	--	--	3,980	15,200	19,100
Copper	240,000	594,000	834,000	25,700	1,500	27,200	266,000	596,000	861,000
Gold:									
Lode	2,890	14,400	17,200	1,670	236	1,910	4,560	14,600	19,200
Placer	3,150	762	3,920	--	(3)	(3)	3,150	762	3,920
Iron ore	170,000	154,000	324,000	7,090	757	7,840	177,000	155,000	332,000
Lead	3	10	13	9,840	2,230	12,100	9,840	2,230	12,100
Mercury	215	900	1,120	--	--	--	215	900	1,120
Silver	553	608	1,160	928	501	1,430	1,480	1,110	2,590
Titanium, ilmenite	37,500	356	37,900	--	--	--	37,500	356	37,900
Tungsten	1,000	10	1,010	748	444	1,190	1,750	454	2,210
Uranium	16,800	227,000	244,000	5,110	4,420	9,530	21,900	232,000	253,000
Zinc	W	W	W	8,560	1,740	10,300	8,560	1,740	10,300
Other[4]	14,000	28,000	42,000	14,700	547	15,200	28,700	28,500	57,200
Total metals[2]	490,000	1,030,000	1,530,000	74,300	12,400	86,700	564,000	1,050,000	1,610,000
NONMETALS									
Abrasives[5]	348	377	725	78	--	78	426	377	803
Asbestos	2,550	3,880	6,430	W	W	W	2,550	3,880	6,430
Barite	3,770	645	4,410	W	W	W	3,770	645	4,410
Clays	47,800	e41,500	89,300	753	e11	764	48,600	41,500	90,100
Diatomite	1,790	4,890	6,680	--	--	--	1,790	4,890	6,680
Feldspar	1,480	145	1,620	W	--	W	1,480	145	1,620
Fluorspar	56	55	111	542	42	584	598	97	695
Gypsum	11,500	9,960	21,500	2,450	--	2,450	14,000	9,960	23,900
Mica (scrap)	986	343	1,330	--	--	--	986	343	1,330
Perlite	778	202	980	--	--	--	778	202	980
Phosphate rock	182,000	328,000	510,000	W	W	W	182,000	328,000	510,000
Potassium salts	--	--	--	19,000	165	19,200	19,000	165	19,200
Pumice	4,110	331	4,440	--	--	--	4,110	331	4,440
Salt	624	--	624	14,500	699	15,200	15,100	699	15,800
Sand and gravel	929,000	--	929,000	--	--	--	929,000	--	929,000
Sodium carbonate (natural)	--	--	--	11,300	5,000	16,300	11,300	5,000	16,300
Stone:									
Crushed and broken	922,000	e75,800	998,000	31,000	e200	81,200	953,000	76,000	1,030,000
Dimension	e3,070	e1,620	4,690	17	--	17	3,080	1,620	4,700

See footnotes at end of table.

Table 2.—Material handled at surface and underground mines in 1977, by commodity[1] —Continued

(Thousand short tons)

Commodity	Surface			Underground			All mines[2]		
	Crude ore	Waste	Total[2]	Crude ore	Waste	Total[2]	Crude ore	Waste	Total
NONMETALS—Continued									
Talc, soapstone, pyrophyllite	935	2,440	3,380	267	116	383	1,200	2,560	3,760
Other[6]	7,890	1,490	9,380	327	22	348	8,220	1,510	9,730
Total nonmetals[2]	2,120,000	472,000	2,590,000	80,200	6,050	86,500	2,200,000	478,000	2,680,000
Grand total[2]	2,610,000	1,510,000	4,120,000	155,000	18,400	173,000	2,760,000	1,520,000	4,290,000

[e]Estimate. W Withheld to avoid disclosing company proprietary data; included in "Other."
[1]Excludes material from wells, ponds, or pumping operations.
[2]Data may not add to totals shown because of independent rounding.
[3]Less than 1/2 unit.
[4]Antimony, beryllium, manganiferous ore, molybdenum, nickel, rare-earth metals, vanadium, zinc, and quantity of metal items indicated by symbol W.
[5]Emery, garnet, and tripoli.
[6]Aplite, boron minerals, graphite, greensand marl, iron oxide pigments (crude), kyanite, lithium minerals, magnesite, millstones, olivine, tube-mill liners, vermiculite, wollastonite, and quantity of nonmetal items indicated by symbol W.

Table 3.—Material handled at surface and underground mines (including sand and gravel and stone) in 1977, by State[1]

(Thousand short tons)

State	Surface			Underground			All mines[2]		
	Crude ore	Waste	Total[2]	Crude ore	Waste	Total[2]	Crude ore	Waste	Total
Alabama	42,700	827	43,500	W	--	W	42,700	827	43,500
Alaska	73,600	750	74,300	(3)	--	(3)	73,600	750	74,300
Arizona	175,000	327,000	502,000	20,600	1,200	21,800	195,000	328,000	523,000
Arkansas	38,700	15,300	54,000	417	2	418	39,100	15,300	54,400
California	164,000	46,600	211,000	1,130	274	1,400	165,000	46,800	212,000
Colorado	36,600	15,200	51,800	16,300	2,840	19,100	52,800	18,000	70,900
Connecticut	15,800	15	15,800	--	--	--	15,800	15	15,800
Delaware	1,360	--	1,360	--	--	--	1,360	--	1,360
Florida	261,000	245,000	506,000	--	--	--	261,000	245,000	506,000
Georgia	51,600	1,540	53,100	652	--	652	52,300	1,540	53,800
Hawaii	6,790	--	6,790	--	--	--	6,790	--	6,790
Idaho	17,600	30,800	48,400	1,330	408	1,740	19,000	31,200	50,200
Illinois	93,300	10	93,300	2,810	36	2,840	96,100	46	96,200
Indiana	53,800	--	53,800	1,730	--	1,730	55,500	--	55,500
Iowa	46,000	418	46,400	2,040	--	2,040	48,000	418	48,500
Kansas	30,400	--	30,400	2,690	--	2,690	33,100	--	33,100
Kentucky	39,000	45	39,000	7,660	6	7,670	46,600	51	46,700
Louisiana	32,600	--	32,600	5,900	236	6,130	38,500	236	38,700
Maine	11,900	--	11,900	W	W	W	11,900	--	11,900
Maryland	29,200	--	29,200	W	--	W	29,200	--	29,200
Massachusetts	24,900	--	24,900	--	--	--	24,900	--	24,900
Michigan	124,000	31,100	155,000	6,210	37	6,250	130,000	31,100	162,000
Minnesota	148,000	66,900	215,000	--	--	--	148,000	66,900	215,000
Mississippi	17,300	--	17,300	--	--	--	17,300	--	17,300
Missouri	62,400	344	62,700	16,700	2,330	19,000	79,000	2,670	81,700
Montana	26,000	42,500	68,600	381	88	469	26,400	42,500	69,100
Nebraska	21,000	--	21,000	W	--	W	21,000	--	21,000
Nevada	43,800	45,100	88,800	281	379	660	44,000	45,400	89,500
New Hampshire	7,640	--	7,640	--	--	--	7,640	--	7,640
New Jersey	33,000	--	33,000	W	--	W	33,000	--	33,000
New Mexico	51,500	157,000	208,000	22,800	1,910	24,700	74,200	158,000	233,000
New York	62,900	1,910	64,800	5,690	130	5,820	68,600	2,040	70,700
North Carolina	54,300	31,900	86,200	--	--	--	54,300	31,900	86,200
North Dakota	5,890	--	5,890	--	--	--	5,890	--	5,890
Ohio	94,200	--	94,200	3,720	456	4,180	97,900	456	98,400
Oklahoma	35,600	13	35,600	W	--	W	35,600	13	35,600
Oregon	38,200	1,660	39,800	2	4	6	38,200	1,670	39,800
Pennsylvania	81,400	--	81,400	4,830	358	5,190	86,200	358	86,600
Rhode Island	3,150	--	3,150	--	--	--	3,150	--	3,150
South Carolina	25,200	--	25,200	--	--	--	25,200	--	25,200
South Dakota	9,780	--	9,780	W	W	W	9,780	--	9,780
Tennessee	57,000	11,000	68,000	7,840	1,300	9,140	64,800	12,300	77,100

See footnotes at end of table.

Table 3.—Material handled at surface and underground mines (including sand and gravel and stone) in 1977, by State[1] —Continued

(Thousand short tons)

State	Surface			Underground			All mines[2]		
	Crude ore	Waste	Total[2]	Crude ore	Waste	Total[2]	Crude ore	Waste	Total
Texas	131,000	7,920	139,000	941	--	941	132,000	7,920	140,000
Utah	53,700	123,000	176,000	1,280	833	2,110	55,000	123,000	178,000
Vermont	6,770	683	7,450	W	--	W	6,770	683	6,770
Virginia	52,100	24	52,100	1,680	19	1,700	53,700	43	53,800
Washington	31,300	12,600	43,900	212	49	261	31,600	12,700	44,200
West Virginia	14,000	--	14,000	2,270	--	2,270	16,300	--	16,300
Wisconsin	53,500	7,270	60,700	W	W	W	53,500	7,270	60,700
Wyoming	20,100	165,000	185,000	12,100	5,330	17,400	32,100	170,000	202,000
Undistributed[4]	1,670	119,000	121,000	4,540	426	5,000	6,210	119,000	126,000
Total[2]	2,610,000	1,510,000	4,120,000	155,000	18,400	173,000	2,760,000	1,520,000	4,290,000

W Withheld to avoid disclosing company proprietary data; included with "Undistributed."
[1]Excludes material from wells, ponds, or pumping operations.
[2]Data may not add to totals shown because of independent rounding.
[3]Less than 1/2 unit.
[4]Includes estimated data in table 2.

Table 4.—Value of principal mineral products and byproducts of surface and underground ores mined in the United States in 1977

(Value per ton)

Ore	Surface			Underground			All mines		
	Principal mineral product	By-product	Total	Principal mineral product	By-product	Total	Principal mineral product	By-product	Total
METALS									
Bauxite	$7.65	$7.92	$15.57	--	--	--	$7.65	$7.92	$15.57
Copper	7.26	1.03	8.29	$10.01	$1.06	$11.07	7.57	1.04	8.61
Gold:									
Lode	14.97	.27	15.24	29.99	1.03	31.02	20.62	.55	21.17
Placer	1.26	--	1.26	--	--	--	1.26	--	1.26
Iron ore	7.71	--	7.71	16.36	.32	16.68	8.05	.01	8.06
Lead	15.72	10.24	25.96	33.53	12.42	45.95	33.52	12.42	45.94
Mercury	17.71	--	17.71	--	--	--	17.71	--	17.71
Silver	10.52	4.75	15.27	73.21	13.53	86.74	54.26	10.88	65.14
Titanium, ilmenite	.67	.57	1.24	--	--	--	.67	.57	1.24
Uranium	47.81	--	47.81	49.73	5.72	55.45	48.76	2.84	51.60
Zinc	W	W	W	24.61	6.34	30.95	24.61	6.34	30.95
Average[1]	7.78	.66	8.44	18.75	3.30	22.05	9.37	1.05	10.42
NONMETALS									
Asbestos	9.64	--	9.64	W	--	W	9.64	--	9.64
Barite	7.86	.01	7.87	W	--	W	7.86	.01	7.87
Clays	11.11	--	11.11	12.29	--	12.29	11.13	--	11.13
Diatomite	36.65	--	36.65	--	--	--	36.65	--	36.65
Feldspar	10.37	.79	11.16	W	--	W	10.37	.79	11.16
Fluorspar	20.49	--	20.49	30.87	7.35	38.22	29.47	6.36	35.83
Gypsum	4.91	.13	5.04	6.44	--	6.44	5.17	.11	5.28
Mica (scrap)	5.84	1.15	6.99	--	--	--	5.84	1.15	6.99
Perlite	13.89	--	13.89	--	--	--	13.89	--	13.89
Phosphate rock	4.50	.06	4.56	W	--	W	4.50	.06	4.56
Potassium salts	63.99	--	63.99	8.83	.06	8.89	8.86	.06	8.92
Pumice	2.95	--	2.95	--	--	--	2.95	--	2.95
Salt	3.29	--	3.29	9.02	1.53	10.55	8.78	1.47	10.25
Sand and gravel	2.18	--	2.18	--	--	--	2.18	--	2.18
Sodium carbonate (natural)	--	--	--	28.07	--	28.07	28.07	--	28.07
Stone:									
Crushed and broken	2.43	.01	2.44	3.15	.01	3.16	2.46	.01	2.47
Dimension	71.81	--	71.81	204.03	--	204.03	73.38	--	73.38
Talc, soapstone, pyrophyllite	10.48	--	10.48	11.74	--	11.74	10.76	--	10.76
Average[1]	2.95	.03	2.98	9.60	.34	9.94	3.20	.04	3.24
Average, metals and nonmetals[1]	3.83	.14	3.97	14.15	1.82	15.97	4.43	.24	4.67
Average, nonmetals (excluding stone and sand and gravel)[1]	7.06	.18	7.24	13.54	.56	14.10	8.08	.24	8.32
Average, metals and nonmetals, (excluding stone and sand and gravel)[1]	7.52	.49	8.01	16.75	2.25	19.00	8.90	.75	9.65

W Withheld to avoid disclosing company proprietary data; included in "Average."
[1]Includes withheld data.

Table 5.—Crude ore and total material handled at surface and underground mines in 1977, by commodity

(Percent)

Commodity	Crude ore		Total material	
	Surface	Underground	Surface	Underground
METALS				
Antimony	W	[1]100.0	W	[1]100.0
Bauxite	100.0	--	100.0	--
Beryllium	100.0	--	100.0	--
Copper	90.3	9.7	96.8	3.2
Gold:				
Lode	63.4	36.6	90.0	10.0
Placer	100.0	--	100.0	--
Iron ore	96.0	4.0	97.6	2.4
Lead	--	100.0	--	100.0
Manganiferous ore	100.0	--	100.0	--
Mercury	100.0	--	100.0	--
Molybdenum	39.1	60.9	69.5	30.5
Nickel	100.0	--	100.0	--
Rare-earth metals	100.0	--	100.0	--
Silver	37.4	62.6	45.1	54.9
Titanium, ilmenite	100.0	--	100.0	--
Tungsten	57.3	42.7	46.2	53.8
Uranium	76.5	23.5	96.2	3.8
Vanadium	100.0	--	100.0	--
Zinc	W	[1]100.0	W	[1]100.0
Total metals	86.8	13.2	94.6	5.4
NONMETALS				
Aplite	100.0	--	100.0	--
Asbestos	[1]100.0	W	[1]100.0	W
Barite	[1]100.0	W	[1]100.0	W
Boron minerals	100.0	--	100.0	--
Clays	98.4	1.6	98.4	1.6
Diatomite	100.0	--	100.0	--
Emery	100.0	--	100.0	--
Feldspar	[1]100.0	W	[1]100.0	W
Fluorspar	9.4	90.6	16.0	84.0
Garnet	100.0	--	100.0	--
Graphite	100.0	--	100.0	--
Greensand marl	100.0	--	100.0	--
Gypsum	82.4	17.6	89.7	10.3
Iron oxide pigments (crude)	100.0	--	100.0	--
Kyanite	100.0	--	100.0	--
Lithium minerals	100.0	--	100.0	--
Magnesite	100.0	--	100.0	--
Mica (scrap)	100.0	--	100.0	--
Millstones	100.0	--	100.0	--
Olivine	100.0	--	100.0	--
Perlite	100.0	--	100.0	--
Phosphate rock	[1]100.0	W	[1]100.0	W
Potassium salts	--	100.0	--	100.0
Pumice	100.0	--	100.0	--
Salt	4.1	95.9	3.9	96.1
Sand and gravel	100.0	--	100.0	--
Sodium carbonate (natural)	--	100.0	--	100.0
Stone:				
Crushed and broken	96.7	3.3	96.7	3.3
Dimension	98.8	1.2	98.8	1.2
Talc, soapstone, pyrophyllite	77.8	22.2	89.8	10.2
Tripoli	42.6	57.4	47.5	52.5
Vermiculite	100.0	--	100.0	--
Wollastonite	--	100.0	--	100.0
Total nonmetals	96.4	3.6	96.6	3.4
Grand total	94.4	5.6	95.9	4.1

W Withheld to avoid disclosing company proprietary data; included with "Underground or Surface."
[1]Includes surface or underground; the Bureau of Mines is not at liberty to publish separately.

Table 6.—Crude ore and total material handled at surface and underground mines in 1977, by State

(Percent)

State	Crude ore		Total material	
	Surface	Underground	Surface	Underground
Alabama	[1]100	W	[1]100	W
Alaska	100	--	100	--
Arizona	89	11	96	4
Arkansas	99	1	99	1
California	99	1	99	1
Colorado	69	31	73	27
Connecticut	100	--	100	--
Delaware	100	--	100	--
Florida	100	--	100	--
Georgia	99	1	99	1
Hawaii	100	--	100	--
Idaho	93	7	97	3
Illinois	97	3	97	3
Indiana	97	3	97	3
Iowa	96	4	96	4
Kansas	92	8	92	8
Kentucky	84	16	84	16
Louisiana	85	15	84	16
Maine	[1]100	W	[1]100	W
Maryland	[1]100	W	[1]100	W
Massachusetts	100	--	100	--
Michigan	95	5	96	4
Minnesota	100	--	100	--
Mississippi	100	--	100	--
Missouri	79	21	77	23
Montana	99	1	99	1
Nebraska	[1]100	W	[1]100	W
Nevada	99	1	99	1
New Hampshire	100	--	100	--
New Jersey	99	1	99	1
New Mexico	69	31	89	11
New York	92	8	92	8
North Carolina	100	--	100	--
North Dakota	100	--	100	--
Ohio	96	4	96	4
Oklahoma	97	3	97	3
Oregon	100	--	100	--
Pennsylvania	94	6	94	6
Rhode Island	100	--	100	--
South Carolina	100	--	100	--
South Dakota	[1]100	W	[1]100	W
Tennessee	88	12	88	12
Texas	99	1	99	1
Utah	98	2	99	1
Vermont	[1]100	W	[1]100	W
Virginia	97	3	97	3
Washington	99	1	99	1
West Virginia	86	14	86	14
Wisconsin	[1]100	W	[1]100	W
Wyoming	62	38	91	9
Total	94	6	96	4

W Withheld to avoid disclosing company proprietary data; included with "Surface."
[1]Includes underground; the Bureau of Mines is not at liberty to publish separately.

Table 7.—Number of domestic metal and nonmetal mines in 1977, by commodity and magnitude of crude ore production[1]

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							
Bauxite	12	--	--	5	7	--	--
Copper	42	2	--	2	7	20	11
Gold:							
Lode	43	25	7	5	4	2	--
Placer	32	8	10	11	2	1	--
Iron ore	53	--	3	7	16	23	4
Lead	35	16	7	--	7	5	--
Mercury	5	4	--	--	1	--	--
Silver	43	24	6	8	5	--	--
Titanium, ilmenite	7	--	--	--	1	6	--
Tungsten	79	60	13	4	2	--	--
Uranium	236	50	99	64	20	3	--
Zinc	32	2	4	3	22	1	--
Other[2]	13	1	1	4	3	3	1
Total metals	632	192	150	113	97	64	16
NONMETALS							
Abrasives[3]	12	--	5	6	1	--	--
Asbestos	4	--	--	1	2	1	--
Barite	33	1	3	20	9	--	--
Boron minerals	3	--	--	--	2	1	--
Clays	1,075	52	270	620	133	--	--
Diatomite	13	--	5	2	6	--	--
Feldspar	20	--	7	8	5	--	--
Fluorspar	7	--	3	2	2	--	--
Gypsum	69	3	5	17	44	--	--
Mica (scrap)	20	3	4	11	2	--	--
Perlite	12	1	3	6	2	--	--
Phosphate rock	44	--	6	1	12	18	7
Potassium salts	8	--	--	--	1	7	--
Pumice	131	26	48	49	8	--	--
Salt	18	--	1	2	8	7	--
Sand and gravel	7,349	217	1,326	3,574	2,147	84	1
Sodium carbonate (natural)	4	--	--	--	1	3	--
Stone:							
Crushed and broken	4,840	446	815	1,696	1,725	157	1
Dimension	406	190	184	32	--	--	--
Talc, soapstone, pyrophyllite	49	9	22	17	1	--	--
Other[4]	35	9	8	11	6	1	--
Total nonmetals	14,152	957	2,715	6,075	4,117	279	9
Grand total	14,784	1,149	2,865	6,188	4,214	343	25

[1]Excludes wells, ponds, or pumping operations.
[2]Antimony, beryllium, manganiferous ore, molybdenum, nickel, rare-earth metals, and vanadium.
[3]Emery, garnet, and tripoli.
[4]Aplite, graphite, greensand marl, crude iron oxide pigments, kyanite, lithium minerals, magnesite, millstones, olivine, tube-mill liners, vermiculite, and wollastonite.

Table 8.—Twenty-five leading metal and nonmetal[1] mines in the United States in 1977, in order of output of crude ore

Mine	State	Operator	Commodity	Mining method
METALS				
Utah Copper	Utah	Kennecott Copper Corp	Copper	Open pit.
Sierrita	Arizona	Duval Sierrita Corp	do	Do.
Minntac	Minnesota	United States Steel Corp	Iron ore	Do.
San Manuel	Arizona	Magma Copper Co	Copper	Do.
Climax	Colorado	Climax Molybdenum Co., a division of AMAX Inc.	Molybdenum	Caving and open pit.
Peter Mitchell	Minnesota	Reserve Mining Co	Iron ore	Open pit.
Morenci	Arizona	Phelps Dodge Corp	Copper	Do.
Berkeley Pit	Montana	The Anaconda Company	do	Do.
Erie Commercial	Minnesota	Pickands Mather & Co	Iron ore	Do.
Tyrone	New Mexico	Phelps Dodge Corp	Copper	Do.
Pima	Arizona	Cyprus Pima Mining Co	do	Do.
Pinto Valley	do	Cities Service Co	do	Do.
Empire	Michigan	Cleveland-Cliffs Iron Co	Iron ore	Do.
Twin Buttes	Arizona	Anamax Mining Co	Copper	Do.
Copper Canyon	Nevada	Pennzoil Co	do	Do.
Ray Pit	Arizona	Kennecott Copper Corp	do	Do.
Metcalf	do	Phelps Dodge Corp	do	Do.
St. Anthony	New Mexico	United Nuclear Corp	Uranium	Do.
Thunderbird	Minnesota	Oglebay Norton Co	Iron ore	Do.
Butler Project	do	Hanna Mining Co	do	Do.
Hibbing Taconite	do	Pickands Mather & Co	do	Do.
Eagle Mountain	California	Kaiser Steel Corp	do	Do.
Tilden	Michigan	Cleveland-Cliffs Iron Co	do	Do.
Trail Ridge	Florida	E. I. du Pont de Nemours & Co.	Titanium	Dredging.
Highland	do	do	do	Do.
NONMETALS				
Suwannee	Florida	Occidental Petroleum Corp	Phosphate rock.	Open pit.
Noralyn	do	International Minerals & Chemical Corp.	do	Do.
Kingsford	do	do	do	Do.
Ft. Green	do	Continental Oil Co	do	Do.
Calcite	Michigan	United States Steel Corp	Stone	Open quarry.
Ft. Meade	Florida	Mobil Oil Corp	Phosphate rock.	Open pit.
Haynsworth	do	Brewster Phosphates	do	Do.
Payne Creek	do	Continental Oil Co	do	Do.
Clear Spring	do	International Minerals & Chemical Corp.	do	Do.
Thornton	Illinois	General Dynamics Corp	Stone	Open quarry.
Tampa Agricultural Chemical Operations.	Florida	Gardinier, Inc	Phosphate rock.	Open pit.
Hookers	do	W. R. Grace & Co	do	Do.
Rockland	do	United States Steel Corp	do	Do.
Feld	Texas	Texas Crushed Stone Co	Stone	Open quarry.
Lee Creek	North Carolina	Texasgulf Inc	Phosphate rock.	Open pit.
Bonny Lake	Florida	W. R. Grace & Co	do	Do.
Stoneport	Michigan	Presque Isle Corp	Stone	Open quarry.
Silver City	Florida	Swift Agricultural Chemicals Corp.	Phosphate rock.	Open pit.
Nichols	do	Mobil Oil Corp	do	Do.
Pennsuco	do	Maule Industries, Inc	Stone	Dredging.
International	New Mexico	International Minerals & Chemical Corp.	Potassium salts.	Open stopes.
Westvaco	Wyoming	FMC Corp	Sodium carbonate.	Artificial stopes.
Watson	Florida	Swift Agricultural Chemicals Corp.	Phosphate rock.	Open pit.
Beckman	Texas	McDonough Bros., Inc.	Stone	Open quarry.
McCook	Illinois	Vulcan Material Co	do	Do.

[1]Brines and materials from wells excepted.

Table 9.—Twenty-five leading metal and nonmetal[1] mines in the United States in 1977, in order of output of total materials handled

Mine	State	Operator	Commodity	Mining method
METALS				
Utah Copper	Utah	Kennecott Copper Corp	Copper	Open pit.
Sierrita	Arizona	Duval Sierrita Corp	do	Do.
Tyrone	New Mexico	Phelps Dodge Corp	do	Do.
Twin Buttes	Arizona	Anamax Mining Co	do	Do.
Berkeley Pit	Montana	The Anaconda Company	do	Do.
Eagle Mountain	California	Kaiser Steel Corp	Iron ore	Do.
Shirley Basin	Wyoming	Utah International Inc	Uranium	Do.
Morenci	Arizona	Phelps Dodge Corp	Copper	Do.
Pinto Valley	do	Cities Service Co	do	Do.
Ray Pit	do	Kennecott Copper Corp	do	Do.
Highland	Wyoming	Exxon Corp	Uranium	Do.
Pima	Arizona	Cyprus Pima Mining Co	Copper	Do.
Chino	New Mexico	Kennecott Copper Corp	do	Do.
Bagdad	Arizona	Cyprus Bagdad Copper Co	do	Do.
Bear Creek	Wyoming	Rocky Mountain Energy Co	Uranium	Do.
Climax	Colorado	Climax Molybdenum Co., a division of AMAX Inc.	Molybdenum	Caving and open pit.
Jackpile-Paquate	New Mexico	The Anaconda Company	Uranium	Open pit.
Hibbing Taconite	Minnesota	Pickands Mather & Co	Iron ore	Do.
Shirley Basin	Wyoming	Getty Oil Co	Uranium	Do.
Erie Commercial	Minnesota	Pickands Mather & Co	Iron ore	Do.
Minntac	do	United States Steel Corp	do	Do.
Metcalf	Arizona	Phelps Dodge Corp	Copper	Do.
Mitchell Pit	Minnesota	Reserve Mining Co	Iron ore	Do.
Empire	Michigan	Cleveland-Cliffs Iron Co	do	Do.
Ruth	Nevada	Kennecott Copper Corp	Copper	Do.
NONMETALS				
Kingsford	Florida	International Minerals & Chemical Corp.	Phosphate rock.	Open pit.
Noralyn	do	do	do	Do.
Ft. Green	do	Continental Oil Co	do	Do.
Lee Creek	North Carolina	Texasgulf Inc	do	Do.
Payne Creek	Florida	Continental Oil Co	do	Do.
Haynsworth	do	Brewster Phosphates	do	Do.
Rockland	do	United States Steel Corp	do	Do.
Bonny Lake	do	W. R. Grace & Co	do	Do.
Ft. Meade	do	Mobil Oil Corp	do	Do.
Clear Spring	do	International Minerals & Chemical Corp.	do	Do.
Suwanee	do	Occidental Chemical Co	do	Do.
Lonesome	do	Brewster Phosphates	do	Do.
Tampa Agricultural Chemical Operations.	do	Gardinier, Inc	do	Do.
Hookers	do	W. R. Grace & Co	do	Do.
Nichols	do	Mobil Oil Corp	do	Do.
Silver City	do	Swift Agricultural Chemicals Corp.	do	Do.
Calcite	Michigan	United States Steel Corp	Stone	Open quarry.
Watson	Florida	Swift Agricultural Chemicals Corp.	Phosphate rock.	Open pit.
Conda	Idaho	J. R. Simplot Co	do	Do.
Westvaco	Wyoming	FMC Corp	Sodium carbonate.	Artificial stopes.
Gay	Idaho	J. R. Simplot Co	Phosphate rock.	Open pit.
Thornton	Illinois	General Dynamics Corp	Stone	Open quarry.
Vernal	Utah	Stauffer Chemical Co	Phosphate rock.	Do.
Wooley Valley	Idaho	do	do	Open pit.
Feld	Texas	Texas Crushed Stone Co	Stone	Open quarry.

[1]Brines and materials from wells excepted.

Table 10.—Ore treated or sold per unit of marketable product at surface and underground mines in the United States in 1977, by commodity

Commodity	Unit of marketable product	Surface: Ore treated (thousand short tons)	Surface: Marketable product (units)	Surface: Ratio of units of ore to units of marketable product	Underground: Ore treated (thousand short tons)	Underground: Marketable product (units)	Underground: Ratio of units of ore to units of marketable product	Total[1]: Ore treated (thousand short tons)	Total[1]: Marketable product (units)	Total[1]: Ratio of units of ore to units of marketable product
METALS										
Bauxite	thousand long tons	3,660	1,980	1.9:1	--	--	--	3,660	1,980	1.9:1
Copper	thousand short tons	233,000	1,260	184.1:1	29,300	220	133.4:1	262,000	1,480	176.6:1
Gold:										
Lode	thousand troy ounces	2,760	278	9.9:1	1,660	336	5.0:1	4,420	614	7.2:1
Placer	do	2,720	23	117.3:1	--	--	--	2,720	23	117.3:1
Iron ore	thousand long tons	169,000	50,100	3.4:1	6,860	3,520	2.0:1	176,000	53,600	3.3:1
Lead	thousand short tons	5	(2)	39.0:1	9,870	539	18.3:1	9,870	539	18.3:1
Mercury	thousand flasks	216	28	7.7:1	--	--	--	216	28	7.7:1
Silver	thousand troy ounces	406	926	0.4:1	938	14,900	0.1:1	1,340	15,800	0.1:1
Titanium, ilmenite	thousand short tons	37,400	542	68.9:1	--	--	--	37,400	542	68.9:1
Uranium	do	6,020	7	826.2:1	5,930	7	794.3:1	11,900	15	810.1:1
Zinc	do	W	W	W	9,290	332	28.0:1	9,290	332	28.0:1
NONMETALS										
Asbestos	do	2,570	101	25.4:1	W	W	W	2,570	101	25.4:1
Barite	do	3,770	1,480	2.5:1	W	W	W	3,770	1,480	2.5:1
Clays	do	47,800	47,800	1.0:1	753	753	1.0:1	48,600	48,600	1.0:1
Diatomite	do	1,740	648	2.7:1	--	--	--	1,740	648	2.7:1
Feldspar	do	1,450	657	2.2:1	W	W	W	1,450	657	2.2:1
Fluorspar	do	76	26	2.9:1	484	143	3.4:1	559	169	3.3:1
Gypsum	do	11,900	10,800	1.1:1	2,450	2,590	1.0:1	14,400	13,400	1.1:1
Mica (scrap)	do	966	142	6.8:1	--	--	--	966	142	6.8:1
Perlite	do	774	597	1.3:1	--	--	--	774	597	1.3:1
Phosphate rock	do	182,000	51,900	3.5:1	W	W	W	182,000	51,900	3.5:1
Potassium salts	do	W	W	W	19,100	2,080	9.2:1	19,100	2,080	9.2:1
Pumice	do	4,060	4,010	1.0:1	--	--	--	4,060	4,010	1.0:1
Salt	do	628	455	1.4:1	14,900	14,800	1.0:1	15,600	15,200	1.0:1
Sand and gravel	do	929,000	929,000	1.0:1	--	--	--	929,000	929,000	1.0:1
Sodium carbonate (natural)	do	--	--	--	11,400	5,960	1.9:1	11,400	5,960	1.9:1
Stone:										
Crushed and broken	do	926,000	921,000	1.0:1	31,000	31,400	1.0:1	957,000	953,000	1.0:1
Dimension	do	[e]3,070	1,400	2.2:1	17	17	1.0:1	3,090	1,420	2.2:1
Talc, soapstone, pyrophyllite	do	949	937	1.0:1	268	267	1.0:1	1,220	1,210	1.0:1

[e]Estimate. W Withheld to avoid disclosing company proprietary data.
[1]Data may not add to totals shown because of independent rounding.
[2]Less than 1/2 unit.

Table 11.—Material handled per unit of marketable product at surface and underground mines in the United States in 1977, by commodity

Commodity	Unit of marketable product	Surface			Underground			Total[1]		
		Total material handled[2] (thousand short tons)	Marketable product (units)	Ratio of units of material handled to units of marketable product[3]	Total material handled[2] (thousand short tons)	Marketable product (units)	Ratio of units of material handled to units of marketable product[3]	Total material handled[2] (thousand short tons)	Marketable product (units)	Ratio of units of material handled to units of marketable product[3]
METALS										
Bauxite	thousand long tons	19,100	1,980	9.5:1	--	--	--	19,100	1,980	9.5:1
Copper	thousand short tons	834,000	1,260	652.3:1	27,200	220	118.1:1	861,000	1,480	573.1:1
Gold:										
Lode	thousand troy ounces	17,200	278	59.2:1	1,910	336	5.1:1	19,200	614	29.6:1
Placer	do	3,920	23	159.6:1	(4)	--	0.0:1	3,920	23	159.6:1
Iron ore	thousand long tons	324,000	50,100	5.5:1	7,840	3,520	2.1:1	332,000	53,600	5.3:1
Lead	thousand short tons	3	(4)	24.8:1	12,100	539	19.1:1	12,100	539	19.1:1
Mercury	thousand flasks	1,120	28	39.6:1	--	--	--	1,120	28	39.6:1
Silver	thousand troy ounces	1,170	926	0.6:1	1,430	14,900	0.1:1	2,600	15,800	0.1:1
Titanium, ilmenite	thousand short tons	37,900	542	69.8:1	--	--	--	37,900	542	69.8:1
Uranium	do	244,000	7	24,386.6:1	9,570	7	1,006.6:1	253,000	15	12,553.9:1
Zinc	do	W	W	W	10,300	332	26.8:1	10,300	332	26.8:1
NONMETALS										
Asbestos	do	6,430	101	32.0:1	W	W	W	6,430	101	32.0:1
Barite	do	4,410	1,480	3.0:1	W	W	W	4,410	1,480	3.0:1
Clays	do	[e]89,300	47,800	1.9:1	[e]764	753	1.0:1	90,100	48,600	1.9:1
Diatomite	do	6,680	648	10.3:1	--	--	--	6,680	648	10.3:1
Feldspar	do	1,620	657	2.5:1	W	W	W	1,620	657	2.5:1
Fluorspar	do	111	26	4.3:1	584	143	3.8:1	695	169	3.9:1
Gypsum	do	21,500	10,800	1.4:1	2,450	2,590	1.0:1	23,900	13,400	1.3:1
Mica (scrap)	do	1,330	142	8.9:1	--	--	--	1,330	142	8.9:1
Perlite	do	980	597	1.6:1	--	--	--	980	597	1.6:1
Phosphate rock	do	510,000	51,900	9.6:1	182	162	1.0:1	510,000	52,100	9.6:1
Potassium salts	do	--	W	W	19,200	2,080	9.2:1	19,200	2,080	9.2:1
Pumice	do	4,440	4,010	1.1:1	--	--	--	4,440	4,010	1.1:1
Salt	do	624	455	1.4:1	15,200	14,800	1.0:1	15,800	15,200	1.0:1
Sand and gravel	do	929,000	929,000	1.0:1	--	--	--	929,000	929,000	1.0:1
Sodium carbonate (natural)	do	--	--	--	16,300	5,960	1.9:1	16,300	5,960	1.9:1
Stone:										
Crushed and broken	do	[e]998,000	921,000	1.1:1	[e]31,200	31,400	1.0:1	1,030,000	953,000	1.1:1
Dimension	do	[e]4,690	1,400	3.4:1	17	17	1.0:1	4,700	1,420	3.3:1
Talc, soapstone, pyrophyllite	do	3,380	937	3.4:1	383	267	1.4:1	3,760	1,210	3.0:1

[e]Estimate. W Withheld to avoid disclosing company proprietary data.
[1]Data may not add to totals shown because of independent rounding.
[2]Includes material from development and exploration activities.
[3]Material from development and exploration activities is excluded from the ratio calculation.
[4]Less than 1/2 unit.

Table 12.—Mining methods used in open pit mining in 1977, by commodity

(Percent)

Commodity	Total material handled	
	Preceded by drilling and blasting	Not preceded by drilling and blasting[1]
METALS		
Antimony	--	100
Bauxite	80	20
Copper	94	6
Gold:		
Lode	100	--
Placer	--	100
Iron ore	91	9
Lead	--	100
Manganiferous ore	98	2
Mercury	--	100
Molybdenum	100	--
Nickel	16	84
Rare-earth metals	100	--
Silver	95	5
Titanium, ilmenite	2	98
Tungsten	2	98
Uranium	59	41
Vanadium	50	50
Zinc	100	--
NONMETALS		
Aplite	17	83
Asbestos	95	5
Barite	22	78
Boron minerals	100	--
Clays	--	100
Diatomite	--	100
Emery	100	--
Feldspar	84	16
Fluorspar	8	92
Garnet	92	8
Graphite	--	100
Greensand marl	--	100
Gypsum	87	13
Iron oxide pigments (crude)	--	100
Kyanite	55	45
Lithium minerals	100	--
Magnesite	100	--
Mica (scrap)	29	71
Millstones	73	27
Olivine	63	37
Perlite	49	51
Phosphate rock	4	96
Pumice	3	97
Salt	100	--
Sand and gravel	--	100
Stone:		
Crushed and broken	97	3
Dimension	--	100
Talc, soapstone, pyrophyllite	79	21
Tripoli	100	--
Vermiculite	--	100
Total	55	45

[1]Includes drilling or cutting without blasting, dredging, mechanical excavation and nonfloat washing, and other surface mining methods.

Table 13.—Exploration and development activity in the United States in 1977, by method

Method	Metals		Nonmetals		Total[1]	
	Feet	Percent of total[2]	Feet	Percent of total[2]	Feet	Percent of total[2]
DEVELOPMENT						
Shaft and winze sinking	19,400	0.6	125	([3])	19,500	0.5
Raising	131,000	3.9	1,310	0.2	132,000	3.3
Drifting, crosscutting, or tunneling	958,000	28.7	629,000	99.8	1,590,000	40.0
Solution mining	2,220,000	66.8	--	--	2,220,000	56.2
Total[1]	3,330,000	100.0	630,000	100.0	3,960,000	100.0
EXPLORATION						
Diamond drilling	1,470,000	7.0	196,000	53.8	1,660,000	7.8
Churn drilling	116,000	.6	20,000	5.5	136,000	.6
Rotary drilling	13,200,000	63.0	140,000	38.3	13,300,000	62.6
Percussion drilling	5,330,000	25.5	7,370	2.0	5,330,000	25.1
Other drilling	755,000	3.6	745	.2	756,000	3.6
Trenching	52,900	.3	900	.2	53,800	.3
Total[1]	20,900,000	100.0	365,000	100.0	21,200,000	100.0
Grand total[1]	24,200,000	XX	995,000	XX	25,200,000	XX

XX Not applicable.
[1]Data may not add to totals shown because of independent rounding.
[2]Based on unrounded footage.
[3]Less than 1/2 of 1%.

Table 14.—Exploration and development in 1977, by method and selected metals and nonmetals

(Feet)

Commodity	Development					Exploration						
	Solution mining	Shaft and winze sinking	Raising	Drifting, cross-cutting, or tunneling	Total[1]	Diamond drilling	Churn drilling	Rotary drilling	Percussion drilling	Other drilling	Trenching	Total[1]
METALS												
Bauxite	--	--	--	--	--	--	28,300	425,000	--	262,000	--	716,000
Copper	W	6,710	49,100	96,600	153,000	326,000	8,000	52,800	12,600	38,100	4,050	442,000
Gold	--	1,000	11,800	52,800	65,600	93,500	3,400	37,600	4,080,000	47,200	37,800	4,290,000
Iron ore	--	106	80	28,700	28,800	45,600	--	13,100	26,100	379	--	85,100
Lead	--	174	6,480	53,300	59,900	197,000	76,200	22,700	67,100	117,000	--	480,000
Molybdenum	--	--	W	W	W	145,000	--	2,250	--	--	--	147,000
Nickel	--	--	--	--	--	8,060	225	--	--	--	--	8,280
Silver	--	186	7,380	43,200	50,800	35,300	--	11,100	11,500	2,930	5,560	66,400
Tungsten	--	777	4,970	24,100	29,800	37,900	--	24,900	6,860	5,430	2,310	77,400
Uranium	870,000	7,780	28,300	492,000	1,400,000	291,000	--	12,500,000	991,000	270,000	3,150	14,100,000
Zinc	--	2,670	12,700	104,000	119,000	285,000	--	48,400	134,000	9,790	--	476,000
Other[2]	1,350,000	--	10,000	62,500	1,420,000	--	--	8,860	1,650	1,800	--	12,300
Total[1]	2,220,000	19,400	131,000	958,000	3,330,000	1,470,000	116,000	13,200,000	5,330,000	755,000	52,900	20,900,000
NONMETALS												
Barite	--	--	--	--	--	300	20,000	2,700	4,520	--	900	28,400
Fluorspar	--	125	950	3,170	4,250	179,000	--	200	300	--	--	180,000
Phosphate rock	--	--	--	7,290	7,290	726	--	79,500	--	15	--	80,200
Talc, soapstone, pyrophyllite	--	--	237	197	434	--	--	--	W	W	--	W
Other[3]	--	--	120	618,000	618,000	16,100	--	57,600	2,650	730	--	77,000
Total[1]	--	125	1,310	629,000	630,000	196,000	20,000	140,000	7,470	745	900	365,000
Grand total[1]	2,220,000	19,500	132,000	1,590,000	3,960,000	1,660,000	136,000	13,300,000	5,330,000	756,000	53,800	21,200,000

W Withheld to avoid disclosing company proprietary data; included with "Other."
[1]Data may not add to totals shown because of independent rounding.
[2]Antimony, beryllium, molybdenum, and platinum group metals.
[3]Asbestos, boron, diatomite, gypsum, millstones, potassium salts, pumice, salt, (natural) sodium carbonate, and (crushed and broken) stone.

Table 15.—Exploration and development in 1977, by method and State

(Feet)

State	Development					Exploration						
	Solution mining	Shaft and winze sinking	Raising	Drifting, cross-cutting, or tunneling	Total[1]	Diamond drilling	Churn drilling	Rotary drilling	Percussion drilling	Other drilling	Trenching	Total[1]
Alaska	--	800	--	--	800	25,900	3,220	--	--	120	4,770	34,000
Arizona	W	1,270	47,600	85,800	135,000	116,000	8,000	115,000	11,600	39,700	6,100	296,000
California	--	223	3,630	10,600	14,500	10,900	20,200	29,400	2,250	12,300	1,880	77,000
Colorado	--	4,180	18,500	170,000	193,000	332,000	--	1,590,000	290,000	613	155	2,210,000
Florida	--	--	--	--	--	--	--	38,200	--	15	--	38,200
Georgia	--	--	--	--	--	1,930	--	3,540	--	55,000	--	60,500
Idaho	--	388	11,000	31,100	42,500	38,000	--	14,500	12,000	2,800	1,160	68,400
Maine	--	--	--	W	W	25,700	--	--	--	--	--	25,700
Michigan	--	--	--	4,540	4,540	9,610	--	--	--	--	--	9,610
Minnesota	--	--	--	--	--	7,680	--	--	--	--	--	7,680
Missouri	--	--	448	50,000	50,500	144,000	76,200	8,070	26,100	117,000	--	372,000
Montana	--	127	35	12,000	12,200	52,000	--	55,300	5,110	--	5,130	118,000
Nevada	--	760	1,870	24,100	26,700	48,900	--	63,200	103,000	50,000	29,100	294,000
New Mexico	--	3,620	14,300	302,000	320,000	91,700	170	3,660,000	614,000	259,000	2,300	4,620,000
New York	--	--	7,040	42,800	49,800	W	--	--	--	--	--	W
North Dakota	--	--	--	--	--	--	--	35,400	--	--	--	35,400
Oregon	--	5	200	710	915	12,000	--	--	40	700	65	12,800
South Dakota	--	--	W	W	W	74,700	--	919,000	3,970,000	--	--	4,970,000
Tennessee	--	2,480	1,260	41,400	45,100	133,000	--	33,500	92,800	--	--	259,000
Texas	W	--	--	--	W	2,410	--	1,120,000	--	--	--	1,120,000
Utah	--	5,460	6,150	66,600	78,200	83,800	--	769,000	149,000	1,700	2,650	1,010,000
Washington	--	--	343	1,080	1,430	59,900	--	7,440	14,700	--	--	82,000
Wisconsin	--	--	--	W	W	28,900	--	--	--	9,790	--	38,700
Wyoming	W	--	4,070	654,000	660,000	11,800	--	2,820,000	1,200	--	502	2,840,000
Undistributed[2]	2,220,000	231	15,000	84,900	2,320,000	351,000	28,200	2,010,000	38,600	207,000	--	2,630,000
Total[1]	2,220,000	19,500	132,000	1,590,000	3,960,000	1,660,000	136,000	13,300,000	5,330,000	756,000	53,800	21,200,000

W Withheld to avoid disclosing company proprietary data; included in "Undistributed."

[1]Data may not add to totals shown because of independent rounding.

[2]Alabama, Arkansas, Illinois, Kansas, Kentucky, Louisiana, New Hampshire, North Carolina, Ohio, Oklahoma, Pennsylvania, South Carolina, Virginia, and items indicated by symbol W.

Table 16.—Total material (ore and waste) produced by mine development in the United States in 1977, by commodity and State

(Thousand short tons)

	Shaft and winze sinking	Raising	Drifting, crosscutting, or tunneling	Stripping	Total[1]
			COMMODITY		
METALS					
Copper	245	100	1,010	10,300	11,600
Gold:					
Lode	1	43	168	795	1,010
Placer	(2)	--	(2)	272	272
Iron ore	4	(2)	437	49,300	49,700
Lead	2	20	1,790	(2)	1,810
Silver	1	41	178	606	825
Tungsten	2	14	242	(2)	258
Uranium	57	94	1,930	66,300	68,400
Zinc	41	19	1,330	95	1,490
Other[3]	--	29	545	292	866
Total metals[1]	352	358	7,620	128,000	136,000
NONMETALS					
Fluorspar	2	4	34	--	40
Gypsum	--	--	--	6,790	6,790
Phosphate rock	--	--	20	10,200	10,200
Pumice	--	--	--	195	195
Salt	--	--	151	--	151
Talc, soapstone, pyrophyllite	--	1	1	196	198
Other[4]	--	(2)	5,000	3,300	8,300
Total nonmetals[1]	2	7	5,240	20,700	25,900
Grand total[1]	354	365	12,800	149,000	162,000
			STATE		
Alabama	--	--	--	W	W
Alaska	--	--	--	251	251
Arizona	45	93	912	7,010	8,060
California	1	10	70	4,630	4,710
Colorado	28	53	991	105	1,180
Idaho	3	55	205	4,260	4,530
Illinois	W	W	W	--	W
Iowa	--	--	--	W	W
Kentucky	W	--	W	--	W
Louisiana	--	--	W	--	W
Maine	--	--	W	--	W
Michigan	--	--	37	17,500	17,500
Minnesota	--	--	--	30,800	30,800
Missouri	--	3	1,960	--	1,960
Montana	1	(2)	52	641	694
Nevada	2	7	255	3,610	3,880
New Mexico	38	57	1,140	2,620	3,850
New York	--	3	127	1,550	1,680
Ohio	--	--	W	--	W
Oklahoma	--	--	--	W	W
Oregon	(2)	1	3	59	63
Pennsylvania	W	W	W	--	W
South Dakota	--	W	W	--	W
Tennessee	39	4	1,060	66	1,170
Texas	--	--	--	4,180	4,180
Utah	191	22	347	4,530	5,090
Virginia	--	W	W	W	W
Washington	--	1	23	5,990	6,020
Wisconsin	--	--	W	--	W
Wyoming	--	6	5,220	60,070	65,300
Undistributed	10	50	423	733	1,210
Total[1]	354	365	12,800	149,000	162,000

W Withheld to avoid disclosing company proprietary data; included with "Undistributed."
[1]Data may not add to totals shown because of independent rounding.
[2]Less than 1/2 unit.
[3]Antimony, bauxite, beryllium, and molybdenum.
[4]Asbestos, barite, garnet, mica (scrap), perlite, natural sodium carbonate, tripoli, and tube-mill liners.

Table 17.—U.S. industrial consumption of explosives

(Thousand pounds)

Year	Coal mining	Metal mining	Quarrying and nonmetal mining	Total mineral industry	Other	Total industrial
1972	1,212,585	430,686	493,677	2,136,948	532,841	2,669,789
1973	1,177,062	495,879	643,292	2,316,233	438,713	2,754,946
1974	1,186,614	465,490	551,380	2,203,484	558,806	2,762,290
1975	1,652,251	449,271	493,125	2,594,647	524,380	3,119,027
1976	1,798,873	488,653	493,656	2,781,182	547,347	3,328,529
1977	[1]2,093,312	446,406	522,678	[1]3,062,396	647,354	3,709,750

[1]Data not comparable to prior years due to change in reporting by the Institute of Makers of Explosives.

Table 18.—U.S. consumption of explosives in the minerals industry

(Thousand pounds)

Year	Coal mining	Metal mining	Quarrying and nonmetal mining	Total
PERMISSIBLE EXPLOSIVES				
1975	41,996	241	1,083	43,320
1976	41,123	204	1,090	42,417
1977	46,663	225	694	47,582
OTHER HIGH EXPLOSIVES				
1975	36,875	25,118	74,796	136,789
1976	34,521	24,265	65,891	124,677
1977	34,407	25,174	63,378	122,959
CYLINDRICALLY PACKED BLASTING AGENTS				
1975	286,608	4,845	28,551	320,004
1976	269,778	3,471	65,922	339,171
1977	634,283	59,059	189,266	[1]882,608
PACKAGED AND BULK WATER GELS AND SLURRIES				
1975	24,118	181,809	73,872	279,799
1976	30,871	205,429	74,176	310,476
1977	42,406	154,704	75,062	272,172
OTHER PROCESSED BLASTING AGENTS AND UNPROCESSED AMMONIUM NITRATE				
1975	1,262,654	237,258	314,823	1,814,735
1976	1,422,580	255,284	286,577	1,964,441
1977	1,335,553	207,244	194,278	[1]1,737,075
TOTAL EXPLOSIVES				
1975	1,652,251	449,271	493,125	2,594,647
1976	1,798,873	488,653	493,656	2,781,182
1977	2,093,312	446,406	522,678	[1]3,062,396

[1]Data not comparable to prior years due to change in reporting by the Institute of Makers of Explosives.

Statistical Summary

By Staff, Office of Technical Data Services

This chapter summarizes data on crude mineral production for the United States, its island possessions, and the Commonwealth of Puerto Rico. Included also are tables that show the principal mineral commodities exported from and imported into the United States, and that compare world and U.S. mineral production. Except for the mineral fuel commodities, the detailed data from which these tables were derived are contained in the individual commodity chapters of volume I and in the State chapters of volume II of this edition of the Minerals Yearbook.

In October 1977, responsibility for the collection of data on mineral fuels—coal, petroleum, natural gas, and natural gas liquids—was transferred to the newly created Department of Energy. Although chapters covering these commodities will no longer appear in Volume I of the Minerals Yearbook, quantity and value data have been included in most of these summary tables to maintain statistical consistency in State and national value of overall crude mineral output. This shift in responsibility has also resulted in changes to the composition of the "Nonmetals" and "Mineral Fuels" groups in table 1 and table 2. The commodities—asphalt and related bitumens (natural), carbon dioxide (natural), helium, and peat—have been removed from the "Mineral Fuels" group, and are now included under the "Nonmetals" group. There has been no change in the components of the "Metals" group.

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

Because of inadequacies in the statistics available, some series deviate from the foregoing definition. In cases of gold, silver, copper, lead, zinc, and tin, the quantities are recorded on a mine basis (as the recoverable content of ore sold or treated). However, the values assigned to these quantities 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 the metal.

The weight or volume units shown are those customarily used in the particular industries producing the commodities. Values shown are in current dollars, with no adjustments made to compensate for changes in the purchasing power of the dollar.

Table 1.—Value of crude mineral production[1] in the United States, by mineral group[2]

(Million dollars)

Year	Metals	Nonmetals[2]	Total	Mineral fuels[2]	Grand total
1973	4,362	7,476	11,838	24,949	36,787
1974	5,501	8,687	[3]14,187	40,889	[3]55,077
1975	5,191	9,570	14,761	47,505	62,266
1976	6,086	10,616	16,702	52,484	[r]69,186
1977	5,810	11,701	17,511	59,575	77,086

[r] Revised.
[1] Production as measured by mine shipments, sales, or marketable production (including consumption by producers).
[2] The commodities comprising the Mineral fuels and Nonmetals groups have been revised. See table 2 for the complete listing of the commodities which now comprise these two groups.
[3] Data do not add to total shown because of independent rounding.

Note: Beginning with 1977, data on mineral fuels supplied by the Department of Energy.

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

Mineral	1974		1975		1976		1977	
	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value (thousands)
METALS								
Antimony ore and concentrate ___ short tons, antimony content	661	$2,040	886	$2,131	283	$600	610	$1,320
Bauxite ___ thousand long tons, dried equivalent	1,949	25,663	1,772	25,083	1,958	26,645	1,981	28,018
Copper (recoverable content of ores, etc.) ___ short tons	1,597,002	2,468,964	1,413,366	1,814,763	1,605,586	2,234,975	1,503,966	2,009,297
Gold (recoverable content of ores, etc.) ___ troy ounces	1,126,886	180,009	1,052,252	169,928	1,048,037	131,340	1,100,347	163,192
Iron ore, usable (excluding byproduct iron sinter) thousand long tons, gross weight	84,985	1,388,447	75,695	1,620,599	76,697	1,860,102	53,880	1,417,418
Lead (recoverable content of ores, etc.) ___ short tons	663,870	298,742	621,464	267,230	609,546	281,610	592,491	363,789
Manganese ore (35% or more Mn) ___ short tons, gross weight	--	--	--	--	--	--	--	--
Manganiferous ore (5% to 35% Mn) ___ do	272,908	2,323	159,225	1,413	256,633	2,260	215,893	2,249
Mercury ___ 76-pound flasks	2,189	617	7,366	1,165	23,133	2,806	28,244	3,833
Molybdenum (content of concentrate) ___ thousand pounds	118,163	234,658	105,170	259,328	114,527	333,494	124,974	450,421
Nickel (content of ore and concentrate) ___ short tons	16,618	W	16,987	W	16,469	W	14,347	W
Rare-earth metal concentrates ___ do	35,218	15,966	W	W	W	W	W	W
Silver (recoverable content of ores, etc.) ___ thousand troy ounces	33,762	159,018	34,938	154,424	34,328	149,328	38,166	176,325
Titanium concentrate:								
Ilmenite ___ short tons, gross weight	755,338	22,715	702,252	26,946	617,896	27,578	542,333	25,200
Rutile ___ do	6,446	996	W	W	W	W	W	W
Tungsten ore and concentrate ___ thousand pounds contained W	7,836	37,413	5,490	29,090	5,869	37,266	6,022	55,073
Uranium (recoverable content of U_3O_8) ___ thousand pounds	23,227	192,560	22,936	276,102	25,146	404,830	29,481	582,249
Vanadium (recoverable in ore and concentrate) ___ short tons	4,870	38,266	4,743	49,329	7,376	81,279	6,504	74,488
Zinc (recoverable content of ores, etc.) ___ do	499,872	358,908	469,355	366,097	484,513	358,541	449,620	309,338
Value of items that cannot be disclosed: Beryllium, magnesium chloride for magnesium metal, manganiferous residuum (1974-1976) platinum-group metals (crude), tin, zircon concentrate, and values indicated by W	XX	73,828	XX	127,459	XX	153,452	XX	147,567
Total metals	XX	5,501,000	XX	5,191,000	XX	6,086,000	XX	5,810,000
NONMETALS (EXCEPT FUELS)								
Abrasive stones[2] ___ short tons	3,134	717	2,953	1,060	2,696	1,404	2,200	3,236
Asbestos ___ do	109,091	13,393	98,654	14,220	114,842	23,693	101,704	25,267
Asphalt and related bitumens, native:								
Bituminous limestone, sandstone, gilsonite ___ do	2,021,165	16,666	1,901,715	17,838	2,011,500	17,647	1,237,000	13,874
Barite ___ thousand short tons	1,106	16,822	1,318	21,200	1,234	28,689	1,494	30,264
Boron minerals ___ do	1,185	128,306	1,172	158,772	1,246	184,852	1,469	236,163
Bromine ___ thousand pounds	432,094	117,715	407,163	113,126	r460,061	r112,348	433,818	99,678
Calcium chloride ___ short tons	739,100	24,552	594,400	29,047	648,979	32,889	710,385	45,048
Carbon dioxide, natural ___ thousand cubic feet	966,118	237	1,070,024	279	1,356,834	298	1,617,149	351

See footnotes at end of table.

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

Mineral	1974 Quantity	1974 Value (thousands)	1975 Quantity	1975 Value (thousands)	1976 Quantity	1976 Value (thousands)	1977 Quantity	1977 Value (thousands)
NONMETALS (EXCEPT FUELS) —Continued								
Cement:								
Portland ---- thousand short tons	75,983	$1,992,695	65,215	$2,015,625	69,163	$2,330,402	75,514	$2,727,564
Masonry ---- do	3,371	111,106	2,868	111,801	3,267	139,564	3,752	169,101
Clays ---- do	60,796	422,542	49,047	424,556	52,389	528,745	53,196	579,171
Diatomite ---- short tons	664,303	50,693	573,000	45,812	r631,380	54,982	648,043	63,870
Feldspar ---- do	762,723	11,396	669,898	11,728	739,684	17,531	733,963	17,186
Fluorspar ---- do	201,116	14,297	139,913	10,888	188,270	17,927	169,489	16,479
Garnet (abrasive) ---- do	24,684	2,550	17,204	1,690	24,565	2,740	20,022	2,234
Gem stones[e]	NA	4,583	NA	13,900	NA	8,907	NA	8,850
Gypsum ---- thousand short tons	11,999	52,894	9,751	44,654	11,980	59,888	13,390	74,341
Helium:								
Crude ---- million cubic feet	184	2,208	334	4,008	r587	r7,048	537	6,443
High-purity ---- do	699	18,105	745	19,915	r752	r18,852	957	24,280
Lime ---- thousand short tons	21,606	473,685	19,133	523,805	20,229	609,010	19,947	666,472
Magnesium compounds from seawater and brine (except for metal) ---- short tons, MgO equivalent	907,492	96,742	W	W	W	W	830,475	127,716
Mica:								
Scrap ---- thousand short tons	137	5,475	135	5,219	r141	r5,765	176	6,480
Sheet ---- pounds	20,000	10	5,000	3	5,000	3	W	W
Peat ---- thousand short tons	706	10,989	746	12,294	r731	r12,079	726	12,520
Perlite ---- short tons	555,000	7,024	512,000	7,282	553,000	9,397	597,000	10,753
Phosphate rock ---- thousand metric tons	41,437	501,429	44,276	1,122,184	44,662	r949,379	47,256	821,657
Potassium salts ---- thousand short tons, K_2O equivalent	2,552	159,148	2,501	223,098	2,500	r210,759	2,461	206,872
Pumice ---- thousand short tons	3,937	9,121	3,892	11,203	4,134	10,466	4,009	11,965
Pyrites ---- thousand long tons	424	4,238	625	4,776	750	8,213	435	7,003
Salt ---- thousand short tons	46,536	360,763	41,030	368,063	44,191	430,959	43,412	451,579
Sand and gravel ---- do	904,646	1,421,237	789,436	1,416,346	885,156	1,774,030	929,200	2,028,000
Sodium carbonate (natural) ---- do	4,059	137,486	4,328	182,620	5,216	259,253	6,228	337,516
Sodium sulfate (natural) ---- do	684	16,411	667	27,667	663	32,655	636	29,313
Stone[3] ---- do	1,043,542	2,186,155	901,393	2,120,286	901,660	2,221,000	955,371	2,456,932
Sulfur, Frasch process ---- thousand long tons	7,898	241,066	6,077	304,843	5,860	299,999	5,935	294,733
Talc, soapstone, pyrophyllite ---- short tons	1,289,462	9,569	964,609	8,929	1,092,433	9,902	1,204,835	13,085
Tripoli ---- do	85,121	623	80,562	565	124,281	776	125,661	777
Vermiculite ---- thousand short tons	341	10,120	330	13,761	304	14,032	359	18,579

Value of items that cannot be disclosed: Aplite, emery, graphite, iodine, kyanite, lithium minerals, magnesite, greensand marl, olivine, staurolite, wollastonite, and values of nonmetal items indicated by W	XX	34,125	XX	157,180	XX	169,491	XX	56,043
Total nonmetals[r]	XX	8,687,000	XX	9,570,000	XX	10,616,000	XX	11,701,000
MINERAL FUELS								
Coal:								
Bituminous and lignite[4] thousand short tons	603,406	9,502,347	648,438	12,472,486	678,685	13,189,481	691,344	13,705,219
Pennsylvania anthracite do	6,617	144,695	6,203	198,481	6,228	209,234	5,861	205,138
Natural gas million cubic feet	21,600,522	6,573,402	20,108,661	8,945,062	19,952,438	11,571,776	20,025,463	15,825,954
Natural gas liquids:								
Natural gasoline and cycle products thousand 42-gallon barrels	168,152	1,107,158	151,872	878,698	149,679	985,442	590,455	4,047,473
LP gases do	447,946	1,980,769	444,086	1,893,890	437,366	2,298,647		
Petroleum (crude) do	3,202,585	21,580,549	3,056,779	23,116,059	2,976,180	24,229,540	3,009,265	25,790,722
Total mineral fuels[r]	XX	40,889,000	XX	47,505,000	XX	52,484,000	XX	59,575,000
Grand total	XX	55,077,000	XX	62,266,000	XX	[r]69,186,000	XX	77,086,000

[e]Estimate. [r]Revised. NA Not available. W Withheld to avoid disclosing company proprietary 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]Grindstones, pulpstones, grinding pebbles, sharpening stones, and tube mill liners.
[3]Excludes abrasive stone, bituminous limestone, bituminous sandstone, and soapstone, all included elsewhere in table.
[4]Includes a small quantity of anthracite mined in States other than Pennsylvania.

Note: Beginning with 1977, data on mineral fuels supplied by the Department of Energy.

Table 3.—Minerals produced in the United States and principal producing States in 1977

Mineral	Principal producing States in order of quantity	Other producing States
METALS AND NONMETALS		
Antimony ore and concentrate	Idaho and Mont.	
Aplite	Va.	
Asbestos	Calif., Vt., Ariz., N.C.	
Asphalt (native)	Tex., Utah, Ala., Mo.	
Barite	Nev., Mo., Ark., Ga	Idaho, Ill., Mont., Tenn.
Bauxite	Ark., Ala., Ga.	
Beryllium concentrate	Utah and S. Dak.	
Boron minerals	Calif.	
Bromine	Ark. and Mich.	
Calcium-chloride	Mich. and Calif.	
Carbon dioxide (natural)	N. Mex., Colo., Calif., Utah.	
Cement	Calif., Tex., Pa., Mich	Ala., Ariz., Ark., Colo., Fla., Ga., Hawaii, Idaho, Ill., Ind., Iowa, Kans., Ky., La., Maine, Md., Miss., Mo., Mont., Nebr., Nev., N. Mex., N.Y., N.C., Ohio, Okla., Oreg., S.C., S. Dak., Tenn., Utah, Va., Wash., W. Va., Wis., Wyo.
Clays	Ga., Tex., Ohio, N.C	All other States except Alaska, R.I., Vt.
Copper (mine)	Ariz., Utah, N. Mex., Mont	Alaska, Calif., Colo., Idaho, Maine, Mich., Mo., Nev., Oreg., Pa., Tenn., Wash.
Diatomite	Calif., Nev., Wash., Oreg.	
Emery	N.Y.	
Feldspar	N.C., Conn., Ga., Calif	Ariz., Colo., Maine, Okla., S. Dak., Wyo.
Fluorspar	Ill., Ky., Tex., Mont	Ariz. and Nev.
Garnet, abrasive	Idaho and N.Y.	
Gold (mine)	Nev., S. Dak., Utah, Ariz	Alaska, Calif., Colo., Idaho, Mont., N. Mex., Oreg., Tenn., Wash.
Graphite	Tex.	
Gypsum	Mich., Tex., Calif., Iowa	Ariz., Ark., Colo., Idaho, Ind., Kans., La., Mont., Nev., N. Mex., N.Y., Ohio, Okla., S. Dak., Utah, Va., Wash., Wyo.
Helium	Kans., Okla., Tex	Ariz. and N. Mex.
Iodine	Okla. and Mich.	
Iron ore	Minn., Mich., Calif., Wyo	Colo., Ga., Mo., Mont., Nev., N.J., N.Y., Pa., Tex., Utah, Wis.
Kyanite	Va. and Ga.	
Lead (mine)	Mo., Idaho, Colo., Utah	Ariz., Calif., Ill., Maine, Mont., Nev., N. Mex., N.Y., Okla., Va., Wash., Wis.
Lime	Ohio, Pa., Mo., Tex	Ala., Ariz., Ark., Calif., Colo., Conn., Fla., Hawaii, Idaho, Ill., Ind., Iowa, Kans., Ky., La., Md., Mass., Mich., Minn., Miss., Mont., Nebr., Nev., N.J., N. Mex., N.Y., N. Dak., Okla., Oreg., S. Dak., Tenn., Utah, Va., Wash., W. Va., Wis., Wyo.
Lithium minerals	N.C., Nev., Calif.	
Magnesite	Nev.	
Magnesium chloride	Tex.	
Magnesium compounds	Mich., Calif., Fla., N.J	Del., Miss., Tex., Utah.
Manganiferous ore	Minn., N. Mex., S.C.	
Marl, greensand	N.J.	
Mercury	Nev. and Calif.	
Mica, scrap	N.C., S.C., N. Mex., Ala	Ariz., Conn., Ga., Pa., S. Dak.
Molybdenum	Colo., Ariz., N. Mex., Utah	Calif. and Nev.
Nickel	Oreg.	
Olivine	N.C. and Wash.	
Peat	Mich., Fla., Ind., Ill.	Calif., Colo., Ga., Iowa, Maine, Md., Mass., Minn., Mont., N.J., N. Mex., N.Y., N. Dak., Ohio, Pa., S.C., Wash., Wis.
Perlite	N. Mex., Ariz., Calif., Idaho	Colo. and Nev.
Phosphate rock	Fla., Idaho, N.C., Tenn	Calif., Mo., Mont., Utah, Wyo.
Potassium salts	N. Mex., Calif., Utah.	
Pumice	Oreg., Nev., Calif., Ariz	Colo., Hawaii, Idaho, Mont., N Mex., Okla., Utah, Wash.
Pyrites ore and concentrate	Tenn., Colo., Ariz.	
Rare-earth metal concentrate	Calif. and Fla.	
Salt	La., Tex., N.Y., Mich	Ala., Ariz., Calif., Colo., Kans., Nev., N. Mex., N. Dak., Ohio, Okla., Utah, W. Va.
Sand and gravel	Calif., Alaska, Tex., Ohio	All other States.
Silver (mine)	Idaho, Ariz., Colo., Mont	Alaska, Calif., Ill., Mich., Mo., Nev., N. Mex., N.Y., Oreg., S. Dak., Tenn., Utah, Va., Wash.
Sodium carbonate (natural)	Wyo. and Calif.	
Sodium sulfate (natural)	Calif., Tex., Utah.	
Staurolite	Fla.	
Stone	Tex., Pa., Ill., Mo	All other States except Del. and N. Dak.

Table 3.—Minerals produced in the United States and principal producing States in 1977 —Continued

Mineral	Principal producing States in order of quantity	Other producing States
METALS AND NONMETALS—Continued		
Sulfur (Frasch)	Tex. and La.	
Talc, soapstone, pyrophyllite	Vt., Tex., Mont., N.Y	Ark., Calif., Ga., Nev., N.C., Oreg., Va., Wash.
Tin	Colo.	
Titanium concentrate	N.J., Fla., N.Y.	
Tripoli	Ill., Okla., Ark., Pa.	
Tungsten concentrate	Calif., Colo., Nev	Alaska, Ariz., Idaho, Mont., Oreg., Utah, Wash.
Uranium	N. Mex., Wyo., Utah, Colo	Tex. and Wash.
Vanadium	Ark., Colo., Utah, Idaho	N. Mex.
Vermiculite	Mont. and S.C	Tex.
Wollastonite	N.Y.	
Zinc (mine)	Tenn., Mo., N.Y., Colo	Ariz., Calif., Idaho, Ill., Maine, Mont., Nev., N.J., N. Mex., Okla., Pa., Utah, Va., Wash., Wis.
Zircon concentrate	Fla.	
MINERAL FUELS		
Coal	Ky., W. Va., Pa., Ill	Ala., Alaska, Ariz., Ark., Colo., Ga., Ind., Iowa, Kans., Md., Mo., Mont., N. Mex., N. Dak., Ohio, Okla., Tenn., Tex., Utah, Va., Wash., Wyo.
Natural gas	La., Tex., 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.
Natural gas liquids	Tex., La., N. Mex., Okla	Ala., Alaska, Ark., Calif., Colo., Fla., Ill., Kans., Ky., Mich., Miss., Mont., Nebr., N. Dak., Pa., S. Dak., Utah, W. Va., Wyo.
Petroleum, crude	Tex., La., Calif., Alaska	Ala., Ariz., Ark., Colo., Fla., Ill., Ind., Kans., Ky., Mich., Miss., Mo., Mont., Nebr., Nev., N. Mex., N.Y., N. Dak., Ohio, Okla., Pa., S. Dak., Tenn., Utah, Va., W. Va., Wyo.

Table 4.—Value of mineral production in the United States and principal minerals produced in 1977

State	Value (thousands)	Rank	Percent of U.S. total	Principal minerals, in order of value
Alabama	$1,159,952	19	1.50	Coal, petroleum, cement, stone.
Alaska	1,233,519	18	1.60	Petroleum, sand and gravel, natural gas, stone.
Arizona	1,621,256	12	2.10	Copper, molybdenum, coal, cement.
Arkansas	574,469	25	.75	Petroleum, bromine, natural gas, cement.
California	4,311,824	3	5.59	Petroleum, cement, natural gas, sand and gravel.
Colorado	1,397,039	15	1.81	Petroleum, molybdenum, coal, natural gas.
Connecticut	43,708	44	.06	Stone, sand and gravel, feldspar, lime.
Delaware	[1]2,091	50	([2])	Sand and gravel, magnesium compounds, clays, gem stones.
Florida	1,618,557	13	2.09	Phosphate rock, petroleum, stone, cement.
Georgia	486,256	28	.63	Clays, stone, cement, sand and gravel.
Hawaii	39,980	47	.05	Stone, cement, sand and gravel, pumice.
Idaho	252,670	32	.33	Phosphate rock, silver, lead, zinc.
Illinois	1,663,280	10	2.15	Coal, petroleum, stone, sand and gravel.
Indiana	697,558	23	.91	Coal, cement, stone, petroleum.
Iowa	238,208	33	.31	Cement, stone, sand and gravel, gypsum.
Kansas	1,369,497	16	1.78	Petroleum, natural gas, natural gas liquids, cement.
Kentucky	3,217,860	5	4.17	Coal, stone, petroleum, natural gas.
Louisiana	10,911,885	2	14.16	Natural gas, petroleum, natural gas liquids, sulfur.
Maine	43,225	45	.06	Sand and gravel, cement, zinc, stone.
Maryland	186,699	36	.24	Coal, stone, cement, sand and gravel.
Massachusetts	77,268	43	.10	Stone, sand and gravel, lime, clays.
Michigan	1,622,547	11	2.10	Petroleum, iron ore, cement, natural gas.
Minnesota	875,603	22	1.14	Iron ore, sand and gravel, stone, lime.
Mississippi	492,234	27	.64	Petroleum, natural gas, cement, sand and gravel.
Missouri	893,372	21	1.16	Lead, cement, stone, iron ore.
Montana	691,188	24	.90	Petroleum, coal, copper, natural gas.
Nebraska	144,029	39	.18	Petroleum, cement, sand and gravel, stone.
Nevada	270,845	31	.35	Copper, gold, sand and gravel, cement.
New Hampshire	20,701	48	.03	Sand and gravel, stone, clays, gem stones.
New Jersey	117,060	40	.15	Stone, sand and gravel, zinc, titanium concentrate.
New Mexico	2,910,804	8	3.78	Natural gas, petroleum, natural gas liquids, uranium.
New York	461,807	29	.60	Cement, stone, salt, sand and gravel.
North Carolina	231,511	34	.30	Stone, phosphate rock, sand and gravel, cement.
North Dakota	272,066	30	.35	Petroleum, coal, sand and gravel,natural gas liquids.
Ohio	1,607,454	14	2.08	Coal, natural gas, petroleum, stone.
Oklahoma	3,497,447	4	4.54	Petroleum, natural gas, natural gas liquids, coal.
Oregon	109,132	42	.14	Stone, sand and gravel, cement, nickel.
Pennsylvania	3,043,964	7	3.95	Coal, cement, stone, natural gas.
Rhode Island	6,299	49	.01	Sand and gravel, stone, gem stones.
South Carolina	144,201	38	.18	Cement, stone, clays, sand and gravel.
South Dakota	110,740	41	.14	Gold, cement, stone, sand and gravel.
Tennessee	521,371	26	.68	Coal, stone, zinc, cement.
Texas	19,519,631	1	25.32	Petroleum, natural gas, natural gas liquids, cement.
Utah	1,085,339	20	1.41	Petroleum, copper, coal, uranium.
Vermont	41,454	46	.05	Stone, asbestos, sand and gravel, talc.
Virginia	1,341,686	17	1.74	Coal, stone, lime, cement.
Washington	216,124	35	.28	Cement, coal, sand and gravel, stone.
West Virginia	3,208,068	6	4.16	Coal, natural gas, petroleum, natural gas liquids.
Wisconsin	150,128	37	.19	Sand and gravel, stone, iron ore, lime.
Wyoming	2,331,349	9	3.02	Petroleum, coal, sodium compounds, natural gas.
Total	77,086,000	--	100.00	

[1]Incomplete total.
[2]Less than 1/2 unit.

Table 5.—Value of mineral production per capita and per square mile in 1977, by State

State	Area (square miles)	1977 population (thousands)	Value of mineral production: Total (thousands)	Per square mile: Dollars	Per square mile: Rank	Per capita: Dollars	Per capita: Rank
Alabama	51,609	3,690	$1,159,952	22,476	15	314	16
Alaska	586,412	407	1,233,519	2,104	45	3,031	2
Arizona	113,909	2,296	1,621,256	14,233	20	706	11
Arkansas	53,104	2,144	574,469	10,818	25	268	18
California	158,693	21,896	4,311,824	27,171	12	197	23
Colorado	104,247	2,619	1,397,039	13,401	21	533	13
Connecticut	5,009	3,108	43,708	8,726	30	14	47
Delaware	2,057	582	[1]2,091	1,017	50	4	50
Florida	58,560	8,452	1,618,557	27,639	11	191	24
Georgia	58,876	5,048	486,256	8,259	31	96	32
Hawaii	6,450	895	39,980	6,198	32	45	39
Idaho	83,557	857	252,670	3,024	41	295	17
Illinois	56,400	11,245	1,663,280	29,491	9	148	29
Indiana	36,291	5,330	697,558	19,221	16	130	30
Iowa	56,290	2,879	238,208	4,232	38	83	35
Kansas	82,264	2,326	1,369,497	16,648	18	589	12
Kentucky	40,395	3,458	3,217,860	79,660	3	931	8
Louisiana	48,523	3,921	10,911,885	224,881	1	2,783	3
Maine	33,215	1,085	43,225	1,301	48	40	42
Maryland	10,577	4,139	186,699	17,651	17	45	40
Massachusetts	8,257	5,782	77,268	9,358	28	13	48
Michigan	58,216	9,129	1,622,547	27,871	10	178	26
Minnesota	84,068	3,975	875,603	10,415	26	220	21
Mississippi	47,716	2,389	492,234	10,316	27	206	22
Missouri	69,686	4,801	893,372	12,820	22	186	25
Montana	147,138	761	691,188	4,698	34	908	9
Nebraska	77,227	1,561	144,029	1,865	46	92	33
Nevada	110,540	633	270,845	2,450	43	428	14
New Hampshire	9,304	849	20,701	2,225	44	24	45
New Jersey	7,836	7,329	117,060	14,939	19	16	46
New Mexico	121,666	1,190	2,910,804	23,925	13	2,446	4
New York	49,576	17,924	461,807	9,315	29	26	44
North Carolina	52,586	5,525	231,511	4,403	36	42	41
North Dakota	70,665	653	272,066	3,850	39	417	15
Ohio	41,222	10,701	1,607,454	38,995	7	150	28
Oklahoma	69,919	2,811	3,497,447	50,021	6	1,244	7
Oregon	96,981	2,376	109,132	1,125	49	46	38
Pennsylvania	45,333	11,785	3,043,964	67,147	5	258	20
Rhode Island	1,214	935	6,299	5,189	33	7	49
South Carolina	31,055	2,876	144,201	4,643	35	50	37
South Dakota	77,047	689	110,740	1,437	47	161	27
Tennessee	42,244	4,299	521,371	12,342	24	121	31
Texas	267,338	12,830	19,519,631	73,015	4	1,521	6
Utah	84,916	1,268	1,085,339	12,781	23	856	10
Vermont	9,609	485	41,454	4,314	37	85	34
Virginia	40,817	5,135	1,341,686	32,871	8	261	19
Washington	68,192	3,658	216,124	3,169	40	59	36
West Virginia	24,181	1,859	3,208,068	132,669	2	1,725	5
Wisconsin	56,154	4,651	150,128	2,675	42	32	43
Wyoming	97,914	406	2,331,349	23,810	14	5,742	1
Total[2]	3,615,055	215,642	77,086,000	21,324	XX	356	XX

XX Not applicable.
[1]Incomplete total.
[2]Excludes Washington, D.C., with an area of 67 square miles and a population of 690,000 (which had no mineral production).

Table 6.—Mineral production[1] in the United States, by State

Mineral	1974 Quantity	1974 Value (thousands)	1975 Quantity	1975 Value (thousands)	1976 Quantity	1976 Value (thousands)	1977 Quantity	1977 Value (thousands)
ALABAMA								
Cement:								
Masonry ---- thousand short tons	314	$11,322	262	$10,253	314	$13,671	345	$14,255
Portland ---- do	2,190	61,990	1,968	62,599	2,134	70,365	2,351	79,302
Clays[2] ---- do	2,995	13,298	2,231	9,077	2,239	10,325	2,677	21,984
Coal (bituminous) ---- do	19,824	432,036	22,644	600,767	21,537	611,069	21,545	622,187
Lime ---- do	1,054	22,346	985	29,404	1,009	32,753	1,149	39,213
Natural gas ---- million cubic feet	27,865	20,704	37,814	32,898	41,427	40,806	57,227	84,124
Petroleum (crude) ---- thousand 42-gallon barrels	13,323	113,808	13,477	136,541	14,706	155,437	18,252	176,540
Sand and gravel ---- thousand short tons	12,454	19,120	9,232	17,376	12,023	20,933	14,372	35,204
Stone ---- do	[3]23,773	[3]60,231	22,252	61,515	23,832	65,429	25,262	74,364
Value of items that cannot be disclosed: Asphalt (native), bauxite, clay (bentonite), iron ore, usable (1974-75), mica (scrap), natural gas liquids, salt, stone (dimension 1974), talc (1974-75)	XX	9,891	XX	8,543	XX	8,748	XX	12,779
Total	XX	764,746	XX	968,973	XX	1,029,536	XX	1,159,952
ALASKA								
Barite ---- thousand short tons	20	401	2	30	--	--	--	--
Coal (bituminous) ---- do	700	W	766	W	706	W	705	W
Gem stones	NA	57	NA	57	NA	60	NA	60
Gold (recoverable content of ores, etc.) ---- troy ounces	9,146	1,461	14,980	2,419	22,887	2,868	18,962	2,812
Lead (recoverable content of ores, etc.) ---- short tons	--	--	--	--	14	6	--	--
Natural gas ---- million cubic feet	128,935	21,919	160,270	48,402	166,072	64,602	187,889	75,531
Petroleum (crude) ---- thousand 42-gallon barrels	70,603	347,408	69,834	364,630	63,398	318,789	169,201	988,877
Sand and gravel ---- thousand short tons	43,644	22,954	48,145	25,780	74,208	204,738	66,426	134,251
Silver (recoverable content of ores, etc.) ---- thousand troy ounces	1	3	W	W	3	14	2	8
Stone ---- thousand short tons	5,484	12,947	8,877	26,649	6,727	20,092	4,008	17,494
Tin ---- metric tons	W	W	11	60	--	--	--	--
Value of items that cannot be disclosed: Copper (1974, 1977), mercury (1974), natural gas liquids, platinum-group metals (1974-76), tungsten (1977), and values indicated by W	XX	11,453	XX	12,718	XX	14,019	XX	14,486
Total	XX	418,603	XX	480,745	XX	625,188	XX	1,233,519

ARIZONA

Clays ---- thousand short tons	199	622	129	483	[2]28	[2]361	[2]33	[2]444
Coal (bituminous) ---- do	6,448	W	6,986	W	10,420	W	W	W
Copper ---- short tons	858,783	1,327,678	813,211	1,044,162	1,024,421	1,425,994	923,778	1,234,168
Gem stones	NA	1,500	NA	5,000	NA	4,000	NA	4,500
Gold (recoverable content of ores, etc.) ---- troy ounces	90,586	14,470	85,790	13,854	102,062	12,790	90,167	13,373
Gypsum ---- thousand short tons	141	473	117	419	139	529	187	775
Lead (recoverable content of ores, etc.) ---- short tons	1,059	476	420	181	338	156	318	195
Lime ---- thousand short tons	422	9,071	512	12,444	546	16,115	474	15,528
Mica (scrap) ---- do	2	82	2	65	W	W	W	W
Molybdenum (content of concentrate) ---- thousand pounds	28,346	57,067	25,030	61,411	31,073	89,148	34,574	120,497
Natural gas ---- million cubic feet	224	45	208	58	262	74	240	80
Petroleum (crude) ---- thousand 42-gallon barrels	740	3,885	635	3,332	519	2,724	427	2,243
Pumice ---- thousand short tons	846	865	856	1,294	802	1,240	621	1,226
Sand and gravel ---- do	23,417	41,906	17,222	36,490	[4]18,131	[4]40,184	22,313	49,946
Silver (recoverable content of ores, etc.) ---- thousand troy ounces	6,356	29,935	6,286	27,783	7,615	33,126	6,828	31,546
Stone ---- thousand short tons	4,932	11,479	3,404	11,030	4,147	13,921	5,367	16,495
Zinc (recoverable content of ores, etc.) ---- short tons	9,699	6,964	8,655	6,751	9,501	7,030	4,380	3,013
Value of items that cannot be disclosed: Asbestos, beryl concentrate (1976), cement, clays (ball and common, 1976-77, fire clay, 1977), feldspar, fluorspar (1976-77), helium (high purity, 1974-76), iron ore (1974-76), perlite, pyrite, salt (1975-77), sand and gravel (industrial, 1976), tungsten, and values indicated by W	XX	55,716	XX	63,666	XX	79,229	XX	127,227
Total	XX	1,562,234	XX	1,288,423	XX	1,726,621	XX	1,621,256

ARKANSAS

Bauxite ---- thousand long tons, dried equivalent	1,731	23,597	1,543	22,956	1,667	24,481	1,676	24,851
Clays ---- thousand short tons	984	1,597	995	2,232	1,047	3,396	988	5,407
Coal (bituminous) ---- do	455	9,673	488	16,000	534	19,310	563	21,431
Gem stones	NA	60	NA	70	NA	85	NA	85
Iron ore ---- thousand long tons, gross weight	4	W	(5)	14	--	--	--	--
Lime ---- thousand short tons	187	3,189	170	3,848	182	4,900	152	4,552
Natural gas ---- million cubic feet	123,975	32,234	116,237	40,334	109,533	58,052	104,096	60,896
Natural gas liquids:								
Natural gasoline and cycle products ---- thousand 42-gallon barrels	199	1,344	196	1,360	203	1,422		
LP gases ---- do	418	2,491	407	2,377	408	2,440	555	5,152
Petroleum (crude) ---- do	16,527	122,817	16,133	143,336	18,097	174,636	20,202	200,606
Sand and gravel ---- thousand short tons	14,878	29,922	12,415	25,794	[4]14,736	[4]25,848	16,110	36,091
Stone ---- do	20,381	38,905	17,419	38,796	[3]17,701	[3]39,713	18,323	45,816

See footnotes at end of table.

Table 6.—Mineral production[1] in the United States, by State —Continued

Mineral	1974 Quantity	1974 Value (thousands)	1975 Quantity	1975 Value (thousands)	1976 Quantity	1976 Value (thousands)	1977 Quantity	1977 Value (thousands)
ARKANSAS—Continued								
Value of items that cannot be disclosed: Abrasive stones, barite, bromine, cement, gypsum, phosphate rock (1975-76), sand and gravel (industrial, 1976), stone (dimension, 1976), soapstone, tripoli, vanadium, and values indicated by W	XX	$140,589	XX	$139,324	XX	r$182,744	XX	$169,582
Total	XX	406,418	XX	436,441	XX	r537,027	XX	574,469
CALIFORNIA								
Asbestos ... short tons	58,331	5,697	W	W	78,390	15,706	76,247	18,372
Barite ... thousand short tons	4	W	1	W	--	--	--	--
Boron minerals ... do	1,185	128,306	1,172	158,772	1,246	184,852	1,469	236,163
Cement ... do	8,264	210,520	7,327	232,584	7,897	293,693	9,271	406,185
Clays ... do	2,497	7,626	[2]2,387	[2]7,373	2,295	13,570	2,655	12,179
Copper (recoverable content of ores, etc.) ... short tons	194	300	344	441	375	522	221	295
Diatomite ... do	W	W	354	31,186	386	37,372	397	43,405
Gem stones	NA	220	NA	220	NA	231	NA	230
Gold (recoverable content of ores, etc.) ... troy ounces	5,049	807	9,606	1,551	10,392	1,302	5,704	846
Gypsum ... thousand short tons	1,716	6,642	1,446	6,332	1,647	7,897	1,629	8,500
Lead (recoverable content of ores, etc.) ... short tons	35	16	66	28	54	25	3	2
Lime ... thousand short tons	600	14,877	595	18,626	638	23,324	598	24,074
Magnesium compounds from seawater and bitterns (partly estimated) short tons, MgO content	163,847	18,356	W	W	W	W	W	W
Mercury ... 76-pound flasks	1,311	370	W	W	296	36	W	W
Natural gas ... million cubic feet	365,354	160,756	318,308	222,816	354,334	333,074	311,462	364,099
Natural gas liquids:								
Natural gasoline and cycle products ... thousand 42-gallon barrels	5,709	26,104	4,847	29,543	4,626	31,655	8,117	61,873
LP gases ... do	5,095	29,296	4,481	20,568	4,151	25,487		
Peat ... thousand short tons	14	322	W	W	W	W	W	W
Petroleum (crude) ... thousand 42-gallon barrels	323,003	1,710,350	322,199	1,943,048	326,021	2,005,577	349,609	2,555,965
Pumice ... thousand short tons	909	3,219	348	2,762	705	3,245	636	3,838
Rare-earth metal concentrates ... short tons	34,284	15,798	W	W	W	W	W	W
Sand and gravel ... thousand short tons	105,191	176,213	88,445	168,248	96,592	202,272	109,135	250,951
Silver (recoverable content of ores, etc.) ... thousand troy ounces	42	197	80	353	57	249	58	267
Stone ... thousand short tons	45,709	91,891	33,152	72,740	32,377	75,352	34,037	81,142
Talc, soapstone, pyrophyllite ... short tons	163,841	1,676	152,978	1,598	56,871	1,513	95,602	2,373

Zinc (recoverable content of ores, etc.) do	8	6	206	161	170	126	2	1
Value of items that cannot be disclosed: Bromine (1974-75), calcium-magnesium chloride, carbon dioxide, cement (masonry, 1977), clays (ball and kaolin, 1975), feldspar, iron ore, lithium minerals, molybdenum, perlite, phosphate rock (1976-77), potassium salts, salt, sodium carbonate and sulfate, tungsten concentrate, and values indicated by W	XX	187,684	XX	233,987	XX	226,293	XX	241,064
Total	XX	2,797,249	XX	3,152,937	XX	3,483,373	XX	4,311,824
COLORADO								
Carbon dioxide thousand cubic feet	123,106	W	229,382	W	317,720	W	W	W
Clays thousand short tons	663	1,588	480	1,101	[2]479	[2]1,976	[2]961	[2]4,712
Coal (bituminous) do	6,896	64,677	8,219	135,872	9,437	144,364	11,989	201,289
Copper (recoverable content of ores, etc.) short tons	3,012	4,657	3,560	4,571	2,431	3,384	1,896	2,533
Gem stones	NA	135	NA	145	NA	142	NA	100
Gold (recoverable content of ores, etc.) troy ounces	52,083	8,320	55,483	8,960	50,764	6,362	72,668	10,777
Gypsum thousand short tons	191	800	185	782	215	984	211	1,121
Lead (recoverable content of ore, etc.) short tons	24,609	11,074	27,088	11,648	26,749	12,858	22,994	14,118
Lime thousand short tons	198	3,815	198	4,577	185	4,406	180	5,413
Natural gas million cubic feet	144,629	28,926	171,629	44,624	183,972	88,307	188,792	152,922
Natural gas liquids:								
Natural gasoline and cycle products thousand 42-gallon barrels	1,574	9,319	1,742	9,378	1,904	13,403	9,381	67,066
LP gases do	2,580	14,190	4,821	22,803	6,505	38,249		
Peat thousand short tons	30	201	37	280	33	238	32	195
Petroleum (crude) thousand 42-gallon barrels	37,508	283,904	38,089	365,654	38,992	376,273	39,460	398,457
Sand and gravel thousand short tons	23,793	39,674	20,019	34,850	[4]20,160	[4]32,900	[4]23,910	[4]50,527
Silver (recoverable content of ores, etc.) thousand troy ounces	2,784	13,113	3,366	14,878	4,083	17,762	4,663	21,545
Stone thousand short tons	6,572	15,109	5,315	10,940	5,294	12,555	5,602	14,350
Zinc (recoverable content of ores, etc.) short tons	49,489	35,533	48,460	37,799	50,621	37,460	40,267	27,704
Value of items that cannot be disclosed: Cement, clay (bentonite, 1976-77), feldspar, fluorspar (1974), iron ore, molybdenum, perlite, pumice, pyrites, salt, sand and gravel (industrial, 1976-77), tin, tungsten, uranium, vanadium, and values indicated by W	XX	215,264	XX	249,211	XX	319,043	XX	424,210
Total	XX	750,299	XX	958,073	XX	1,110,166	XX	1,397,039
CONNECTICUT								
Clays thousand short tons	156	363	116	307	130	427	95	250
Gem stones	NA	15	NA	W	NA	W	NA	W
Lime thousand short tons	33	1,148	23	1,013	24	1,103	29	1,412
Mica, scrap do	2	W	W	W	W	W	W	W
Sand and gravel do	6,345	11,272	4,900	10,040	6,414	12,978	[4]8,543	[4]18,316

See footnotes at end of table.

Table 6.—Mineral production[1] in the United States, by State —Continued

Mineral	1974 Quantity	1974 Value (thousands)	1975 Quantity	1975 Value (thousands)	1976 Quantity	1976 Value (thousands)	1977 Quantity	1977 Value (thousands)
CONNECTICUT—Continued								
Stone ... thousand short tons	8,457	$21,134	7,322	$20,117	6,016	$17,598	6,989	$20,559
Value of items that cannot be disclosed: Feldspar, mica (sheet, 1974), sand and gravel (industrial, 1977), and values indicated by W	XX	1,430	XX	1,533	XX	2,212	XX	3,171
Total	XX	35,362	XX	33,010	XX	34,318	XX	43,708
DELAWARE								
Clays ... thousand short tons	14	8	9	6	11	8	11	7
Gem stones	NA	2	NA	W	NA	W	NA	W
Sand and gravel ... thousand short tons	2,396	3,783	976	1,900	1,117	1,829	1,351	2,084
Value of items that cannot be disclosed: Other nonmetals and values indicated by W	XX	W	XX	W	XX	W	XX	W
Total	XX	[6]3,793	XX	[6]1,906	XX	[6]1,837	XX	[6]2,091
FLORIDA								
Cement:								
Masonry ... thousand short tons	235	4,737	W	W	W	W	W	W
Portland ... do	2,562	75,133	1,721	62,525	1,949	67,832	2,540	87,561
Clays ... do	[2]808	[2]14,261	712	17,063	680	20,672	581	[2]22,313
Lime ... do	185	5,315	199	7,708	179	7,798	165	7,350
Natural gas ... million cubic feet	38,137	20,441	44,383	43,185	43,165	42,388	48,171	52,458
Peat ... thousand short tons	67	616	82	1,037	79	1,287	125	1,396
Petroleum ... thousand 42-gallon barrels	36,351	351,331	41,877	490,258	44,460	499,573	46,641	544,254
Sand and gravel ... thousand short tons	24,372	33,400	13,237	20,199	13,204	19,164	20,218	38,989
Stone[3] ... do	54,560	100,378	39,071	73,372	38,606	74,412	48,558	101,435
Titanium concentrates (rutile) ... short tons	6,446	996	W	W	W	W	W	W
Value of items that cannot be disclosed: Clay (kaolin, 1974, 1976-77), magnesium compounds, natural gas liquids, phosphate rock, rare-earth metal concentrate, staurolite, stone (dimension), titanium concentrate (ilmenite), zircon concentrate, and values indicated by W	XX	437,287	XX	1,060,153	XX	919,106	XX	762,801
Total	XX	1,043,895	XX	1,775,500	XX	1,652,232	XX	1,618,557

GEORGIA									
Cement:									
Masonry	thousand short tons	40	1,304	W	W	W	W	W	W
Portland	do	1,150	31,535	828	25,822	930	30,085	1,192	37,711
Clays	do	[2]7,692	[2]203,936	6,156	195,300	7,471	273,145	7,554	288,223
Coal (bituminous)	do	--	--	W	W	186	6,152	W	W
Peat	do	1	6	([5])	5	W	W	W	W
Sand and gravel	do	4,989	9,639	5,105	8,818	4,835	8,387	5,141	13,207
Stone	do	40,321	105,582	30,084	91,157	31,855	98,806	38,105	119,852
Talc	short tons	33,850	102	27,400	82	W	W	23,540	63
Value of items that cannot be disclosed: Barite, bauxite, fire clay (1974), feldspar, iron ore, kyanite, mica (scrap), rare-earth metal concentrate (1974), titanium concentrate (1974), zircon concentrate (1974), and values indicated by W		XX	10,996	XX	12,203	XX	11,904	XX	27,200
Total		XX	363,100	XX	333,387	XX	428,479	XX	486,256
HAWAII									
Cement:									
Masonry	thousand short tons	14	706	13	762	11	663	10	607
Portland	do	487	16,405	456	19,942	328	17,747	320	16,315
Gem stones		NA	W	NA	W	NA	W	NA	W
Lime	thousand short tons	6	221	6	250	W	W	W	W
Pumice, pumicite, volcanic ash	do	385	792	318	912	330	636	260	574
Sand and gravel	do	990	2,379	671	2,460	573	1,634	771	2,452
Stone	do	[3]7,638	[3]21,370	7,569	25,319	[3]6,092	[3]21,193	5,758	19,880
Value of items that cannot be disclosed: Clays, stone (dimension, 1974, 1976), and values indicated by W		XX	169	XX	65	XX	379	XX	152
Total		XX	42,042	XX	49,710	XX	42,252	XX	39,980
IDAHO									
Antimony ore and concentrate	short tons, antimony content	445	W	W	W	133	282	446	W
Clays	thousand short tons	[2]9	[2]10	30	284	W	W	W	W
Copper (recoverable content of ores, etc.)	short tons	2,841	4,393	3,192	4,099	3,362	4,680	4,052	5,413
Gem stones		NA	120	NA	120	NA	126	NA	100
Gold (recoverable content of ores, etc.)	troy ounces	2,898	463	2,529	408	2,755	345	12,894	1,912
Lead (recoverable content of ores, etc.)	short tons	51,717	23,273	50,395	21,670	53,636	24,780	47,258	29,016
Pumice	thousand short tons	108	182	111	187	W	W	W	W
Sand and gravel	do	7,665	10,484	6,881	12,768	[4]6,549	[4]11,504	[4]7,750	[4]15,282

See footnotes at end of table.

Table 6.—Mineral production[1] in the United States, by State —Continued

Mineral	1974 Quantity	1974 Value (thousands)	1975 Quantity	1975 Value (thousands)	1976 Quantity	1976 Value (thousands)	1977 Quantity	1977 Value (thousands)
IDAHO—Continued								
Silver (recoverable content of ores, etc.) thousand troy ounces	12,436	$58,572	13,868	$61,297	11,561	$50,292	15,292	$70,649
Stone thousand short tons	3,528	9,868	3,316	8,952	[3]3,462	[3]9,122	[3]3,077	[3]8,005
Zinc (recoverable content of ores, etc.) short tons	39,469	28,339	40,926	31,922	46,586	34,473	30,998	21,327
Value of items that cannot be disclosed: Barite, cement, clays (selected, 1974, 1976-77), garnet (abrasive), gypsum, iron ore (1974-75), lime, perlite, phosphate rock, sand and gravel (industrial, 1976-77), stone (dimension, 1976-77), tungsten concentrate, vanadium, and values indicated by W	XX	72,854	XX	92,081	XX	74,642	XX	100,966
Total	XX	208,558	XX	233,788	XX	210,246	XX	252,670
ILLINOIS								
Cement:								
Masonry thousand short tons	69	3,228	W	W	W	W	W	W
Portland do	1,460	41,023	1,374	42,756	1,632	53,524	1,823	61,849
Clays[2] do	1,587	3,744	1,366	3,249	1,309	3,272	951	5,117
Coal (bituminous) do	58,215	582,010	59,537	871,377	58,239	925,968	53,493	924,506
Fluorspar short tons	151,898	12,247	99,898	8,957	142,666	14,563	131,218	13,941
Gem stones	NA	2	NA	2	NA	2	NA	2
Lead (recoverable content of ores, etc.) short tons	493	222	W	W	W	W	W	W
Natural gas million cubic feet	1,436	574	1,440	1,008	1,556	1,533	1,003	1,204
Peat thousand short tons	96	1,412	96	1,511	87	763	82	1,478
Petroleum (crude) thousand 42-gallon barrels	27,553	244,395	26,067	273,182	26,272	267,449	25,608	314,293
Sand and gravel thousand short tons	42,705	68,566	39,000	83,515	38,784	87,152	37,633	101,230
Stone do	63,231	121,763	60,640	130,104	61,862	141,543	57,077	136,073
Zinc (recoverable content of ores, etc.) short tons	4,104	2,947	W	W	W	W	W	W
Value of items that cannot be disclosed: Barite, clay (fuller's earth), copper (1974), lime, natural gas liquids, silver, tripoli, and values indicated by W	XX	65,517	XX	74,937	XX	85,396	XX	103,587
Total	XX	1,147,650	XX	1,490,598	XX	1,581,165	XX	1,663,280
INDIANA								
Cement:								
Masonry thousand short tons	W	W	343	12,263	396	14,270	W	W
Portland do	W	W	2,185	63,077	2,490	73,432	W	W

Clays ---- do----	1,092	1,947	1,094	1,961	1,265	2,308	1,268	2,237
Coal (bituminous) ---- do----	23,726	198,410	25,124	280,130	25,369	312,990	27,797	384,493
Natural gas ---- million cubic feet--	176	25	346	135	192	100	183	126
Peat ---- thousand short tons--	71	946	76	1,918	[r]66	[r]829	51	759
Petroleum (crude) ---- thousand 42-gallon barrels--	4,919	42,402	4,632	48,821	4,630	50,421	5,314	66,212
Sand and gravel ---- thousand short tons--	26,077	35,656	21,641	35,234	25,884	45,521	26,248	50,089
Stone ---- do----	[3]31,031	[3]64,106	28,947	68,850	28,450	72,205	26,984	73,196
Value of items that cannot be disclosed: Abrasive stone, gypsum, lime, sandstone (1974), and values indicated by W ----	XX	97,198	XX	[r]29,211	XX	34,358	XX	120,446
Total ----	XX	440,690	XX	541,600	XX	[r]606,434	XX	697,558
IOWA								
Cement:								
Masonry ---- thousand short tons--	65	2,660	62	2,988	76	4,143	86	5,052
Portland ---- do----	2,424	64,156	2,258	73,786	2,438	86,107	2,645	99,383
Clays ---- do----	960	1,869	959	1,916	1,017	2,245	883	2,461
Coal (bituminous) ---- do----	590	4,591	622	6,891	616	8,351	513	6,518
Gem stones ----	NA	W	NA	W	NA	1	NA	1
Gypsum ---- thousand short tons--	1,397	7,142	1,208	6,546	1,486	8,288	1,593	10,035
Sand and gravel ---- do----	17,091	26,104	15,410	26,844	[4]15,206	[4]26,277	[4]16,600	[4]33,290
Stone ---- do----	32,842	66,119	30,336	73,782	[3]30,272	[3]75,921	[3]29,183	[3]76,964
Value of items that cannot be disclosed: Lime, peat, sand and gravel (industrial, 1976-77), stone (dimension, 1976-77), and values indicated by W ----	XX	4,079	XX	3,092	XX	4,694	XX	4,504
Total ----	XX	176,720	XX	195,740	XX	216,027	XX	238,208
KANSAS								
Cement:								
Masonry ---- thousand short tons--	64	2,208	57	2,811	72	3,281	79	3,742
Portland ---- do----	1,940	46,940	1,832	55,038	2,005	66,478	2,020	72,815
Clays ---- do----	1,311	1,785	1,178	1,604	[2]1,064	[2]1,869	[2]1,117	[2]1,965
Coal (bituminous) ---- do----	718	5,463	479	9,481	590	11,473	897	16,983
Helium (high-purity) ---- million cubic feet--	499	11,477	497	11,928	503	11,066	W	W
Lime ---- thousand short tons--	28	535	W	W	W	W	15	409
Natural gas ---- million cubic feet--	886,782	147,206	843,625	145,103	829,170	348,251	781,289	378,925

See footnotes at end of table.

Table 6.—Mineral production[1] in the United States, by State —Continued

Mineral	1974 Quantity	1974 Value (thousands)	1975 Quantity	1975 Value (thousands)	1976 Quantity	1976 Value (thousands)	1977 Quantity	1977 Value (thousands)
KANSAS—Continued								
Natural gas liquids:								
Natural gasoline ---- thousand 42-gallon barrels	6,630	$24,810	6,295	$25,062	6,434	$31,017	31,022	$190,811
LP gases ---- do	24,402	78,818	23,563	71,632	23,767	83,422		
Petroleum (crude) ---- do	61,691	490,984	59,106	561,508	58,714	557,783	57,496	574,960
Salt[7] ---- thousand short tons	1,367	27,007	1,446	31,214	1,310	35,291	1,430	41,154
Sand and gravel ---- do	11,687	13,388	10,866	13,467	[4]12,291	[4]14,940	[4]13,973	[4]23,299
Stone ---- do	[3]17,869	34,869	15,907	35,850	[3]16,348	[3]38,228	[3]17,229	[3]41,807
Value of items that cannot be disclosed: Clays (bentonite, 1976-77), diatomite (1974-76), gypsum, helium (crude), pumice (1974-75), salt (brine), sand and gravel (industrial, 1976-77), stone (dimension, 1976-77), and values indicated by W	XX	3,913	XX	6,418	XX	10,749	XX	22,627
Total	XX	889,398	XX	970,611	XX	1,213,848	XX	1,369,497
KENTUCKY								
Clays[2] ---- thousand short tons	848	1,477	778	1,483	754	2,395	716	2,500
Coal (bituminous) ---- do	137,197	2,340,961	143,613	2,499,295	143,972	2,848,690	146,262	2,928,678
Natural gas ---- million cubic feet	71,876	35,938	60,511	32,676	66,137	36,375	60,902	33,496
Petroleum (crude) ---- thousand 42-gallon barrels	7,837	68,340	7,556	84,520	7,483	85,454	6,581	85,659
Sand and gravel ---- thousand short tons	8,710	12,887	8,924	14,466	9,154	15,271	9,764	19,686
Stone ---- do	35,452	66,632	31,734	67,906	33,378	77,060	36,096	88,941
Zinc (recoverable content of ores, etc.) ---- short tons	--	--	41	32	59	44	--	--
Value of items that cannot be disclosed: Cement, clay (ball), fluorspar, lead (1975), lime, and natural gas liquids	XX	36,975	XX	38,481	XX	49,300	XX	58,900
Total	XX	2,563,210	XX	2,738,859	XX	3,114,589	XX	3,217,860
LOUISIANA								
Clays ---- thousand short tons	770	1,425	531	1,132	513	1,158	401	785
Lime ---- do	796	17,665	485	12,484	W	W	W	W
Natural gas ---- million cubic feet	7,753,631	2,380,365	7,090,645	2,999,179	7,006,596	3,223,034	7,215,006	5,068,295
Natural gas liquids:								
Natural gasoline and cycle products ---- thousand 42-gallon barrels	35,860	234,954	31,808	178,930	27,078	151,683	117,763	804,183
LP gases ---- do	108,439	423,996	103,714	392,039	91,701	375,057		

Petroleum (crude) do	737,324	4,811,772	650,840	4,611,879	606,501	4,556,761	562,905	4,689,122
Salt thousand short tons	13,543	76,960	12,166	77,116	13,491	91,952	13,201	96,878
Sand and gravel do	12,341	27,781	14,587	35,990	22,528	51,293	21,987	50,790
Stone do	[3]10,940	[3]24,046	10,489	38,260	9,685	28,127	9,710	26,920
Sulfur (Frasch process) thousand long tons	3,426	W	2,672	W	2,445	W	2,455	W
Value of items that cannot be disclosed: Cement, gypsum, stone (miscellaneous, 1974), and values indicated by W	XX	147,614	XX	166,266	XX	173,042	XX	174,912
Total	XX	8,146,578	XX	8,513,275	XX	8,652,107	XX	10,911,885
MAINE								
Clays thousand short tons	146	183	125	202	134	216	98	160
Copper short tons	1,522	2,353	2,024	2,599	1,766	2,459	1,337	1,787
Gem stones	NA	W	NA	W	NA	1,105	NA	W
Lead (recoverable content of ores, etc.) short tons	279	126	364	157	216	100	178	109
Peat thousand short tons	4	194	4	207	5	173	5	80
Sand and gravel do	8,755	10,673	9,875	11,403	[4]10,312	[4]13,950	10,487	19,023
Stone do	1,491	4,255	[3]1,253	[3]3,741	1,443	4,609	1,312	4,110
Zinc (recoverable content of ores, etc.) short tons	10,425	7,485	8,318	6,488	7,810	5,779	7,269	5,001
Value of items that cannot be disclosed: Cement, feldspar (1976-77), sand and gravel (industrial, 1976), silver (1974-76), stone (dimension, 1975), and values indicated by W	XX	11,079	XX	11,944	XX	11,973	XX	12,955
Total	XX	36,348	XX	36,741	XX	40,364	XX	43,225
MARYLAND								
Clays[2] thousand short tons	884	2,066	580	1,450	702	1,817	893	2,344
Coal (bituminous) do	2,337	48,630	2,606	50,502	2,830	61,974	3,036	53,676
Gem stones	NA	8	NA	W	NA	W	NA	W
Lime thousand short tons	23	527	15	434	16	494	W	W
Natural gas million cubic feet	133	32	93	25	75	24	82	32
Peat thousand short tons	3	45	2	39	2	W	3	W
Sand and gravel do	11,690	29,386	11,786	29,477	12,942	31,914	11,702	29,562
Stone do	18,072	47,630	14,796	43,110	15,709	47,669	16,766	50,680
Value of items that cannot be disclosed: Cement, clay (ball), talc and soapstone (1974), and items indicated by W	XX	44,556	XX	39,882	XX	41,026	XX	50,405
Total	XX	172,880	XX	164,919	XX	184,918	XX	186,699
MASSACHUSETTS								
Clays thousand short tons	218	379	124	228	126	238	149	275
Gem stones	NA	5	NA	W	NA	W	NA	W

See footnotes at end of table.

Table 6.—Mineral production[1] in the United States, by State —Continued

Mineral	1974 Quantity	1974 Value (thousands)	1975 Quantity	1975 Value (thousands)	1976 Quantity	1976 Value (thousands)	1977 Quantity	1977 Value (thousands)
MASSACHUSETTS—Continued								
Lime ---- thousand short tons	170	$4,972	152	$5,215	178	$6,354	W	W
Peat ---- do	3	85	W	W	W	W	2	W
Sand and gravel ---- do	17,334	26,565	13,281	24,556	16,084	29,666	16,639	$34,346
Stone ---- do	8,103	30,103	7,170	28,681	7,937	33,502	8,093	35,357
Value of items that cannot be disclosed: Nonmetals and values indicated by W	XX	--	XX	166	XX	90	XX	7,290
Total	XX	62,109	XX	58,846	XX	69,850	XX	77,268
MICHIGAN								
Cement:								
Masonry ---- thousand short tons	217	6,309	183	6,429	218	8,370	246	9,761
Portland ---- do	5,903	140,513	4,573	131,324	4,931	145,381	5,582	166,803
Clays ---- do	2,161	4,074	1,818	3,580	1,934	4,741	2,007	5,126
Copper (recoverable content of ores, etc.) ---- short tons	67,012	103,601	73,690	94,618	43,707	60,840	42,375	56,613
Gem stones	NA	8	NA	8	NA	10	NA	12
Gypsum ---- thousand short tons	1,482	7,258	1,224	5,936	1,837	9,842	1,924	8,778
Iron ore (usable) ---- thousand long tons, gross weight	11,602	213,598	14,089	339,113	16,245	441,206	12,009	356,227
Lime ---- thousand short tons	1,528	30,036	1,434	36,540	1,456	39,686	1,347	42,015
Magnesium compounds from seawater and brine (except for metal) short tons, MgO equivalant	503,281	53,302	W	W	W	W	W	W
Natural gas ---- million cubic feet	69,133	34,843	102,113	64,740	119,262	106,739	129,954	131,254
Natural gas liquids:								
Natural gasoline ---- thousand 42-gallon barrels	466	3,089	656	3,294	3,504	19,725		
LP gases ---- do	849	5,383	1,348	5,945	1,215	6,306	7,919	73,675
Peat ---- thousand short tons	244	3,811	245	3,206	r280	r3,397	226	3,917
Petroleum (crude) ---- thousand 42-gallon barrels	18,021	154,746	24,420	262,352	30,421	329,637	32,965	362,722
Salt ---- thousand short tons	4,445	62,055	4,020	68,353	4,219	79,740	3,939	78,808
Sand and gravel ---- do	60,027	82,617	47,051	73,397	47,403	78,455	46,486	101,542
Silver (recoverable content of ores, etc.) ---- thousand troy ounces	643	3,028	632	2,795	311	1,352	335	1,550
Stone ---- thousand short tons	47,479	72,748	39,946	73,800	41,485	82,331	40,525	85,118
Value of items that cannot be disclosed: Bromine, calcium-chloride, iodine, and values indicated by W	XX	54,411	XX	116,223	XX	r128,557	XX	138,626
Total	XX	1,035,430	XX	1,291,653	XX	r1,546,315	XX	1,622,547

MINNESOTA								
Clays ---- thousand short tons	W	W	W	W	W	W	[2]163	[2]276
Gem stones	NA	14	NA	14	NA	15	NA	15
Iron ore (usable) ---- thousand long tons, gross weight	59,422	949,678	49,167	1,015,272	47,874	1,137,733	30,245	782,627
Lime ---- short tons	W	W	W	W	103,389	2,794	122,860	4,315
Manganiferous ore (5% to 35% Mn) ---- short tons, gross weight	225,560	W	108,749	W	202,271	W	166,440	W
Peat ---- thousand short tons	20	471	13	230	26	1,505	28	1,280
Sand and gravel ---- do	36,720	42,370	33,398	45,214	[4]33,486	[4]44,503	30,713	59,629
Stone ---- do	8,301	22,041	6,854	23,302	7,567	25,767	7,865	25,124
Value of items that cannot be disclosed: Abrasive stones, cement (1974-75), clay (kaolin, 1977), sand and gravel (industrial, 1976), and values indicated by W	XX	11,792	XX	13,056	XX	5,713	XX	2,337
Total	XX	1,026,366	XX	1,097,088	XX	1,218,030	XX	875,603
MISSISSIPPI								
Clays ---- thousand short tons	2,013	10,468	1,592	10,605	[2]1,487	[2]8,849	[2]1,483	[2]8,841
Lime ---- do	70	1,393	53	1,060	57	1,248	49	1,079
Natural gas ---- million cubic feet	78,787	23,242	74,345	36,875	70,762	50,241	82,995	60,589
Petroleum (crude) ---- thousand 42-gallon barrels	50,779	309,753	46,614	310,346	46,072	328,957	43,022	352,844
Sand and gravel ---- thousand short tons	14,939	19,487	14,372	23,098	[4]12,033	[4]20,394	[4]13,353	[4]25,375
Stone ---- do	1,719	2,572	1,629	2,730	1,762	2,968	2,176	3,933
Value of items that cannot be disclosed: Cement, clays (selected, 1976-77), magnesium compounds, natural gas liquids, and sand and gravel (industrial, 1976-77)	XX	24,240	XX	25,295	XX	37,205	XX	39,573
Total	XX	391,155	XX	410,009	XX	449,862	XX	492,234
MISSOURI								
Barite ---- thousand short tons	177	3,386	171	3,989	124	3,860	117	4,061
Cement:								
Masonry ---- do	75	2,434	65	2,110	76	2,718	82	3,286
Portland ---- do	4,229	106,985	3,962	116,260	4,353	142,976	4,654	155,945
Clays[2] ---- do	2,565	13,151	2,168	13,214	2,133	14,915	2,373	16,892
Coal (bituminous) ---- do	4,623	29,383	5,638	48,054	6,075	56,934	6,366	66,089
Copper (recoverable content of ores, etc.) ---- short tons	12,665	19,580	14,258	18,308	11,050	15,382	11,737	15,681

See footnotes at end of table.

Table 6.—Mineral production[1] in the United States, by State —Continued

Mineral	1974 Quantity	1974 Value (thousands)	1975 Quantity	1975 Value (thousands)	1976 Quantity	1976 Value (thousands)	1977 Quantity	1977 Value (thousands)
MISSOURI—Continued								
Iron ore (usable) thousand long tons, gross weight	1,866	W	2,273	W	2,133	W	W	W
Lead (recoverable content of ores, etc.) short tons	562,097	$252,944	515,958	$221,862	500,991	$231,458	500,255	$307,156
Lime thousand short tons	1,901	36,369	1,606	40,630	1,731	49,907	1,723	51,529
Natural gas million cubic feet	33	10	30	10	29	10	20	8
Petroleum (crude) thousand 42-gallon barrels	56	W	57	W	61	W	W	W
Phosphate rock thousand short tons	35	W	35	W	W	W	W	W
Sand and gravel do	10,933	19,462	9,752	18,216	15,375	26,550	14,002	31,473
Silver (recoverable content of ores, etc.) thousand troy ounces	2,387	11,244	2,525	11,161	2,277	9,905	2,363	10,916
Stone thousand short tons	50,626	90,204	46,988	95,535	47,546	98,327	49,615	105,297
Zinc (recoverable content of ores, etc.) short tons	91,987	66,047	74,867	58,396	83,530	61,812	81,689	56,203
Value of items that cannot be disclosed: Asphalt (native), clays (selected, 1974-75, 1977), and values indicated by W	XX	39,850	XX	74,983	XX	70,406	XX	68,836
Total	XX	691,049	XX	722,728	XX	785,160	XX	893,372
MONTANA								
Antimony short tons	W	W	273	813	150	318	164	663
Clays thousand short tons	298	2,189	223	[2]1,878	192	W	224	3,557
Coal (bituminous and lignite) do	14,106	54,961	22,054	111,579	26,231	128,534	27,226	161,567
Copper (recoverable content of ores, etc.) short tons	131,131	202,728	87,959	112,940	91,111	126,827	86,203	115,167
Gem stones	NA	400	NA	400	NA	170	NA	100
Gold (recoverable content of ores, etc.) troy ounces	28,268	4,516	17,259	2,787	24,075	3,017	22,348	3,314
Iron ore (usable) thousand long tons, gross weight	30	W	18	W	18	W	W	W
Lead (recoverable content of ores, etc.) short tons	154	69	205	88	92	43	106	65
Lime thousand short tons	226	3,364	221	5,188	224	5,980	223	7,705
Natural gas million cubic feet	54,873	13,883	40,734	17,638	42,563	18,941	46,819	33,663
Peat thousand short tons	W	W	1	51	W	W	W	W
Petroleum (crude) thousand 42-gallon barrels	34,554	229,802	32,844	257,169	32,814	276,419	32,680	280,470
Pumice thousand short tons	—	—	—	—	5	8	5	7
Sand and gravel do	4,242	6,126	4,127	6,963	4,786	7,336	4,867	10,421
Silver (recoverable content of ores, etc.) thousand troy ounces	3,512	16,542	2,617	11,565	3,279	14,262	3,367	15,558
Stone thousand short tons	[3]3,115	[3]6,242	[3]3,130	[3]6,753	3,468	7,994	3,683	8,037
Talc do	W	W	W	W	225	2,960	226	2,947
Zinc (recoverable content of ores, etc.) short tons	136	98	110	86	64	47	79	54

Value of items that cannot be disclosed: Barite (1975-77), cement, clays (selected, 1975), fluorspar, gypsum, natural gas liquids, phosphate rock, stone (dimension, 1974-75), tungsten ore and concentrate, vermiculite, and values indicated by W	XX	33,881	XX	37,252	XX	43,433	XX	47,893
Total	XX	574,801	XX	573,150	XX	636,289	XX	691,188
NEBRASKA								
Clays thousand short tons	182	414	195	416	149	345	161	368
Gem stones	NA	11	NA	11	NA	11	NA	11
Lime thousand short tons	36	591	W	W	W	W	W	W
Natural gas million cubic feet	2,538	863	2,565	1,388	2,511	1,288	2,789	1,818
Petroleum (crude) thousand 42-gallon barrels	6,611	45,167	6,120	55,133	6,182	55,551	5,968	62,425
Sand and gravel thousand short tons	13,231	17,727	11,759	16,901	[4]14,230	[4]21,483	[4]16,848	[4]30,566
Stone do	4,630	10,364	4,242	10,322	4,101	11,054	4,128	12,974
Value of items that cannot be disclosed: Cement, natural gas liquids, sand and gravel (industrial, 1976-77), and values indicated by W	XX	23,497	XX	27,734	XX	33,633	XX	35,867
Total	XX	98,634	XX	111,905	XX	123,365	XX	144,029
NEVADA								
Barite thousand short tons	761	8,115	947	11,533	900	18,379	1,158	18,329
Clays do	39	218	[2]5	[2]136	[2]7	[2]174	[2]10	[2]158
Copper (recoverable content of ores, etc.) short tons	84,101	130,021	81,210	104,274	58,160	80,958	67,061	89,593
Gem stones	NA	400	NA	2,814	NA	1,300	NA	1,000
Gold (recoverable content of ores, etc.) troy ounces	298,754	47,723	332,814	53,746	287,962	36,087	324,003	48,053
Gypsum thousand short tons	843	2,959	558	2,375	792	3,884	1,242	6,834
Iron ore (usable) thousand long tons, gross weight	139	W	109	1,017	W	W	W	W
Lead (recoverable content of ores, etc.) short tons	1,785	803	2,976	1,280	582	269	743	456
Mercury 76-pound flasks	W	W	W	W	22,837	2,770	W	W
Petroleum (crude) thousand 42-gallon barrels	129	W	115	W	143	W	W	W
Pumice thousand short tons	W	W	W	W	388	763	656	1,154
Sand and gravel do	8,736	14,515	8,056	16,848	9,671	20,106	10,185	21,172
Silver (recoverable content of ores, etc.) thousand troy ounces	872	4,108	1,609	7,111	784	3,410	738	3,411
Stone thousand short tons	2,186	4,203	[3]1,829	[3]4,524	[3]1,904	[3]5,975	1,668	5,506
Tungsten ore and concentrate thousand pounds contained W	132	537	33	152	99	561	263	1,687
Zinc (recoverable content of ores, etc.) short tons	3,405	2,445	5,496	4,287	1,438	1,064	1,672	1,150
Value of items that cannot be disclosed: Antimony (1974), cement, clays (selected, 1975-77), diatomite, fluorspar, lime, lithium minerals, magnesite, molybdenum, perlite, salt, stone (dimension, 1975-76), talc, and values indicated by W	XX	41,829	XX	48,820	XX	57,983	XX	72,342
Total	XX	257,876	XX	258,917	XX	233,683	XX	270,845

See footnotes at end of table.

Table 6.—Mineral production[1] in the United States, by State —Continued

Mineral	1974 Quantity	1974 Value (thousands)	1975 Quantity	1975 Value (thousands)	1976 Quantity	1976 Value (thousands)	1977 Quantity	1977 Value (thousands)
NEW HAMPSHIRE								
Clays ______ thousand short tons__	34	$55	W	W	W	W	W	W
Gem stones ______	NA	42	NA	W	NA	W	NA	W
Sand and gravel______ thousand short tons__	6,126	8,223	5,150	$9,077	[4]6,180	[4]$10,409	6,835	$13,888
Stone ______ do____	590	5,371	1,519	7,938	742	7,032	792	6,686
Value of items that cannot be disclosed ______	--	--	XX	92	XX	138	XX	127
Total ______	XX	13,691	XX	17,107	XX	17,579	XX	20,701
NEW JERSEY								
Clays ______ thousand short tons__	104	524	67	372	61	331	68	374
Gem stones ______	NA	16	NA	16	NA	17	NA	17
Peat______ thousand short tons__	31	603	29	686	22	568	30	769
Sand and gravel______ do____	17,924	47,292	13,012	39,640	12,420	39,439	9,697	29,327
Stone[3] ______ do____	15,749	52,456	11,821	42,381	11,234	39,012	12,993	46,621
Zinc (recoverable content of ores, etc.) ______ short tons__	32,848	23,585	31,105	24,262	33,767	24,987	33,464	23,024
Value of items that cannot be disclosed: Iron ore (1977), lime (1976-77), magnesium compounds, manganiferous residuum (1974-76), greensand marl, stone (dimension), and titanium concentrate ______	XX	16,272	XX	16,345	XX	15,532	XX	16,928
Total ______	XX	140,748	XX	123,702	XX	119,886	XX	117,060
NEW MEXICO								
Carbon dioxide ______ million cubic feet__	W	W	569,352	60	856,548	80	W	W
Clays[2]______ thousand short tons__	55	317	44	61	56	116	69	113
Coal (bituminous)______ do____	9,392	W	8,785	W	9,760	W	11,083	87,952
Copper (recoverable content of ores, etc.)______ short tons__	196,585	303,920	146,263	187,802	172,360	239,925	164,698	220,037
Gem stones ______	NA	200	NA	200	NA	210	NA	170
Gold (recoverable content of ores) ______ troy ounces__	15,427	2,464	15,049	2,430	15,198	1,905	13,560	2,011
Gypsum ______ thousand short tons__	157	532	W	W	W	W	182	1,227
Helium (high-purity)______ million cubic feet__	--	--	W	W	W	W	W	W
Iron ore (usable)______ thousand long tons, gross weight__	6	135	W	W	--	--	--	--
Lead (recoverable content of ores, etc.) ______ short tons__	2,364	1,064	1,931	830	W	W	W	W
Lime ______ thousand short tons__	58	1,679	W	W	W	W	W	W
Manganiferous ore (5% to 35% Mn)______ short tons, gross weight__	47,348	W	49,976	W	45,362	W	29,120	W

Mica, scrap ---- thousand short tons	12	60	W	W	W	W	14	W
Natural gas ---- million cubic feet	1,244,779	390,861	1,217,430	493,059	1,230,976	695,501	1,202,973	974,408
Natural gas liquids:								
Natural gasoline and cycle products ---- thousand 42-gallon barrels	9,713	53,545	9,194	45,292	9,490	51,369	} 44,916	} 286,299
LP gases ---- do	30,271	120,781	30,214	122,065	32,654	180,577		
Peat ---- thousand short tons	4	111	--	--	--	--	2	55
Perlite ---- do	480	6,306	429	6,400	481	8,403	521	9,543
Petroleum (crude) ---- thousand 42-gallon barrels	98,695	712,578	95,063	788,073	92,130	814,419	87,223	805,065
Potassium salts ---- thousand short tons, K_2O equivalent	[r]2,061	[r]126,023	[r]1,749	[r]150,622	2,083	165,354	2,085	169,616
Pumice ---- thousand short tons	471	1,466	397	1,280	486	1,560	457	1,835
Salt ---- do	167	W	147	1,048	W	W	W	W
Sand and gravel ---- do	7,413	10,605	6,220	13,798	7,702	16,671	8,604	17,685
Silver (recoverable content of ores, etc.) ---- thousand troy ounces	1,195	5,628	792	3,501	892	3,880	918	4,242
Stone ---- thousand short tons	[3]3,531	[3]8,359	2,197	4,683	1,935	4,394	1,967	4,892
Uranium (recoverable content of U_3O_8) ---- thousand pounds	9,971	104,693	10,393	127,829	11,880	191,271	13,167	260,037
Zinc (recoverable content of ores, etc.) ---- short tons	13,784	9,897	11,015	8,592	W	W	W	W
Value of items that cannot be disclosed: Cement, clay (fire), fluorspar (1974-75), molybdenum, stone (dimension, 1974), tin (1974-76), vanadium, and values indicated by W	XX	77,755	XX	104,614	XX	134,492	XX	65,617
Total	XX	[r]1,938,979	XX	[r]2,062,239	XX	2,510,127	XX	2,910,804
NEW YORK								
Clays[2] ---- thousand short tons	1,451	2,348	817	1,561	649	2,089	564	1,728
Gem stones ----	NA	16	NA	16	NA	15	NA	15
Gypsum ---- thousand short tons	364	2,942	W	W	W	W	W	W
Lead (recoverable content of ores, etc.) ---- short tons	3,076	1,384	3,027	1,302	3,196	1,476	2,778	1,706
Natural gas ---- million cubic feet	4,990	2,745	7,628	5,645	9,235	10,436	10,682	12,391
Peat ---- thousand short tons	18	181	22	377	32	684	39	569
Petroleum (crude) ---- thousand 42-gallon barrels	896	9,538	875	10,693	857	10,497	824	11,701
Salt ---- thousand short tons	6,464	57,705	5,978	57,344	6,495	66,441	6,452	72,623
Sand and gravel ---- do	30,614	46,652	22,158	44,064	27,881	56,132	29,197	57,570
Silver (recoverable content of ores, etc.) ---- thousand troy ounces	64	304	56	248	49	214	56	260
Stone ---- thousand short tons	38,207	87,724	31,713	80,929	28,136	75,040	29,947	90,781
Zinc (recoverable content of ores, etc.) ---- short tons	93,077	66,829	76,612	59,757	73,671	54,517	70,839	48,737
Value of items that cannot be disclosed: Cement, clay (ball), emery, garnet (abrasive), iron ore, lime, mercury (1975), talc, titanium concentrate, wollastonite, and values indicated by W	XX	162,205	XX	135,792	XX	150,423	XX	163,726
Total	XX	440,573	XX	397,728	XX	427,964	XX	461,807

See footnotes at end of table.

Table 6.—Mineral production[1] in the United States, by State —Continued

Mineral	1974 Quantity	1974 Value (thousands)	1975 Quantity	1975 Value (thousands)	1976 Quantity	1976 Value (thousands)	1977 Quantity	1977 Value (thousands)
NORTH CAROLINA								
Clays[2] thousand short tons	3,422	$4,648	2,582	$4,094	2,750	$4,677	3,022	$4,990
Feldspar short tons	650,684	11,147	468,401	7,905	515,477	11,549	509,976	11,410
Gem stones	NA	50	NA	50	NA	75	NA	75
Mica (scrap) thousand short tons	76	3,679	75	3,265	70	3,793	91	4,207
Sand and gravel do	12,784	20,844	8,169	15,610	9,049	18,287	9,690	21,269
Stone do	34,762	75,142	28,308	69,327	30,877	82,462	32,850	90,295
Talc and pyrophyllite short tons	110,978	993	95,575	1,605	113,754	1,087	W	W
Value of items that cannot be disclosed: Asbestos, cement, clay (kaolin), iron ore (1974), lithium minerals, mica (sheet), olivine, phosphate rock, and values indicated by W	XX	39,366	XX	51,479	XX	81,409	XX	99,265
Total	XX	155,869	XX	153,335	XX	203,339	XX	231,511
NORTH DAKOTA								
Coal (lignite) thousand short tons	7,463	16,351	8,515	27,010	11,102	41,507	12,028	48,495
Gem stones	NA	2	NA	2	NA	2	NA	2
Natural gas million cubic feet	31,206	6,210	24,786	5,701	31,470	10,699	29,173	10,303
Peat short tons	240	W	W	W	W	W	([5])	W
Petroleum (crude) thousand 42-gallon barrels	19,697	119,022	20,452	149,705	21,725	170,411	23,273	186,184
Sand and gravel thousand short tons	4,991	6,211	5,636	8,133	5,171	8,345	5,821	12,102
Stone do	35	115	30	153	--	--	--	--
Value of items that cannot be disclosed: Clays, lime, natural gas liquids, salt, and values indicated by W	XX	11,516	XX	10,800	XX	13,141	XX	14,980
Total	XX	159,427	XX	201,504	XX	244,105	XX	272,066
OHIO								
Cement:								
Masonry thousand short tons	158	5,227	136	4,576	155	7,288	186	8,875
Portland do	2,884	73,815	2,364	70,268	2,130	65,656	1,970	65,899
Clays do	4,325	13,488	3,451	11,822	4,288	14,704	3,568	12,835
Coal (bituminous) do	45,409	559,519	46,770	766,875	46,582	773,699	47,918	848,074
Gem stones	NA	8	NA	W	NA	W	NA	W

Lime	thousand short tons	4,171	93,695	3,482	95,136	3,788	114,299	3,199	111,100
Natural gas	million cubic feet	92,055	44,371	84,960	59,982	88,891	90,491	99,327	138,760
Peat	thousand short tons	5	74	4	99	3	121	15	107
Petroleum (crude)	thousand 42-gallon barrels	9,088	89,348	9,578	113,917	9,994	117,655	10,359	136,281
Salt	thousand short tons	5,029	49,089	5,083	54,651	5,052	66,332	3,701	63,485
Sand and gravel	do	41,353	68,258	37,195	68,552	38,876	76,730	46,521	100,736
Stone	do	[3]51,709	[3]105,098	46,303	108,580	42,699	106,996	45,001	119,966
Value of items that cannot be disclosed: Abrasive stone, gypsum, stone (dimension, 1974), and values indicated by W		XX	5,680	XX	1,996	XX	1,925	XX	1,336
Total		XX	1,107,670	XX	1,356,454	XX	1,435,896	XX	1,607,454
OKLAHOMA									
Clays	thousand short tons	1,289	2,105	995	1,701	1,155	1,678	1,016	1,687
Coal (bituminous)	do	2,356	24,759	2,872	47,946	3,635	58,102	5,978	105,433
Gypsum	do	1,225	5,622	1,028	4,835	1,120	5,822	1,238	6,959
Helium:									
High-purity	million cubic feet	169	5,915	224	7,411	[r]241	[r]7,610	389	11,507
Crude	do	134	1,608	148	1,776	[r]183	[r]2,200	W	W
Lead (recoverable content of ores, etc.)	short tons	W	W	--	--	W	W	W	W
Natural gas	million cubic feet	1,638,942	458,904	1,605,410	513,731	1,726,513	866,710	1,769,519	1,397,920
Natural gas liquids:									
Natural gasoline and cycle products	thousand 42-gallon barrels	12,581	84,638	10,835	63,383	10,894	74,416		
LP gases	do	31,231	166,461	29,640	140,197	31,620	179,602	41,893	271,214
Petroleum (crude)	do	177,785	1,277,076	163,123	1,389,164	161,426	1,484,297	156,382	1,560,240
Pumice	thousand short tons	W	W	1	W	1	W	1	W
Sand and gravel	do	8,708	13,772	9,591	16,749	10,037	19,050	11,669	26,827
Stone	do	22,228	36,599	20,111	36,840	19,635	37,339	23,332	47,443
Zinc (recoverable content of ores, etc.)	short tons	W	W	--	--	W	W	W	W
Value of items that cannot be disclosed: Cement, copper (1974-75), feldspar (1974, 1976-77), iodine (1977) lime, salt, silver (1974-75), tripoli, and values indicated by W		XX	45,142	XX	43,362	XX	53,100	XX	68,217
Total		XX	2,122,601	XX	2,267,095	XX	[r]2,789,926	XX	3,497,447
OREGON									
Clays	thousand short tons	140	243	120	214	147	315	119	193
Copper	short tons	W	W	W	W	--	--	6	7
Gem stones		NA	500	NA	500	NA	525	NA	520
Gold (recoverable content of ores, etc.)	troy ounces	W	W	W	W	28	4	675	100
Lead (recoverable content of ores, etc.)	short tons	W	W	W	W	--	--	--	--
Lime	thousand short tons	98	2,818	96	3,281	W	W	W	W

See footnotes at end of table.

Table 6.—Mineral production[1] in the United States, by State —Continued

Mineral	1974 Quantity	1974 Value (thousands)	1975 Quantity	1975 Value (thousands)	1976 Quantity	1976 Value (thousands)	1977 Quantity	1977 Value (thousands)
OREGON—Continued								
Nickel (content of ore and concentrate) short tons	16,618	W	16,987	W	16,469	W	14,347	W
Pumice thousand short tons	915	$1,887	1,470	$3,937	1,125	$2,311	1,083	$2,429
Sand and gravel do	18,558	30,948	16,527	29,596	[4]17,554	[4]33,473	15,833	33,127
Silver (recoverable content of ores, etc.) thousand troy ounces	9	42	W	W	--	--	7	33
Stone thousand short tons	23,353	43,406	21,275	40,321	20,349	42,686	17,600	39,400
Value of items that cannot be disclosed: Cement, diatomite, emery (1975), sand and gravel (industrial, 1976), talc and soapstone, tungsten (1976-77), and values indicated by W	XX	24,076	XX	28,155	XX	33,252	XX	33,323
Total	XX	103,920	XX	106,004	XX	112,566	XX	109,132
PENNSYLVANIA								
Cement:								
Masonry thousand short tons	404	14,642	357	14,640	379	16,903	411	19,927
Portland do	7,448	191,594	5,815	168,220	5,989	185,170	6,162	196,443
Clays[2] do	2,732	16,496	1,945	13,672	2,291	16,037	2,304	13,075
Coal:								
Anthracite do	6,617	144,695	6,203	198,481	6,228	209,234	5,861	205,138
Bituminous do	80,462	1,637,394	84,137	2,111,009	85,777	2,173,009	84,639	2,166,685
Copper (recoverable content of ores, etc.) short tons	--	--	--	--	W	W	W	W
Gem stones	NA	9	NA	9	NA	9	NA	10
Lime thousand short tons	2,080	50,147	1,940	60,047	2,069	68,356	2,007	72,591
Mica, scrap do	--	--	W	W	W	W	1	W
Natural gas million cubic feet	82,637	36,360	84,676	57,156	89,386	61,229	91,717	73,374
Peat thousand short tons	30	515	27	488	W	W	16	353
Petroleum (crude) thousand 42-gallon barrels	3,478	36,220	3,264	39,647	3,019	36,700	2,715	38,810
Sand and gravel thousand short tons	18,071	45,181	17,401	48,742	19,038	55,611	18,846	52,578
Stone do	73,092	159,615	60,177	149,670	63,607	165,889	63,588	169,014
Zinc (recoverable content of ores, etc.) short tons	20,288	14,567	21,090	16,450	22,280	16,487	22,825	15,703
Value of items that cannot be disclosed: Abrasives (1977), clay (kaolin), iron ore, natural gas liquids, tripoli, and values indicated by W	XX	26,993	XX	29,607	XX	32,716	XX	20,263
Total	XX	2,374,428	XX	2,907,838	XX	3,037,350	XX	3,043,964

RHODE ISLAND								
Sand and gravel ---- thousand short tons	2,784	4,605	2,910	5,070	2,914	4,805	2,872	5,059
Stone ---- do	W	W	293	1,125	305	1,295	274	1,238
Value of items that cannot be disclosed: Other nonmetals and values indicated by W	XX	1,377	XX	3	XX	300	XX	2
Total	XX	5,982	XX	6,198	XX	6,400	XX	6,299
SOUTH CAROLINA								
Clays ---- thousand short tons	[2]2,297	[2]13,765	[2]1,698	[2]12,828	2,270	17,288	[2]2,172	[2]18,705
Gem stones	NA	5	NA	5	NA	4	NA	4
Mica (scrap) ---- thousand short tons	W	252	7	318	W	W	43	589
Peat ---- do	18	W	18	W	15	W	16	W
Sand and gravel ---- do	7,380	13,054	7,363	14,128	7,887	17,154	7,766	19,281
Stone ---- do	[3]12,242	[3]21,719	13,836	30,082	13,027	30,690	14,785	36,670
Value of items that cannot be disclosed: Cement, clay (fuller's earth, 1974-75, 1977), manganiferous ore (1975-77), stone (crushed, 1974), vermiculite, and values indicated by W	XX	56,376	XX	58,107	XX	60,397	XX	68,952
Total	XX	105,171	XX	115,468	XX	125,533	XX	144,201
SOUTH DAKOTA								
Clays[2] ---- thousand short tons	190	202	187	185	124	137	197	233
Gem stones	NA	42	NA	42	NA	44	NA	40
Gold (recoverable content of ores, etc.) ---- troy ounces	343,723	54,906	304,935	49,244	318,511	39,916	304,846	45,212
Gypsum ---- thousand short tons	32	135	23	60	W	W	W	W
Lime ---- do	94	2,059	W	W	W	W	W	W
Mica (scrap) ---- do	W	W	W	W	--	--	56	5
Petroleum (crude) ---- thousand 42-gallon barrels	494	3,283	472	5,996	447	5,519	632	7,584
Sand and gravel ---- thousand short tons	9,028	9,720	6,481	8,668	5,763	8,057	6,043	9,815
Silver (recoverable content of ores, etc.) ---- thousand troy ounces	62	294	68	299	58	253	69	317
Stone ---- thousand short tons	2,968	14,231	2,647	15,350	3,241	17,240	3,412	18,881
Value of items that cannot be disclosed: Beryllium concentrate (1975-77), cement, clay (bentonite), feldspar, iron ore (1974-76), natural gas liquids, and values indicated by W	XX	17,938	XX	21,977	XX	30,364	XX	28,653
Total	XX	102,810	XX	101,821	XX	101,530	XX	110,740

See footnotes at end of table.

Table 6.—Mineral production[1] in the United States, by State —Continued

Mineral	1974 Quantity	1974 Value (thousands)	1975 Quantity	1975 Value (thousands)	1976 Quantity	1976 Value (thousands)	1977 Quantity	1977 Value (thousands)
TENNESSEE								
Barite thousand short tons	W	W	13	$260	W	W	W	W
Cement:								
Masonry do	154	$4,706	138	4,778	175	$6,476	195	$7,878
Portland do	1,525	43,339	1,136	37,866	1,256	43,495	1,522	52,894
Clays[2] do	1,638	9,776	1,310	9,008	1,530	11,578	1,578	13,968
Coal (bituminous) do	7,541	135,874	8,206	140,293	9,283	151,372	9,433	206,226
Copper (recoverable content of ores, etc.) short tons	6,304	9,745	10,041	12,893	11,131	15,494	6,187	8,266
Gold (recoverable content of ores, etc.) troy ounces	18	3	W	W	W	W	13	2
Lime thousand short tons	136	3,449	106	3,735	W	W	W	W
Natural gas million cubic feet	17	6	27	12	47	24	263	195
Petroleum (crude) thousand 42-gallon barrels	769	7,256	682	7,849	598	8,203	820	11,271
Phosphate rock thousand short tons	2,411	18,465	2,291	28,803	1,801	r14,541	1,926	14,253
Sand and gravel do	10,702	19,476	10,909	22,102	11,096	25,129	12,773	29,197
Silver (recoverable content of ores, etc.) thousand troy ounces	20	94	54	238	78	339	60	278
Stone thousand short tons	41,720	75,547	38,439	81,187	37,600	86,156	41,911	100,137
Zinc (recoverable content of ores, etc.) short tons	85,671	61,512	83,293	64,968	82,512	61,059	90,438	62,221
Value of items that cannot be disclosed: Clays (selected), pyrites, and values indicated by W	XX	6,360	XX	8,526	XX	15,862	XX	14,585
Total	XX	395,608	XX	422,518	XX	r439,728	XX	521,371
TEXAS								
Cement:								
Masonry thousand short tons	195	6,438	181	7,089	213	10,596	254	13,095
Portland do	7,739	207,706	7,195	224,804	7,388	271,066	8,482	331,758
Clays do	5,315	13,677	4,248	13,411	[2]3,706	[2]8,847	[2]3,682	[2]11,465
Coal (lignite) do	7,684	W	11,002	W	14,063	W	W	W
Gem stones	NA	160	NA	160	NA	168	NA	160
Gypsum thousand short tons	1,365	5,276	1,094	4,277	1,531	6,322	1,718	8,837
Helium (crude) million cubic feet	35	420	36	432	12	r149	W	W
Iron ore thousand long tons	W	W	601	W	566	W	W	W
Lime thousand short tons	1,835	39,644	1,735	46,179	1,455	43,983	1,612	49,965
Natural gas million cubic feet	8,170,798	2,541,118	7,485,764	3,885,112	7,191,859	5,163,755	7,051,027	6,367,077

Natural gas liquids:								
Natural gasoline and cycle products -- thousand 42-gallon barrels	88,316	629,529	78,835	479,700	77,578	560,831	283,772	2,009,366
LP gases do	213,756	1,004,653	212,635	965,363	209,514	1,223,562		
Petroleum (crude) do	1,262,126	8,773,003	1,221,929	9,336,570	1,189,523	10,217,702	1,137,880	9,986,002
Salt thousand short tons	11,379	51,296	8,560	42,119	9,718	48,875	10,941	53,264
Sand and gravel do	42,466	81,364	38,649	87,106	47,848	103,217	55,495	133,420
Stone do	[3]63,074	[3]109,758	57,985	106,554	54,856	101,652	65,474	126,706
Sulfur (Frasch process) thousand long tons	4,473	W	3,406	W	3,415	W	3,480	W
Talc and soapstone short tons	188,262	1,310	129,626	795	199,663	1,071	233,024	2,191
Value of items that cannot be disclosed: Asphalt (native), clays (selected, 1976-77), fluorspar, graphite, magnesium chloride (for metal), magnesium compounds (except for metal), sodium sulfate, stone (dimension, 1974), uranium, vermiculite (1977), and values indicated by W	XX	245,792	XX	325,701	XX	381,413	XX	426,325
Total	XX	13,711,144	XX	15,525,372	XX	[r]18,143,209	XX	19,519,631
UTAH								
Carbon dioxide, natural thousand cubic feet	93,571	6	108,941	8	21,875	2	W	W
Clays thousand short tons	232	953	[2]220	[2]548	[2]206	[2]531	[2]244	[2]713
Coal (bituminous) do	5,858	71,699	6,961	138,134	7,967	182,712	8,581	174,342
Copper (recoverable content of ores, etc.) short tons	230,593	356,497	177,155	227,467	185,458	258,157	194,130	259,357
Fluorspar do	2,967	98	9,542	389	W	W	--	--
Gem stones	NA	100	NA	100	NA	105	NA	100
Gold (recoverable content of ores, etc.) troy ounces	254,909	40,719	189,620	30,622	187,318	23,475	210,501	31,219
Gypsum thousand short tons	248	1,076	247	1,457	270	1,657	324	2,510
Iron ore (usable) thousand long tons, gross weight	1,808	14,016	1,334	10,399	W	W	1,932	19,780
Lead (recoverable content of ores, etc.) short tons	10,510	4,729	12,679	5,452	16,297	7,529	10,746	6,598
Lime thousand short tons	176	4,911	161	4,540	202	6,855	209	8,274
Natural gas million cubic feet	50,522	20,815	55,354	26,570	57,416	28,995	60,696	37,146
Petroleum (crude) thousand 42-gallon barrels	39,363	279,858	42,301	348,131	34,304	318,911	33,113	308,872
Pumice thousand short tons	15	19	17	23	164	264	W	W
Salt do	771	7,321	631	7,717	705	10,090	843	10,831
Sand and gravel do	11,578	12,985	10,159	14,342	[4]10,547	[4]13,442	[4]11,895	[4]18,662
Silver (recoverable content of ores, etc.) thousand troy ounces	3,208	15,109	2,822	12,472	3,134	13,633	3,283	15,169
Stone thousand short tons	2,869	6,410	2,486	6,167	2,751	7,009	2,771	7,310

See footnotes at end of table.

Table 6.—Mineral production[1] in the United States, by State —Continued

Mineral	1974 Quantity	1974 Value (thousands)	1975 Quantity	1975 Value (thousands)	1976 Quantity	1976 Value (thousands)	1977 Quantity	1977 Value (thousands)
UTAH—Continued								
Tungsten ore and concentrate ____thousand pounds contained W__	W	W	W	W	W	W	27	$219
Zinc (recoverable content of ores, etc.) ____short tons__	12,619	$9,060	19,640	$15,319	22,481	$16,636	17,759	12,218
Value of items that cannot be disclosed: Asphalt (gilsonite), beryl concentrate, cement, clays (kaolin, 1975-77, fuller's earth, 1977), magnesium chloride (1974-75), magnesium compounds, molybdenum, natural gas liquids, phosphate rock, potassium salts, sand and gravel (industrial, 1976-77), sodium sulfate, uranium, vanadium, and values indicated by W	XX	105,664	XX	116,550	XX	153,978	XX	172,019
Total ____	XX	952,045	XX	966,407	XX	1,043,981	XX	1,085,339
VERMONT								
Peat ____thousand short tons__	(5)	4	(5)	W	--	--	--	--
Sand and gravel ____do____	2,394	3,588	2,356	3,693	[4]2,379	[4]3,758	3,405	5,837
Stone ____do____	1,932	21,630	1,224	15,718	1,978	22,443	2,244	27,196
Talc ____short tons__	W	W	230,973	1,918	252,371	1,685	310,038	2,006
Value of items that cannot be disclosed: Asbestos, other nonmetals, and values indicated by W ____	XX	8,723	XX	7,450	XX	7,211	XX	6,415
Total ____	XX	33,945	XX	28,779	XX	35,097	XX	41,454
VIRGINIA								
Clays ____thousand short tons__	1,957	2,614	819	1,152	862	1,210	890	1,294
Coal (bituminous) ____do____	34,326	856,099	35,510	1,081,587	39,996	964,669	37,624	1,115,438
Gem stones ____	NA	13	NA	13	NA	12	NA	12
Lead (recoverable content of ores, etc.) ____short tons__	3,106	1,398	2,551	1,097	1,946	899	2,203	1,352
Lime ____thousand short tons__	895	18,929	705	20,192	878	25,993	846	28,767
Natural gas ____million cubic feet__	7,096	3,619	6,723	3,462	6,937	7,908	8,220	10,357
Petroleum (crude) ____thousand 42-gallon barrels__	3	W	3	W	3	W	W	W
Sand and gravel ____thousand short tons__	14,314	29,270	9,895	24,776	[4]10,191	[4]23,089	[4]10,447	[4]24,605
Stone ____do____	44,176	95,988	35,384	84,204	36,132	91,723	41,717	111,601
Zinc (recoverable content of ores, etc.) ____short tons__	17,195	12,346	15,151	11,818	11,214	8,319	13,272	9,131
Value of items that cannot be disclosed: Aplite, cement, gypsum, kyanite, sand and gravel (industrial, 1976-77), silver (1975-77), soapstone, and values indicated by W ____	XX	36,293	XX	33,673	XX	36,823	XX	39,129
Total ____	XX	1,056,569	XX	1,261,974	XX	1,160,645	XX	1,341,686

WASHINGTON									
Cement:									
Masonry	thousand short tons	6	193	5	209	6	334	W	W
Portland	do	1,377	36,347	1,147	40,666	1,238	48,669	1,462	65,281
Clays[2]	do	269	698	290	778	381	1,141	309	1,091
Coal (bituminous)	do	3,913	W	3,743	W	4,109	W	5,057	57,042
Gem stones		NA	160	NA	160	NA	168	NA	160
Gold	troy ounces	W	W	W	W	W	W	24,006	3,560
Lead (recoverable content of ores, etc.)	short tons	1,299	585	W	W	W	W	1,201	738
Peat	thousand short tons	14	85	13	98	14	103	12	117
Pumice	do	([5])	1	--	--	--	--	W	W
Sand and gravel	do	22,842	35,030	19,069	32,990	19,813	36,017	18,505	39,124
Silver	thousand troy ounces	W	W	W	W	W	W	121	557
Stone	thousand short tons	15,095	24,483	7,920	18,754	10,223	24,091	12,244	28,596
Zinc (recoverable content of ores, etc.)	short tons	6,909	4,960	W	W	W	W	5,572	3,834
Values of items that cannot be disclosed: Clay (fire), copper, diatomite, gypsum, lime, olivine, talc, tungsten, uranium, and values indicated by W		XX	41,388	XX	64,850	XX	76,699	XX	16,024
Total		XX	143,930	XX	158,505	XX	187,222	XX	216,124
WEST VIRGINIA									
Clays[2]	thousand short tons	339	520	278	439	275	463	389	599
Coal (bituminous)	do	102,462	2,218,418	109,283	3,206,951	108,834	3,278,180	95,433	2,961,186
Gem stones		NA	2	NA	2	NA	2	NA	2
Natural gas	million cubic feet	202,306	66,356	154,484	57,005	153,322	87,394	152,767	93,188
Petroleum (crude)	thousand 42-gallon barrels	2,665	27,058	2,479	29,712	2,519	30,227	2,518	35,175
Salt	thousand short tons	1,201	6,296	972	4,671	1,118	W	1,048	W
Sand and gravel	do	5,382	16,018	5,068	17,872	[4]4,337	[4]11,006	[4]3,891	[4]10,402
Stone	do	10,954	22,308	[3]10,583	[3]24,333	[3]9,717	[3]24,133	[3]10,495	[3]28,022
Value of items that cannot be disclosed: Cement, clays (fire), lime, natural gas liquids, sand and gravel (industrial, 1976-77), stone (dimension, 1975-77), and values indicated by W		XX	46,201	XX	49,226	XX	66,596	XX	79,494
Total		XX	2,403,177	XX	3,390,211	XX	3,498,001	XX	3,208,068

See footnotes at end of table.

Table 6.—Mineral production[1] in the United States, by State —Continued

Mineral	1974 Quantity	1974 Value (thousands)	1975 Quantity	1975 Value (thousands)	1976 Quantity	1976 Value (thousands)	1977 Quantity	1977 Value (thousands)
WISCONSIN								
Clays ____ thousand short tons	2	$4	2	$4	W	W	W	W
Gem stones	NA	1	NA	1	NA	$1	NA	$1
Iron ore (usable) ____ thousand long tons, gross weight	899	W	791	W	664	W	668	W
Lead (recoverable content of ores, etc.) ____ short tons	1,285	578	W	W	W	W	W	W
Lime ____ thousand short tons	311	6,764	296	8,604	325	10,058	378	13,521
Peat ____ do	W	W	11	502	11	W	14	196
Sand and gravel ____ do	28,850	34,577	30,057	40,580	30,879	42,001	29,025	50,210
Stone ____ do	22,443	40,912	20,566	40,156	20,739	41,338	22,314	46,918
Zinc (recoverable content of ores, etc.) ____ short tons	8,737	6,273	W	W	W	W	W	W
Value of items that cannot be disclosed: Abrasive stones, cement, copper (1974-75), silver (1974-75), and values indicated by W	XX	25,654	XX	42,413	XX	39,055	XX	39,282
Total	XX	114,763	XX	132,260	XX	132,453	XX	150,128
WYOMING								
Clays ____ thousand short tons	2,511	29,339	2,582	36,046	2,697	40,015	2,966	48,369
Coal (bituminous) ____ do	20,703	103,915	23,804	160,447	30,836	215,936	46,028	377,990
Gem stones	NA	140	NA	140	NA	147	NA	200
Gypsum ____ thousand short tons	315	960	271	902	317	1,280	356	2,571
Iron ore (usable) ____ thousand long tons, gross weight	2,105	W	2,039	26,792	2,139	29,461	W	W
Lime ____ thousand short tons	29	464	W	W	W	W	W	W
Natural gas ____ million cubic feet	326,657	80,031	316,123	106,533	328,768	134,795	330,180	211,315
Natural gas liquids:								
Natural gasoline ____ thousand 42-gallon barrels	2,933	18,577	2,909	17,694	3,044	19,866	10,148	64,970
LP gases ____ do	6,804	31,707	6,061	29,578	6,681	35,677		
Petroleum (crude) ____ do	139,997	914,360	135,943	983,785	134,149	971,235	136,472	1,039,948
Sand and gravel ____ thousand short tons	5,532	9,508	4,328	10,746	5,470	10,782	5,084	11,026
Stone ____ do	2,384	[3]5,989	2,882	7,618	2,757	7,630	[3]2,434	[3]7,585
Uranium (recoverable content of U_3O_8) ____ thousand pounds	7,449	78,213	6,862	84,406	8,064	129,823	9,857	194,682

Value of items that cannot be disclosed: Cement, feldspar, phosphate rock, sodium carbonate, stone (dimension, 1974, 1977), and values indicated by W	XX	163,997	XX	179,751	XX	254,952	XX	372,693
Total	XX	1,437,200	XX	1,644,438	XX	1,851,599	XX	2,331,349

[r]Revised. NA Not available. W Withheld to avoid disclosing company proprietary data. XX Not applicable.
[1]Production as measured by mine shipments, sales, or marketable production (including consumption by producers).
[2]Excludes certain clays, included with "Value of items that cannot be disclosed."
[3]Excludes certain stones, included with "Value of items that cannot be disclosed."
[4]Excludes industrial sand and gravel, included with "Value of items that cannot be disclosed."
[5]Less than 1/2 unit.
[6]Total of items listed.
[7]Excludes salt in brine, included with "Value of items that cannot be disclosed."

Note: Beginning with 1977, data on mineral fuels supplied by the Department of Energy.

Table 7.—Mineral production[1] in the islands administered by the United States

(Thousand short tons and thousand dollars)

Area and mineral	1974 Quantity	1974 Value	1975 Quantity	1975 Value	1976 Quantity	1976 Value	1977 Quantity	1977 Value
American Samoa:								
Pumice	27	183	15	15	47	30	1	10
Stone	50	122	34	147	30	156	6	31
Total	XX	305	XX	162	XX	186	XX	41
Guam: Stone	798	1,444	781	1,837	457	1,438	577	1,897
Virgin Islands: Stone	638	3,869	253	1,813	279	2,050	262	2,076

XX Not applicable.
[1]Production as measured by mine shipments, sales, or marketable production (including consumption by producers).

Table 8.—Mineral production[1] in the Commonwealth of Puerto Rico

(Thousand short tons and thousand dollars)

Mineral	1974 Quantity	1974 Value	1975 Quantity	1975 Value	1976 Quantity	1976 Value	1977 Quantity	1977 Value
Cement	1,881	70,277	1,582	60,968	1,558	66,150	1,367	67,775
Clays	291	332	341	440	W	W	272	387
Lime	39	2,923	28	2,231	28	2,513	40	3,007
Salt	29	624	27	639	27	639	27	639
Sand and gravel	NA	NA	NA	NA	NA	NA	[e]12,000	[e]21,000
Stone	14,362	41,640	13,595	47,515	13,404	47,124	12,187	44,281
Total	XX	[2]115,796	XX	[2]111,793	XX	[2]116,426	XX	137,089

[e]Estimate. NA Not available. W Withheld to avoid disclosing company proprietary data. XX Not applicable.
[1]Production as measured by mine shipments, sales, or marketable production (including consumption by producers).
[2]Total does not include value of items withheld or not available.

Table 9.—U.S. exports of principal minerals and products

Mineral	1976 Quantity	1976 Value (thousands)	1977 Quantity	1977 Value (thousands)
METALS				
Aluminum:				
Ingots, slabs, crude ---- short tons--	152,366	$118,644	97,771	$94,498
Scrap ---- do----	108,958	63,245	101,663	64,060
Plates, sheets, bars, etc ---- do----	203,843	261,759	190,118	284,199
Castings and forgings ---- do----	5,611	21,232	6,895	27,432
Aluminum sulfate ---- do----	50,758	1,569	12,019	900
Other aluminum compounds ---- do----	911,460	166,084	33,623	17,575
Antimony, metals and alloys, crude ---- do----	341	853	742	1,219
Bauxite, including bauxite concentrates thousand long tons--	15	1,297	25	2,344
Beryllium ---- pounds--	114,143	1,756	160,505	1,911
Bismuth, metals and alloys ---- do----	[1]68,488	[1]514	95,334	637
Cadmium ---- thousand pounds--	504	713	236	316
Calcium:				
Carbonate ---- short tons--	3,411	735	14,887	4,053
Chloride ---- do----	33,533	2,578	39,552	3,383
Dicalcium phosphate ---- do----	32,302	7,612	53,309	9,550
Chrome:				
Ore and concentrates:				
Exports ---- thousand short tons--	124	5,609	187	10,105
Reexports ---- do----	85	5,475	61	4,913
Ferrochrome ---- do----	14	8,785	12	7,268
Cobalt ---- thousand pounds--	3,892	12,427	2,585	11,149
Columbium metals, alloys, other forms ---- do----	67	778	75	1,408
Copper:				
Ore, concentrate, composition metal, and unrefined (copper content) ---- short tons--	22,689	19,769	35,953	24,708
Scrap ---- do----	37,473	37,079	37,892	36,006
Refined copper and semimanufactures ---- do----	176,877	313,377	146,004	331,265
Other copper manufactures ---- do----	4,923	8,435	6,920	10,923
Copper sulfate or blue vitriol ---- do----	2,071	2,935	2,616	3,370
Copper-base alloys ---- do----	110,665	177,270	112,097	167,306
Ferroalloys:				
Ferrosilicon ---- do----	12,416	7,449	10,548	6,035
Ferrophosphorus ---- do----	1,636	153	2,381	297
Ferroalloys, n.s.p.f ---- do----	6,687	13,121	7,982	8,558
Spiegeleisen ---- do----	5,471	901	40	13
Gold:				
Ore and base bullion ---- troy ounces--	337,517	41,624	395,760	57,477
Bullion, refined ---- do----	3,193,248	333,424	8,275,095	1,055,234
Iron ore ---- thousand long tons--	2,913	82,192	2,143	62,756
Iron and steel:				
Pig iron ---- short tons--	57,480	5,408	51,357	4,266
Iron and steel products (major):				
Semimanufactures ---- do----	1,856,573	592,126	1,444,572	525,592
Manufactures and steel mill products ---- do----	1,814,776	1,870,281	1,653,428	1,758,832
Iron and steel scrap:				
Ferrous scrap, including rerolling materials thousand short tons--	8,168	636,758	6,211	415,345
Slag ---- short tons--	38,718	1,264	33,376	961
Lead and zinc ores and concentrates ---- do----	148,787	28,892	128,056	28,753
Lead:				
Pigs, bars, anodes, sheets, etc ---- do----	5,877	5,320	9,845	8,425
Scrap ---- do----	46,883	11,539	85,411	22,442
Magnesium, metal and alloys, scrap, semimanufactured forms, n.e.c ---- do----	13,444	26,902	28,061	51,848
Manganese:				
Ore and concentrate ---- do----	127,971	7,510	138,250	9,221
Ferromanganese ---- do----	6,789	3,462	6,051	3,391
Metal ---- do----	4,654	3,434	2,953	3,208
Mercury:				
Exports ---- 76-pound flasks--	501	306	852	287
Reexports ---- do----	12	6	101	36
Molybdenum:				
Ore and concentrates (molybdenum content) ---- thousand pounds--	62,474	183,536	65,666	245,777
Metals and alloys, crude and scrap ---- do----	223	390	332	851
Wire ---- do----	343	3,672	475	6,047
Semimanufactured forms, n.e.c ---- do----	184	1,584	164	2,441
Powder ---- do----	25	136	151	759
Ferromolybdenum ---- do----	3,596	9,447	1,595	4,863
Nickel:				
Alloys and scrap (including Monel metal), ingots, bars, sheets, etc ---- short tons--	[r]37,748	[r]141,324	29,958	132,093
Catalysts ---- do----	4,442	16,282	4,064	15,674
Nickel-chrome electric resistance wire ---- do----	769	5,253	764	6,006
Semifabricated forms, n.e.c ---- do----	4,207	30,736	4,626	36,807

See footnotes at end of table.

Table 9.—U.S. exports of principal minerals and products —Continued

Mineral	1976 Quantity	1976 Value (thousands)	1977 Quantity	1977 Value (thousands)
METALS —Continued				
Platinum:				
Ore, concentrate, metal and alloys in ingots, bars, sheets, anodes, other forms, including scrap ---- troy ounces--	325,805	$37,868	289,307	$33,076
Palladium, rhodium, iridium, osmiridium, ruthenium, and osmium (metal and alloys including scrap) ---- do----	186,602	14,885	137,324	13,414
Rare earths:				
Ferrocerium and alloys ---- short tons--	60	335	260	1,043
Compounds ---- pounds--	1,465,364	2,720	1,931,245	6,038
Selenium ---- thousand pounds--	118	2,131	68	1,145
Silicon:				
Ferrosilicon ---- short tons--	12,416	7,449	10,548	6,035
Silicon carbide, crude and in grains ---- do----	10	6,174	11	7,062
Silver:				
Ore, concentrates, waste, sweepings thousand troy ounces--	7,000	28,849	13,400	45,480
Bullion, refined ---- do----	7,596	32,586	8,994	39,165
Tantalum:				
Ore, metal, other forms ---- thousand pounds--	r426	6,711	587	12,874
Powder ---- do----	r219	7,982	234	9,380
Tin:				
Ingots, pigs, bars, etc.:				
Exports ---- metric tons--	540	2,998	545	5,176
Reexports ---- do----	1,798	13,967	4,935	50,175
Tin scrap and other tin-bearing material except tinplate scrap ---- do----	6,927	7,391	NA	9,328
Titanium:				
Ore and concentrate ---- short tons--	4,802	477	22,679	743
Sponge (including iodide titanium and scrap) ---- do----	6,144	8,547	3,394	5,643
Intermediate mill shapes and mill products, n.e.c. do----	1,065	15,039	1,050	14,254
Pigments and oxides ---- do----	20,580	16,229	16,336	12,628
Tungsten:				
Ores and concentrates:				
Exports ---- thousand pounds--	1,729	11,189	1,283	11,400
Reexports ---- do----	887	1,903	NA	NA
Ferrotungsten ---- do----	--	--	2	31
Uranium:				
Ores and concentrates (U_3O_8 content) ---- pounds--	1,495,130	24,432	1,929,467	65,913
Metal ---- do----	7,108	146	NA	NA
Compounds ---- do----	369,036	7,232	245,570	2,848
Isotopes (stable) and their compounds ----	NA	2,103	NA	4,627
Radioactive materials ---- thousand curies--	31,474,488	25,905	33,605,884	32,862
Special nuclear materials ----	NA	426,423	NA	501,590
Vanadium:				
Ore and concentrate, pentoxide, etc. (vanadium content) ---- pounds--	197,035	742	384,000	1,959
Ferrovanadium ---- do----	2,421,776	9,180	1,316,000	4,954
Zinc:				
Slabs, pigs, or blocks ---- short tons--	3,513	2,306	237	210
Sheets, plates, strips, other forms n.e.c ---- do----	2,271	2,817	2,681	3,144
Waste, scrap, and dust (zinc content) ---- do----	8,945	3,535	9,230	3,698
Semifabricated forms, n.e.c ---- do----	9,320	6,076	6,147	4,618
Zirconium:				
Ore and concentrate ---- thousand pounds--	18,856	2,784	28,727	2,242
Oxide ---- do----	5,325	6,104	3,704	3,846
Metals, alloys, other forms ---- do----	2,304	43,809	1,965	36,828
NONMETALS				
Abrasives:				
Dust and powder of precious or semiprecious stones, including diamond dust and powder thousand carats--	14,155	35,450	17,272	42,714
Crushing bort ---- do----	77	182	6	42
Industrial diamonds ---- do----	639	3,677	376	1,854
Diamond grinding wheels ---- do----	730	4,911	797	5,900
Other natural and artificial metallic abrasives and products ----	NA	68,979	NA	71,069
Asbestos:				
Exports:				
Unmanufactured ---- short tons--	46,317	12,640	37,390	11,701
Products ---- do----	NA	60,276	NA	78,350
Reexports:				
Unmanufactured ---- do----	606	151	247	30
Products ---- do----	NA	296	NA	472

See footnotes at end of table.

Table 9.—U.S. exports of principal minerals and products —Continued

Mineral	1976 Quantity	1976 Value (thousands)	1977 Quantity	1977 Value (thousands)
NONMETALS —Continued				
Barite:				
Natural barium sulfate and carbonate _ short tons	41,063	$2,871	49,551	$3,426
Lithopone do	779	937	435	698
Boron:				
Boric acid do	36,492	12,363	35,992	12,931
Sodium borates, refined do	211,362	49,156	265,470	64,634
Cement do	466,055	26,601	238,906	23,740
Clays:				
Kaolin or china clay thousand short tons	839	57,649	952	71,907
Fire clay do	296	12,895	307	11,632
Other clays do	1,351	81,409	1,302	77,251
Diatomite do	149	16,932	152	18,876
Feldspar, leucite, nepheline syenite thousand pounds	12,289	352	12,404	394
Fluorspar short tons	4,923	764	6,642	975
Gem stones:				
Diamonds thousand carats	313	306,098	316	335,991
Pearls	NA	581	NA	545
Other	NA	30,896	NA	24,050
Graphite short tons	[r]12,236	[r]2,388	13,783	2,662
Gypsum:				
Crude, crushed or calcined thousand short tons	284	6,739	143	6,090
Manufactures, n.e.c	NA	25,855	NA	9,613
Helium million cubic feet	174	8,790	168	10,561
Lithium hydroxide thousand pounds	534	674	665	730
Kyanite and allied minerals short tons	63,329	4,942	38,832	3,417
Lime do	55,852	2,981	32,954	2,185
Magnesium compounds:				
Magnesite, dead-burned do	71,373	13,466	76,489	16,477
Magnesite, crude, caustic calcined, lump or ground do	10,121	5,422	12,040	6,336
Mica sheet, waste and scrap, and ground pounds	14,449,150	3,477	18,202,383	3,557
Mica, manufactured do	2,481,151	3,776	1,012,977	3,267
Mineral-earth pigments, iron oxide, natural and manufactured short tons	11,867	11,387	15,529	16,815
Nitrogen compounds (major) thousand short tons	4,714	449,147	5,103	537,739
Phosphate rock thousand metric tons	9,994	327,410	14,014	362,223
Phosphatic fertilizers:				
Superphosphates do	1,210	110,835	1,181	110,534
Ammonium phosphates do	2,182	269,855	2,581	335,883
Elemental phosphorus short tons	29,038	30,387	17,954	20,722
Mixed chemical fertilizers thousand metric tons	[r]219	30,284	177	26,908
Pigments and compounds (lead and zinc):				
Lead oxides:				
Pigment grade short tons	2,620	1,661	NA	NA
Other grade do	345	438	NA	NA
Zinc oxides:				
Pigment grade do	4,261	2,587		
Other grade do	577	524	6,771	3,634
Zinc compounds do	779	937	435	698
Potash:				
Fertilizer do	1,669,691	91,887	1,650,200	90,186
Chemical do	60,025	19,422	40,013	18,805
Pumice and pumicite do	1,011	271	1,797	516
Salt:				
Crude and refined thousand short tons	1,007	10,326	1,008	10,881
Shipments to noncontiguous territories do	18	2,230	17	2,205
Sand and gravel:				
Sand:				
Construction do	559	1,337	632	1,610
Industrial do	2,553	17,080	2,457	18,707
Gravel do	579	1,099	600	1,198
Sodium and sodium compounds:				
Sodium sulfate do	57	3,636	43	2,801
Sodium carbonate do	645	[r]47,004	759	52,943
Stone:				
Dolomite, block do	63	1,486	12	484
Limestone, crushed, ground, broken do	3,191	10,537	3,235	10,365
Marble and other building and monumental do	NA	2,596	NA	3,476
Stone, crushed, ground, broken do	866	7,073	694	6,048
Manufactures of stone do	NA	2,273	NA	2,242
Sulfur:				
Crude thousand long tons	1,183	60,226	1,059	47,599
Crushed, ground, flowers of do	15	3,358	12	4,512
Talc, crude and ground short tons	212,344	9,034	322,000	9,166
Total	XX	8,484,889	XX	9,171,199

[r]Revised. NA Not available. XX Not applicable.
[1]Adjusted by the Bureau of Mines.

Table 10.—U.S. imports for consumption of principal minerals and products

Mineral	1976 Quantity	1976 Value (thousands)	1977 Quantity	1977 Value (thousands)
METALS				
Aluminum:				
Metal ---- short tons--	575,350	$439,570	670,200	$631,601
Scrap ---- do----	85,714	46,166	89,895	63,168
Plates, sheets, bars, etc ---- do----	87,560	96,312	75,459	103,736
Aluminum oxide (alumina) ---- do----	3,624,367	404,478	4,145,000	512,413
Antimony:				
Ore (antimony content) ---- do----	10,023	16,911	3,438	6,832
Needle or liquated ---- do----	41	129	259	580
Metal ---- do----	2,083	4,986	1,722	4,536
Oxide ---- do----	11,611	17,029	9,641	15,150
Arsenic:				
White (As_2O_3 content) ---- do----	4,262	1,528	5,981	1,962
Metallic ---- do----	288	1,735	357	1,381
Bauxite, crude ---- thousand long tons--	12,548	NA	12,784	NA
Beryllium ore ---- short tons--	1,058	380	746	298
Bismuth, metal and alloys, gross weight ---- pounds--	2,328,051	14,154	2,013,333	10,238
Cadmium:				
Metal ---- short tons--	3,411	14,511	2,570	11,680
Flue dust (cadmium content) ---- do----	246	536	14	4
Calcium:				
Metal ---- pounds--	461,965	475	458,319	706
Chloride ---- short tons--	16,046	480	19,708	1,002
Cesium compounds ---- pounds--	3,621	147	7,865	329
Chromite:				
Ore and concentrates (Cr_2O_3 content) thousand short tons--	533	70,075	538	68,697
Ferrochrome (Cr_2O_3 content) ---- do----	150	124,819	134	100,528
Metal ---- do----	2	9,142	2	10,893
Cobalt:				
Metal ---- thousand pounds--	15,129	66,299	16,833	91,381
Oxide (gross weight) ---- do----	138	573	506	2,346
Salts and compounds (gross weight) ---- do----	235	365	246	381
Columbium ore ---- do----	3,968	[r]5,567	3,364	6,771
Copper (copper content):				
Ore and concentrates ---- short tons--	35,197	49,861	18,007	21,423
Regulus, black, coarse ---- do----	14,097	54,878	3,257	12,153
Unrefined, black, blister ---- do----	19,388	22,144	9,063	11,843
Refined in ingots, etc ---- do----	381,343	453,279	386,865	471,666
Old and scrap ---- do----	19,735	19,231	19,856	20,741
Ferroalloys, n.s.p.f ---- do----	[r]98,524	[r]40,550	107,387	46,541
Gallium ---- kilograms--	4,920	2,326	2,884	1,242
Germanium ---- pounds--	7,646	1,022	5,904	1,059
Gold (general imports):				
Ore and base bullion ---- troy ounces--	166,312	20,007	239,444	35,319
Bullion ---- do----	2,489,679	311,011	4,214,656	638,707
Hafnium ---- pounds--	3,270	31	3,322	41
Indium ---- thousand troy ounces--	290	1,808	291	2,254
Iron ore ---- thousand long tons--	44,390	980,348	37,905	956,584
Iron and steel:				
Pig iron ---- short tons--	[r]414,663	51,142	372,767	44,916
Iron and steel products (major):				
Iron products ---- do----	44,877	32,002	55,758	35,895
Steel products ---- do----	[r]14,563,278	[r]4,372,464	19,619,662	5,695,171
Scrap ---- thousand short tons--	496	34,524	601	39,723
Tinplate ---- do----	12	596	13	778
Lead:				
Ore, flue dust, matte (lead content) ---- short tons--	88,988	29,492	97,862	39,812
Base bullion (lead content) ---- do----	2,334	955	8,068	4,244
Pigs and bars (lead content) ---- do----	141,980	60,245	253,608	149,419
Reclaimed scrap, etc. (lead content) ---- do----	2,644	1,022	3,884	1,935
Sheet, pipe, shot ---- do----	294	495	980	1,516
Magnesium:				
Metallic and scrap ---- do----	13,066	19,020	5,599	6,684
Alloys (magnesium content) ---- do----	1,820	3,604	299	1,073
Sheets, tubing, ribbons, wire, other forms (magnesium content) ---- do----	21	38	66	219
Manganese:				
Ore (35% or more contained manganese) ---- do----	649,245	73,627	454,228	56,357
Ferromanganese (manganese content) ---- do----	417,433	164,698	416,081	155,662
Metal ---- do----	7,082	5,258	6,841	5,244
Mercury:				
Compounds ---- pounds--	35,536	90	21,961	100
Metal ---- 76-pound flasks--	44,415	4,325	28,750	3,263
Molybdenum:				
Ore (content) ---- pounds--	2,092,623	4,850	2,106,501	5,361
Waste and scrap ---- do----	297,554	1,183	2,107,988	1,468
Metal ---- do----	[r]136,108	[r]844	143,458	1,536
Compounds ---- do----	679,289	690	491,484	573

See footnotes at end of table.

Table 10.—U.S. imports for consumption of principal minerals and products —Continued

Mineral	1976 Quantity	1976 Value (thousands)	1977 Quantity	1977 Value (thousands)
METALS —Continued				
Nickel:				
Ore short tons	6,706	$272	111	$2
Pigs, ingots, shot, cathodes do	111,255	456,398	103,269	451,582
Plates, bars, etc do	3,223	20,348	9,341	33,280
Slurry do	33,280	98,178	24,762	78,039
Scrap do	2,359	4,827	3,175	6,546
Powder and flakes do	10,181	45,267	13,760	67,708
Ferronickel do	55,721	72,161	80,436	95,275
Oxide do	5,932	21,948	4,914	17,477
Platinum-group metals:				
Unwrought:				
Grains and nuggets (platinum) troy ounces	596	88	6,632	1,118
Sponge (platinum) do	904,048	139,378	771,843	125,328
Sweepings, waste, scrap do	146,773	20,080	247,865	18,463
Iridium do	18,179	5,045	8,288	2,225
Palladium do	994,360	48,535	1,102,607	59,683
Rhodium do	62,260	18,342	79,290	31,560
Ruthenium do	75,673	3,580	53,741	4,639
Other platinum-group metals do	224,560	32,195	126,921	16,076
Semimanufactured:				
Platinum do	95,653	15,623	44,405	7,495
Palladium do	128,951	6,325	49,070	2,719
Rhodium do	1,864	382	650	276
Other platinum-group metals do	14,142	1,963	19,062	2,391
Radium: Radioactive substitutes	NA	12,200	NA	15,869
Rare-earth metals:				
Ferrocerium, other cerium alloys short tons	20	167	23	262
Monazite do	2,103	431	5,480	900
Metals, including scandium and yttrium pounds	74	9	91	12
Rhenium:				
Metal, including scrap do	82	38	148	56
Ammonium perrhenate do	4,047	1,407	6,411	1,620
Selenium and selenium compounds do	811,257	12,118	585,673	9,322
Silicon:				
Metal (over 96% silicon content) short tons	[r]9,630	[r]11,703	26,806	26,158
Ferrosilicon (silicon content) do	[r]63,681	[r]39,648	75,254	44,371
Silver:				
Ore and base bullion thousand troy ounces	16,716	70,206	7,071	30,460
Bullion do	67,187	289,032	69,450	315,343
Sweepings, waste, dore do	4,454	18,823	2,626	10,150
Tantalum ore thousand pounds	2,557	[r]15,025	1,524	8,941
Tellurium pounds	203,534	1,745	171,291	3,158
Thallium do	66	1	25	2
Tin:				
Ore (tin content) metric tons	5,733	38,529	6,724	60,840
Blocks, pigs, grains, etc do	45,055	325,453	47,774	459,544
Dross, skimmings, scrap, residue, and tin alloys, n.s.p.f do	2,666	3,550	813	1,816
Tinfoil, powder, flitters, etc	NA	8,148	NA	3,733
Tin scrap, and other tin bearing material exluding tinplate scrap do	NA	7,391	NA	9,328
Tin compounds do	176	1,195	170	1,448
Titanium:				
Ilmenite[1] short tons	431,718	18,715	568,307	21,717
Rutile do	281,712	54,849	123,800	24,481
Metal do	[r]3,638	[r]9,752	6,881	15,551
Ferrotitanium and ferrosilicon titanium do	899	1,438	1,136	1,991
Compounds and mixtures do	[r]70,398	53,806	117,078	87,728
Tungsten (tungsten content):				
Ore and concentrate thousand pounds	5,301	28,320	6,919	55,927
Waste and scrap do	170	694	315	2,510
Other alloys do	1,898	11,104	2,473	14,255
Ferrotungsten and ferrosilicon tungsten do	844	5,451	505	4,565
Uranium and other uranium-bearing and nuclear materials:				
Oxide U_3O_8 do	11,074,298	203,926	7,717,679	88,150
Compounds, n.e.c do	33,876,908	441,603	23,531,191	413,028
Metal thousand pounds	NA	NA	70	284
Isotopes (stable) and their compounds	NA	1,067	NA	1,121
Radio isotopes, elements, etc thousand curies	60,302,966	12,200	71,695,692	12,492
Vanadium (content):				
Ferrovanadium thousand pounds	518	2,448	673	3,438
Vanadium-bearing materials (vanadium pentoxide content) do	10,702	7,721	10,057	8,269

See footnotes at end of table.

Table 10.—U.S. imports for consumption of principal minerals and products —Continued

Mineral	1976 Quantity	1976 Value (thousands)	1977 Quantity	1977 Value (thousands)
METALS —Continued				
Zinc:				
Ore (zinc content) short tons	155,803	$50,553	120,457	$37,897
Blocks, pigs, slabs do	695,131	482,265	555,147	359,134
Sheets, etc do	209	329	205	211
Fume (zinc content) do	6,927	2,558	257	516
Waste and scrap	1,803	516	10,128	2,175
Old, dross, skimmings do	12,445	4,884	12,940	5,204
Dust, powder, flakes do	6,009	5,134	7,388	6,277
Manufactures	NA	96	NA	262
Zirconium:				
Ore, including zirconium sand short tons	64,643	13,733	65,204	11,401
Metal, scrap, and compounds do	914	1,153	1,380	10,269
NONMETALS				
Abrasives:				
Diamonds (industrial) thousand carats	[r]17,047	[r]61,102	22,640	79,122
Other abrasives	NA	96,130	NA	113,168
Asbestos short tons	657,851	142,145	607,022	145,146
Barite:				
Crude and ground thousand short tons	918	17,829	974	18,176
Witherite short tons	[r]284	[r]61	518	103
Chemicals do	16,913	5,095	24,871	7,362
Boron:				
Carbide do	15	240	111	695
Boric acid do	56	14	14,132	5,596
Calcium borate, crude do	30,247	1,953	51,087	3,695
Cement thousand short tons	3,107	67,085	4,038	94,005
Clays:				
Raw short tons	34,359	1,207	31,212	1,335
Manufactured do	4,309	607	4,787	582
Cryolite do	11,325	4,329	11,776	4,279
Feldspar:				
Crude do	93	17,614	--	--
Ground and crushed do	--	--	242	8,115
Fluorspar do	895,254	56,580	971,355	60,298
Gem stones:				
Diamond thousand carats	[r]5,551	1,011,839	6,411	1,444,537
Emeralds do	1,165	55,286	1,563	64,375
Other	NA	112,241	NA	129,192
Graphite short tons	79,098	6,753	87,556	8,058
Gypsum:				
Crude, ground, calcined thousand short tons	6,253	18,285	7,078	22,139
Manufactures	NA	[r]3,471	NA	9,259
Iodine, crude thousand pounds	6,482	13,824	6,940	13,831
Kyanite short tons	110	12	53	7
Lime:				
Hydrated do	48,461	1,814	52,875	1,878
Other do	316,442	8,816	370,012	11,192
Lithium:				
Ore do	68	1	--	--
Compounds do	48	621	23	419
Magnesium compounds:				
Crude magnesite do	[r]20	2	249	11
Lump, ground, caustic-calcined magnesia do	8,194	808	5,788	566
Refractory magnesia, dead-burned, fused magnesite, dead-burned dolomite do	88,035	14,518	75,624	12,995
Compounds do	27,039	2,267	41,878	3,086
Mica:				
Uncut sheet and punch thousand pounds	1,654	941	2,179	988
Scrap do	[r]4,213	[r]205	2,348	112
Manufactures do	3,328	3,193	3,267	3,373
Mineral-earth pigments, iron oxide pigments:				
Ocher, crude and refined short tons	[r]53	11	44	13
Siennas, crude and refined do	624	122	620	171
Umber, crude and refined do	6,908	561	6,957	591
Vandyke brown do	739	147	1,052	194
Other natural and refined do	1,231	190	1,102	226
Synthetic do	40,547	15,523	48,918	19,402
Nepheline syenite:				
Crude do	2,112	38	860	17
Ground, crushed, etc do	499,135	8,785	501,696	9,118
Nitrogen compounds (major), including urea thousand short tons	3,467	296,814	4,738	447,050

See footnotes at end of table.

Table 10.—U.S. imports for consumption of principal minerals and products —Continued

Mineral	1976		1977	
	Quantity	Value (thousands)	Quantity	Value (thousands)
NONMETALS —Continued				
Peat:				
Fertilizer grade short tons	332,433	$28,939	324,058	$30,310
Poultry and stable grade do	5,618	553	6,252	612
Phosphate, crude metric tons	r42	r2,209	158	6,079
Phosphatic materials:				
Fertilizer and fertilizer materials thousand metric tons	43	6,631	54	5,095
Ammonium phosphates used as fertilizers do	317	44,250	338	39,331
Elemental phosphorous do	1	1,604	(2)	1,461
Other phosphatic materials do	4	1,032	6	1,133
Pigments and salts:				
Lead pigments and compounds short tons	17,836	9,462	22,316	14,724
Zinc pigments and compounds do	27,969	15,557	30,154	17,332
Potash do	7,595,246	360,756	8,405,338	392,235
Pumice:				
Crude or unmanufactured do	3,344	148	6,291	205
Wholly or partly manufactured do	78,057	350	247,172	993
Manufactures, n.s.p.f	NA	70	NA	133
Quartz crystal (Brazilian pebble) pounds	1,148,801	368	1,333,863	780
Salt thousand short tons	4,352	23,476	4,529	26,694
Sand and gravel:				
Glass sand do	61	489	35	333
Other sand and gravel do	292	431	351	392
Sodium compounds:				
Sodium carbonate and bicarbonate do	2	155	5	594
Sodium sulfate do	316	16,111	223	11,230
Stone and whiting	NA	46,211	NA	48,581
Strontium:				
Mineral short tons	35,711	1,486	42,986	1,915
Compounds do	5,375	r2,335	1,759	1,021
Sulfur and compounds, sulfur ore and other forms, n.e.s. thousand long tons	1,727	59,494	1,977	65,154
Talc, unmanufactured short tons	20,071	1,861	22,090	2,094
Total	XX	r14,109,153	XX	16,744,111

rRevised. NA Not available. XX Not applicable.
[1]Includes titanium slag averaging about 70% TiO_2, for detail see Titanium chapter.
[2]Less than 1/2 unit.

Table 11.—Comparison of world and U. S. production of selected nonfuel mineral commodities

(Thousand short tons unless otherwise specified)

Minerals	1976 World production[1]	1976 U.S. production	1976 U.S. percent of world production	1977[p] World production[1]	1977[p] U.S. production	1977[p] U.S. percent of world production
METALS, MINE BASIS						
Antimony (content of ore and concentrate) short tons	76,576	283	(2)	78,977	610	1
Arsenic, white do	38,505	W	NA	37,798	W	NA
Bauxite thousand long tons	76,602	[3]1,958	3	81,102	[3]1,981	2
Beryl short tons	2,675	W	NA	2,656	W	NA
Bismuth thousand pounds	8,532	W	NA	8,844	W	NA
Chromite	9,454	--	--	10,804	--	--
Cobalt (contained) short tons	31,197	--	--	32,611	--	--
Columbium-tantalum concentrate[4] thousand pounds	51,940	--	--	58,759	W	NA
Copper (content of ore and concentrate)	8,272	[5]1,606	19	8,503	1,504	18
Gold thousand troy ounces	39,089	1,048	3	38,966	1,100	3
Iron ore thousand long tons	881,157	[6]79,993	9	844,000	55,751	7
Lead (content of ore and concentrate)	3,677	610	17	3,759	592	16
Manganese ore (35% or more Mn)	27,153	--	--	24,267	--	--
Mercury thousand 76-pound flasks	240	23	10	199	28	14
Molybdenum (content of ore and concentrate) thousand pounds	191,736	113,233	59	205,921	122,408	59
Nickel (content of ore and concentrate)	905	16	2	852	14	2
Platinum-group metals thousand troy ounces	5,979	6	(2)	6,386	6	(2)
Silver do	312,150	34,328	11	325,475	38,166	12
Tin (content of ore and concentrate) metric tons	228,005	W	NA	231,438	W	NA
Titanium concentrates:						
Ilmenite	3,526	652	18	3,723	639	17
Rutile[4]	471	W	NA	396	W	NA
Tungsten concentrate (contained tungsten) thousand pounds	91,767	5,830	6	93,630	6,008	6
Uranium oxide (U_3O_8)[4] short tons	28,234	11,521	41	34,616	13,426	39
Vanadium (content of ore and concentrate) do	31,271	7,376	24	33,317	6,504	20
Zinc (content of ore and concentrate)	6,358	485	8	6,683	450	7
METALS, SMELTER BASIS						
Aluminum	13,771	4,251	31	15,049	4,539	30
Cadmium short tons	18,180	[7]2,256	12	18,898	2,204	12
Copper	8,039	[8]1,535	19	18,278	1,435	17
Iron, pig	551,193	86,848	16	542,696	81,494	15
Lead	3,811	[9]653	17	3,847	[9]605	16
Magnesium	149	W	NA	151	W	NA
Selenium[4] thousand pounds	2,501	401	16	3,019	499	17
Steel ingots and castings	747,103	[10]128,000	17	741,648	[10]125,333	17

Tellurium[4]	thousand pounds	NA	W	NA	NA	W	NA
Tin	metric tons	229,861	[11]5,700	2	230,243	[11]6,700	3
Zinc		5,908	499	8	6,041	450	7
NONMETALS							
Asbestos		5,623	115	2	5,879	102	2
Barite		5,666	1,234	22	5,892	1,494	25
Cement		810,656	[12]74,495	9	856,939	[12]80,060	9
Clay, china		18,247	[13]6,115	34	18,795	[13]6,469	34
Corundum		9	--	--	10	--	--
Diamond	thousand carats	38,073	--	--	39,470	--	--
Diatomite		1,919	631	33	1,976	648	33
Feldspar		2,936	740	25	3,045	734	24
Fluorspar		4,932	188	4	5,148	169	3
Graphite		498	W	NA	504	W	NA
Gypsum		69,175	11,980	17	72,164	13,390	19
Lime (sold or used)		119,117	[12]20,257	17	121,649	[12]19,987	16
Magnesite		9,847	W	NA	9,753	W	NA
Mica (including scrap)	thousand pounds	494,596	281,429	57	587,437	352,759	60
Nitrogen, agricultural[14]		48,291	[12]10,572	22	50,565	[12]10,792	21
Peat		222,745	774	([2])	223,577	781	([2])
Phosphate rock	thousand metric tons	107,616	44,662	42	115,948	47,256	41
Potash (K_2O equivalent)		26,741	2,400	9	28,356	2,457	9
Pumice[4]		17,375	4,181	24	17,060	4,011	24
Pyrites (sulfur content)	thousand long tons	9,311	286	3	9,127	166	2
Salt		185,324	[12]44,218	24	187,292	[12]43,439	23
Strontium[4]		67	--	--	74	--	--
Sulfur, elemental	thousand long tons	49,697	10,707	22	50,649	10,558	21
Talc, pyrophyllite, soapstone		5,976	1,092	18	6,331	1,205	19
Vermiculite[4]		577	304	53	570	359	63

[p]Preliminary. NA Not available. W Withheld to avoid to disclosing company proprietary data.
[1]May not represent total world production because confidential U.S. data are excluded for some commodities. World totals include reported figures and reasonable estimates; however, for some commodities where data were not available, no reasonable estimates could be made and none have been included.
[2]Less than 1/2 unit.
[3]Dry bauxite, equivalent of crude ore.
[4]World total exclusive of the U.S.S.R.
[5]Recoverable.
[6]Includes byproduct ore.
[7]Includes secondary.
[8]Smelter output from domestic and foreign ores, exclusive of scrap.
[9]Lead refined from domestic and foreign ores; excludes lead refined from imported base bullion.
[10]Data from American Iron and Steel Institute. Excludes production of castings by companies that do not produce steel ingot.
[11]Includes tin content of alloys made directly from ore.
[12]Includes Puerto Rico.
[13]Kaolin sold or used by producers.
[14]Year ended June 30 of year stated (United Nations).

Abrasive Materials

By W. Timothy Adams[1]

The production of natural abrasives varied in quantity and value compared with 1976. Output of tripoli-type materials was approximately the same in both quantity and value. Special silica stone products decreased in quantity and increased in value. Garnet production decreased both in quantity and value. The production of emery increased and the production and value of manufactured abrasive material was approximately the same.

Table 1.—Salient abrasives statistics in the United States

Kind		1973	1974	1975	1976	1977
Natural abrasives (domestic) sold or used by producers:						
Tripoli (crude)	short tons	101,519	85,121	80,562	124,281	125,661
Value	thousands	$929	$623	$565	$776	$777
Special silica stone products[1]	short tons	3,466	3,134	2,953	2,696	2,200
Value	thousands	$667	$717	$1,061	$1,404	$3,236
Garnet	short tons	22,772	24,684	17,204	24,565	20,022
Value	thousands	$2,380	$2,551	$1,690	e$2,740	e$2,234
Emery	short tons	2,884	2,520	3,487	W	W
Value	thousands	W	W	W	W	W
Artificial abrasives[2]	short tons	[3]645,813	[3]730,405	[3]528,307	[3]620,328	640,723
Value	thousands	[3]$108,808	[3]$175,678	[3]$141,580	$176,064	$186,654
Foreign trade (natural and artificial abrasives):						
Exports (value)	do	$82,969	$115,508	$102,849	$113,199	$121,579
Reexports (value)	do	$29,413	$29,829	$28,362	$29,285	$35,363
Imports for consumption (value)	do	$136,655	$142,974	$121,863	r$157,740	$192,870

eEstimate. rRevised. W Withheld to avoid disclosing company proprietary data.
[1]Includes grinding pebbles, grindstones, oilstones, tube-mill liners, and whetstones.
[2]Production of silicon carbide and aluminum oxide (the United States and Canada); shipments of metallic abrasives (the United States).
[3]Includes production of aluminum zirconium oxide (the United States and Canada).

FOREIGN TRADE

Imports of abrasive materials were 23% more in value than in 1976, and exports plus reexports increased in value 10%. Net imports, the excess of imports over exports and reexports, were $35.3 million. The volume and value of all abrasive materials exported varied.

Industrial diamond imports totaled 22.6 million carats of loose material valued at $79.7 million, an increase of 33% in quantity and 29% in value from those of 1976. The exports of industrial diamond, loose, were 17.7 million carats, an increase of 19%, and the value was $44.6 million, an increase of 13%. Reexports of industrial diamond, loose, were 3.9 million carats, an increase of 26%, and the value was $35.0 million, an increase of 21%. The diamond content in diamond wheels, exported and reexported, was 830,166 carats, an increase of 11%, and the declared value was $6.1 million for an increase of 22% in value. The imports of diamond wheels are listed by number and value; the value in 1977 increased to $1,882,000 from $1,302,000 in 1976.

The 1977 imports of industrial diamond from Ireland were 7.6 million carats valued at $17.7 million, for an increase of 29% in quantity and 27% in value over those of

1976. The share of imports from Ireland was 34% of the total quantity and 22% of the value. Of the industrial imported bort, powder, and dust, synthetic diamond was 6.4 million carats valued at $12.9 million and natural diamond was 8.6 million carats valued at $18.4 million.

Table 2.—U.S. exports of abrasive materials, by kind

(Thousands)

Kind	1976		1977	
	Quantity	Value	Quantity	Value
NATURAL ABRASIVES				
Dust and powder of natural and synthetic precious or semi-precious stones, including diamond dust and powder ---carats--	14,155	$35,450	17,272	$42,714
Crushing bort, except dust and powder ---do--	77	182	6	42
Industrial diamond ---do--	639	3,677	376	1,854
Emery, natural corundum, other natural abrasives, n.e.c ---pounds--	33,619	6,189	38,803	8,147
MANUFACTURED ABRASIVES				
Artificial corundum (fused aluminum oxide) ---do--	43,682	14,820	39,361	13,226
Silicon carbide, crude or in grains ---do--	20,212	6,174	22,441	7,062
Carbide abrasives, n.e.c ---do--	1,919	5,331	2,074	4,513
Grinding and polishing wheels and stones:				
Diamond ---carats--	730	4,911	797	5,900
Pulpstones ---pounds--	1,109	657	1,545	966
Polishing stones, whetstones, oilstones, hones, similar stone ---do--	739	1,222	660	1,303
Wheels and stones, n.e.c ---do--	5,027	13,759	5,268	14,526
Abrasive paper and cloth, coated with natural or artificial abrasive materials ---reams--	436	17,051	536	17,017
Coated abrasives, n.e.c	NA	3,776	NA	4,309
Total	XX	113,199	XX	121,579

NA Not available. XX Not applicable.

Table 3.—U. S. reexports of abrasive materials, by kind

(Thousands)

Kind	1976		1977	
	Quantity	Value	Quantity	Value
NATURAL ABRASIVES				
Dust and powder of natural and synthetic precious or semi-precious stones, including diamond dust and powder ---carats--	302	$744	464	$1,372
Crushing bort, except dust and powder ---do----	356	2,108	320	1,758
Industrial diamond ---do----	2,438	26,027	3,132	31,839
Emery, natural corundum, other natural abrasives, n.e.c ---pounds--	2	6	--	--
MANUFACTURED ABRASIVES				
Artificial corundum (fused aluminum oxide) ---do----	129	38	--	--
Silicon carbide, crude or in grains ---do----	(1)	2	--	--
Carbide abrasives, n.e.c ---do----	7	90	5	34
Grinding and polishing wheels and stones:				
Diamond ---carats--	19	122	33	235
Wheels and stones, n.e.c ---pounds--	30	51	16	60
Abrasive paper and cloth, coated with natural or artificial abrasive materials ---reams--	1	47	(1)	5
Coated abrasives, n.e.c	NA	50	NA	60
Total	XX	29,285	XX	35,363

NA Not available. XX Not applicable.

[1]Less than 1/2 unit.

Table 4.—U. S. imports for consumption of abrasive materials (natural and artificial), by kind

(Thousands)

Kind	1976 Quantity	1976 Value	1977 Quantity	1977 Value
Corundum, crude ---- short tons	2	$230	2	$241
Emery, flint, rottenstone, tripoli, crude or crushed ---- do	5	379	9	363
Silicon carbide, crude ---- do	89	21,191	93	25,339
Aluminum oxide, crude ---- do	174	37,628	180	42,740
Other crude artificial abrasives ---- do	1	198	3	712
Abrasives, ground grains, pulverized or refined:				
Rottenstone and tripoli ---- do	(1)	1	(1)	(1)
Silicon carbide ---- do	1	1,356	3	2,731
Aluminum oxide ---- do	5	2,059	3	1,889
Emery, corundum, flint, garnet, other, including artificial abrasives ---- do	1	762	3	1,752
Papers, cloths, other materials wholly or partly coated with natural or artificial abrasives	(2)	24,492	(2)	27,952
Hones, whetstones, oilstones, polishing stones ---- number	207	194	203	182
Abrasive wheels and millstones:				
Burrstones manufactured or bound up into millstones ---- short tons	--	--	(1)	2
Solid natural stone wheels ---- number	10	18	8	32
Diamond ---- do	41	1,302	55	1,882
Abrasive wheels bonded with resins ---- do	1	3,270	1	3,556
Other	(2)	2,255	(2)	2,729
Articles not especially provided for:				
Emery or garnet	(2)	25	(2)	36
Natural corundum or artificial abrasive materials	(2)	418	(2)	345
Other	(2)	352	(2)	685
Diamond:				
Diamond dies ---- number	r12	r508	16	580
Crushing bort ---- carats	186	402	260	592
Other industrial diamond ---- do	4,484	31,344	6,263	40,822
Miners' diamond ---- do	1,119	5,591	1,342	6,986
Dust and powder ---- do	11,258	23,765	14,775	30,722
Total	XX	r157,740	XX	192,870

rRevised. XX Not applicable.
[1]Less than 1/2 unit.
[2]Quantity not reported.

TRIPOLI

Fine-grained, porous, silica materials are grouped together because they have similar properties and end uses. Production of crude tripoli (table 1) increased 1% in quantity and had the same value. Processed tripoli sold or used (table 5) increased 2% in quantity and 14% in value. The uses for processed tripoli in 1977 were 61% for abrasives and 37% for fillers compared with 60% and 35%, respectively, in 1976.

Tripoli producers in 1975 were Malvern Minerals Co., Garland County, Ark., which produced crude and finished material; Midwestern Minerals Corp., Ottawa County, Okla., which produced crude and finished material; and American Tripoli Co., Div. of The Carborundum Co., which produced crude in Ottawa County, Okla., and finished material in Newton County, Mo. Illinois Minerals Co. and Tammsco, Inc., both in Alexander County, Ill., produced amorphous silica. Keystone Filler and Mfg. Co., in Northumberland County, Pa., mined and processed rottenstone.

Prices quoted in Engineering and Mining Journal, December 1977, for tripoli and amorphous silica were as follows:

Tripoli, paper bags, carload lots, f.o.b., in cents per pound:	
White, Elco, Ill.: Air floated through 200 mesh	2.30
Rose and cream, Seneca, Mo. and Rogers, Ark.:	
Once ground	2.90
Double ground	2.90
Air float	3.15

Table 5.—Processed tripoli[1] sold or used by producers in the United States, by use[2]

Use		1973	1974	1975	1976	1977
Abrasives	short tons	55,420	50,615	38,815	68,874	70,631
Value	thousands	$2,233	$2,251	$1,518	$2,525	$2,805
Filler	short tons	32,407	33,361	27,630	40,247	42,599
Value	thousands	$1,158	$1,346	$1,205	$1,811	$2,212
Other	short tons	2,105	2,025	1,739	5,000	2,689
Value	thousands	$62	$66	$60	$175	$119
Total[3]	short tons	89,932	86,000	68,184	114,121	115,919
Value[3]	thousands	$3,453	$3,665	$2,783	$4,511	$5,136

[1]Includes amorphous silica and Pennsylvania rottenstone.
[2]Partly estimated.
[3]Data may not add to totals shown because of independent rounding.

SPECIAL SILICATE STONE PRODUCTS

Special silica stone products produced in 1977 included oilstones from Arkansas, whetstones from Arkansas and Indiana, grindstones from Ohio, grinding pebbles and deburring media from Minnesota and Wisconsin, and tube-mill liners from Minnesota.

Producers of oilstones and whetstones in Garland County, Ark., were John O. Glassford; Hiram A. Smith, Inc.; Arkansas Abrasives, Inc.; and Norton Pike Division of Norton Co. Whetstones were produced by Milroy and Smith in Hot Springs County, Ark., and by K & K Mines, Inc., in Pike County, Ark. Hindostan Whetstone Co. operated a plant in Lawrence County, Ind., to finish stone obtained from a quarry in Orange County, Ind. Cleveland Quarries Co. produced grindstones at its Amherst quarry, Lorrain County, Ohio. Jasper Stone Co. produced grinding media, rough and rounded, from its quarry in Rock County, Minn., and Baraboo Quartzite Co., Inc. produced deburring media at its quarry in Sauk County, Wis.

Table 6.—Special silica stone products sold or used in the United States[1]

Year	Quantity (short tons)	Value (thousands)
1973	3,466	$667
1974	3,134	717
1975	2,953	1,061
1976	2,696	1,404
1977	2,200	3,236

[1]Includes grinding pebbles, grindstones, oilstones, tube-mill liners, and whetstones.

NATURAL SILICATE ABRASIVES

Garnet.—Sales of domestic garnet decreased 18% in quantity and value in 1977. Three producers were active in 1975——two in Idaho and one in New York. Barton Mines Corp., Warren County, N.Y., sold garnet for use in coated abrasives, glass grinding and polishing, and metal lapping. Emerald Creek Garnet Milling Co. and Idaho Garnet Abrasive Co., both in Benewah County, Idaho, reported their garnet was used in sandblasting, water filtration, as a filler in rubber products, and as an additive in decoration.

The Peampaludo rutile deposit, situated in the Liguria region around Genoa, Italy also contains approximately 30% garnet. Early testing work suggests that a grade of garnet suitable for sandblasting can be recovered by magnetic separation at an early stage in the recovery process.[2]

The use of garnet in tire treads has been approved by the States of Oregon, Washington, Minnesota, and Michigan. One pound of garnet is added to 10 pounds of rubber tread compound used on winter tires for trucks and automobiles. Patents are held by the Garnetread Co. a Portland, Oreg. based firm. Approximately 100 tons of Idaho garnet was used in 1976-77.[3]

Table 7.—Abrasive garnet sold or used by producers in the United States

Year	Quantity (short tons)	Value (thousands)
1973	22,772	$2,380
1974	24,684	2,551
1975	17,204	1,690
1976	24,565	[e]2,740
1977	20,022	[e]2,234

[e]Estimate.

NATURAL ALUMINA ABRASIVES

Corundum.—No domestic corundum was produced in 1977. Requirements for domestic consumption were met by imports mainly from the Republic of South Africa. A small quantity of corundum was imported from India. Total imports were 2,160 tons at a declared value of $240,683.

Prices quoted in Engineering and Mining Journal, December 1977, for crystal corundum, per short ton of crude, c.i.f. U.S. ports, were $150 to $160.

Emery.—Two producers of emery were active in 1977: De Luca Emery Mine, Inc. and Emeri Crete, Inc., both near Peekskill in Westchester County, N.Y. Domestic emery was used mostly in aggregates as a nonslip additive for floors, pavements, and stair treads. The minor use for domestic emery was in abrasive materials for coated abrasives and tumbling or deburring media.

World production data for emery are principally for Greece and Turkey. In 1976, production of emery in Greece was estimated to be 7,165 tons. Production of emery in Turkey in 1976 was reported as 71,500 tons. No value was placed on the production in either country.

Prices quoted in Industrial Minerals, No. 123, December 1977, for emery, per metric ton, c.i.f. main European port, were as follows, in dollars: Coarse grain, $135 to $144; medium and fine grain, $144 to $162.

Table 8.—Natural corundum: World production, by country

(Short tons)

Country[1]	1975	1976	1977[p]
India	[r]343	582	[e]590
South Africa, Republic of	266	157	152
U.S.S.R.[e]	8,300	8,300	8,800
Uruguay	460	420	[e]420
Total	[r]9,369	9,459	9,962

[e]Estimate. [p]Preliminary. [r]Revised.

[1]In addition to the countries listed, Southern Rhodesia presumably continued to produce natural corundum at a significant level (several thousand tons annually), and both Argentina and Kenya may have produced minor quantities of this commodity, but output is not reported and available information is inadequate for the formulation of reliable estimates of output levels.

INDUSTRIAL DIAMOND

Domestic production of synthetic industrial diamond in 1977 was estimated to be 30.8 million carats, an increase of 5.5 million carats over that of 1976. Secondary production, comprising salvage from used diamond tools and from wet and dry diamond-containing wastes, was estimated to be 2.7 million carats from a consumption canvass by the Department of Commerce.

The Government stockpile inventory as of December 31, 1977, was 28.4 million carats of crushing bort and 20.0 million carats of stones. The objective for crushing bort was 15.0 million carats and 5.6 million carats of stones. Excesses are 13.4 million carats and 14.4 million carats, respectively. Available for disposal from prior enabling legislation were 4.7 million carats of bort. The inventory of small diamond dies was 25,473 of which the objective was 0 and 25,473 was excess.

State officials in Colorado have confirmed the discovery of diamond in a north-to-south belt straddling the Colorado-Wyoming border extending southward to Fort Collins and to areas west of Boulder. All diamonds found so far are very small which limits them to industrial use. The value of the deposit cannot be estimated until a 13-cubic-yard sample of diamond-bearing ore is mined and assayed.[4]

The United States is the largest consumer of industrial diamond stones and is totally dependent on foreign sources. At this time supplies from Angola are disrupted. Supplies from the Territory of South-West Africa, Zaire, and other areas also are in potential danger of disruption. Output of industrial stones is largely dependent on the output of gem diamond, which is limited by economic and other factors not directly related to the diamond for industrial stones.

World reserves are not expected to be sufficient to meet world demand for industrial stones through the year 2000.

Exports and reexports of industrial diamond dust and powder, which included synthetics, were 17.7 million carats valued at $44.1 million. Crushing bort, except dust and powder, exports and reexports were 325,239 carats valued at $1.8 million. Exports and reexports of stones were 3.5 million carats valued at $33.7 million. The total of exports and reexports of dust and powder, bort, and stones was 21.6 million carats valued at $79.6 million.

Table 9.—U.S. imports for consumption of industrial diamond (excluding diamond dies)

(Thousand carats and thousand dollars)

Year	Quantity	Value
1975	14,291	53,383
1976	17,047	61,102
1977	22,640	79,122

WORLD REVIEW

Central African Empire.—Data recently released by the Director-General of Mines and Geology indicate that diamond output continued to decrease. Total diamond production was 286,000 carats in 1976 and barely half of the 524,000 carats mined as recently as 1972. Part of the decline in diamonds mined is due to legal difficulties between the leading alluvial diamond mining company, Société Centrafricaine d'Exploitation Diamantifere (SCED) and the Government. Operations relating to SCED status under the investment and tax code led to a temporary suspension of mining in 1976.[5]

Sierra Leone.—The difficulties experienced by the diamond mining industry in 1975-76 with 732,000 and 481,000 carats produced, respectively, were expected to continue to 1977 with an anticipated production of 450,000 carats. Small producers in the alluvial diamond mining scheme are reputed to have fared better in 1976. Smuggling to Liberia declined due to the Government cutting the export duty on larger stones from 71% to 21%, thus making smuggling to Liberia uneconomic.[6]

South Africa, Republic of.—DeBeers Consolidated Mines Dutoilspan and Bultfontein mines, which contributed over 369,000 carats to the total 1976 Kimberly output of over 1 million carats, have been closed by flooding. Workers have been transferred to the DeBeers and Wisselton mines in the Kimberly division. The company did not estimate how long it would take to revive production from the affected mines, but divisional production of stones is expected to be maintained.[7]

U.S.S.R.—According to the Belgian trade magazine Diamant, Russalmaz NV of Antwerp, described as the most important Soviet sales office for cut diamonds in Europe, is setting up a new department to purchase industrial diamonds on the Antwerp market. These stones are destined exclusively for the Soviet diamond industry. The goods in question are presumably tool and die stones and, if confirmed, would appear to indicate a demand in excess of supply from the Yakut mines and also that manufactured polycrystalline diamond tool elements cannot meet technological requirement in certain demanding requirements.[8]

Zaire.—Société Miniere de BaKwanga (MIBA) is Zaire's principal producer of industrial diamond. The average export value of MIBA production has been between $3 to $4 per carat. MIBA is suffering from many of the same supply problems of other Zairian firms: Shortages of fuel, food, and spare parts. It also has suffered a cash squeeze that has prevented it from making normal investments to maintain and upgrade capital equipment. As a result, MIBA production and exports are approximately 15% below its export quota of 13.5 million carats.[9]

TECHNOLOGY

Tighter machining tolerances than ever are needed for a wide variety of parts. These include mirrors with complex shapes, computer memory discs, ordnance parts, gravure printing rolls, hydraulic pumps, and plastic lenses. For such parts, the single crystal diamond can give contour tolerances to 10 microinches per inch and surface finishes down to 1 or 2 microinches. Diamond machining to those tolerances gives an optical surface in a fraction of the time of conventional lapping and grinding techniques. The single crystal diamond, used in an ultraprecise machine tool is the quickest way to cut nonferrous metals to tight tolerances. The special machines required for diamond turning are made by two companies: Moore Special Tool Co., Inc., Bridgeport, Conn., and Pneumo Precision Inc., Keene, N.H.[10]

Table 10.—U. S. imports for consumption of industrial diamond, by country

(Thousand carats and thousand dollars)

Country	Crushing bort (including all types of bort suitable for crushing)				Other industrial diamond (including glazers' and engravers' diamond, unset)				Miners' diamond				Powder and dust			
	1976		1977		1976		1977		1976		1977		1976		1977	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Belgium-Luxembourg	--	--	--	--	591	2,329	661	2,891	(1)	1	32	165	818	1,218	939	1,566
Canada	2	15	--	--	67	564	32	306	9	53	31	50	28	44	110	166
Congo	--	--	--	--	15	54	104	523	--	--	--	--	--	--	2	4
Cyprus	--	--	--	--	15	35	2	26	--	--	--	--	--	--	2	12
Finland	--	--	--	--	88	121	82	100	--	--	--	--	--	--	147	188
France	--	--	--	--	--	--	11	579	2	23	2	24	3	8	(1)	31
Germany, Federal Republic of	--	--	--	--	3	43	1	5	1	2	4	22	11	28	85	76
Ghana	--	--	--	--	9	125	8	81	2	31	1	1	19	27	29	42
Greece	--	--	--	--	--	--	--	--	--	--	--	--	71	94	--	--
Hong Kong	--	--	--	--	3	46	1	14	--	--	--	--	7	12	265	257
Ireland	--	--	15	30	101	471	17	102	109	159	39	100	5,705	13,250	7,543	17,455
Israel	--	--	--	--	13	359	14	240	--	--	7	39	2	4	(1)	(1)
Japan	--	--	--	--	27	563	38	641	130	197	277	422	659	1,088	591	861
Liberia	--	--	--	--	13	42	2	3	2	26	14	339	--	--	--	--
Mexico	--	--	--	--	(1)	1	--	--	--	--	--	--	23	41	16	27
Netherlands	53	131	118	250	163	1,425	178	1,650	18	32	(1)	4	38	84	27	63
Sierra Leone	--	--	--	--	(1)	1	3	195	--	--	--	--	--	--	--	--
South Africa, Republic of	113	210	89	245	2,901	19,741	3,918	24,429	94	549	92	421	2,324	5,471	2,799	6,961
South-West Africa, Territory of	--	--	--	--	7	86	30	138	--	--	--	--	--	--	--	--
Spain	--	--	--	--	--	--	--	--	--	--	20	41	--	--	14	32
Switzerland	--	--	22	42	16	1,018	1	9	--	--	4	26	127	191	309	459
Tunisia	--	--	--	--	--	--	--	--	--	--	--	--	--	--	16	31
U.S.S.R	--	--	--	--	--	--	67	153	--	--	--	--	479	610	549	684
United Kingdom	14	35	15	22	405	3,222	1,026	8,013	37	208	4	27	904	1,498	1,299	1,709
Upper Volta	--	--	--	--	--	--	--	--	--	--	17	108	--	--	--	--
Venezuela	--	--	--	--	25	716	9	305	91	596	10	453	--	--	--	--
Western Africa, n.e.c.[2]	--	--	--	--	9	117	34	343	--	--	--	--	(1)	(1)	--	--
Zaire	4	11	1	3	4	17	16	29	624	3,695	783	4,605	39	94	31	95
Other	--	--	--	--	r9	r248	8	47	(1)	19	5	139	r1	r3	2	3
Total	186	402	260	592	4,484	31,344	6,263	40,822	1,119	5,591	1,342	6,986	11,258	23,765	14,775	30,722

r Revised.
1 Less than 1/2 unit.
2 Prior to 1975, formerly Western Portuguese Africa.

Table 11.—Diamond (natural): World production, by country[1]

(Thousand carats)

Country	1975			1976			1977[p]		
	Gem	Industrial	Total	Gem	Industrial	Total	Gem	Industrial	Total
Africa:									
Angola	[r]743	[r]248	[r]991	255	85	340	265	88	353
Botswana	[r]359	[r]2,038	2,397	358	2,026	2,384	404	2,287	2,691
Central African Empire	220	119	339	172	114	286	182	119	301
Ghana	233	2,095	2,328	228	2,055	2,283	230	2,070	[e]2,300
Guinea[e]	25	55	80	25	55	80	25	55	80
Ivory Coast	84	125	209	24	36	60	26	39	[e]65
Lesotho	[2]1	[2]2	[2]3	[2]1	[2]4	[2]5	6	22	[e]28
Liberia	[r] [3]244	[r] [3]162	[3]406	[3]176	[3]144	[3]320	163	163	326
Sierra Leone	293	439	732	192	289	481	180	270	[e]450
South Africa, Republic of:									
Premier mine	509	1,527	2,036	458	1,375	1,833	502	1,508	2,010
Other DeBeers properties[4]	2,518	2,061	4,579	2,549	2,086	4,635	2,796	2,287	5,083
Other	408	272	680	333	222	555	564	376	940
Total	3,435	3,860	7,295	3,340	3,683	7,023	3,862	4,171	8,033
South-West Africa, Territory of	1,660	[r]88	[r]1,748	1,609	85	1,694	1,901	100	2,001
Tanzania	224	224	448	219	219	438	187	188	[e]375
Zaire	395	12,415	12,810	591	11,230	11,821	561	10,652	11,213
Other areas:									
Brazil	[r]131	[r]131	262	38	38	76	100	100	[e]200
Guyana	8	13	21	6	8	14	7	10	17
India	17	3	20	17	3	20	19	3	[e]22
Indonesia[e]	[r]3	[r]12	15	3	12	15	3	12	15
U.S.S.R	1,950	7,750	9,700	2,000	7,900	9,900	2,100	8,200	10,300
Venezuela	239	821	1,060	190	643	833	160	540	700
World total	[r]10,264	[r]30,600	[r]40,864	9,444	28,629	38,073	10,381	29,089	39,470

[e]Estimate. [p]Preliminary. [r]Revised.

[1]Total (gem plus industrial) diamond output for each country is actually reported except where indicated to be an estimate by footnote. In contrast, the detailed separate reporting of gem diamond and industrial diamond represents Bureau of Mines estimates in the case of every country except Lesotho (1975-76), Liberia (1977), Venezuela (1975-76), and Zaire (1975), where sources give both total output and detail. The estimated distribution of total output between gem and industrial diamond is conjectural in the case of several countries, based on unofficial information of varying reliability.

[2]Exports of diamond originating in Lesotho; excludes stone imported for cutting and subsequently reexported.

[3]Exports.

[4]All company output from the Republic of South Africa except for that credited to the Premier mine; also excludes company output from the Territory of South-West Africa and Botswana.

Polycrystalline diamond layers bonded to tungsten carbide may provide better bit-cutting edges. Drill bits with composite inserts have been successfully tested in several wells as well as in the laboratory. Composite inserts exhibit high impact and abrasion resistance while out-drilling conventional cone bits. The new inserts consist of a diamond layer 0.02 inch thick bonded to a cemented tungsten carbide substrate 0.11 inch thick. The blank is brazed to tungsten carbide as an insert or press-fitted into specially designed bits. The diamond layer is polycrystalline. Numerous, tiny, randomly oriented diamond crystals in the upper layer are bonded to each other and to the substrate. During drilling the diamond will not fracture as a natural single diamond stone may, but rather will chip in small discrete amounts limited by the random orientation of the individual grains. By microfracturing, more of the diamond crystals in the polycrystalline layer are exposed so that a fresh cutting edge is always forward. The diamond composite blanks have been deemed commercial by the manufacturer, but are not applicable to all drilling situations. Very hard, abrasive formations are not drilled economically by the new material; however, penetration rates in soft, medium, and medium-hard formations can be increased dramatically under certain conditions.[11]

Many different diamond synthesis techniques are known. The most widely practical method of producing industrial diamond on a commercial scale involves the rearrangement of the graphite lattice into the diamond lattice through the catalytic action of a suitable metal solvent with the simultaneous application of ultrahigh pressure and temperature. Current techniques of synthesis and theories on the mechanism of synthesis are reviewed.[12]

Improvements in diamond anvils for high-pressure studies have opened areas of application for research in solid-state physics, geophysics, mineralogy, and chemistry. Further development of diamond anvil technique has brought about significant advances in these areas. Current technology, present state-of-the-art, and possible improvements and areas of application are viewed.[13]

The high refractive index of diamond (average 2.417) is exploited in an advanced far-infrared spectrometer system for organic chemical and other research analysis. The instrument in which diamond micrometer-size powders are used as filters is described as a complete far infrared spectrometer consisting of a Michelson interferometer with stabilized arc source, multisample reflectance and transmittance module with multiposition filter holder, and a 3-millimeter diamond-windowed Golay detector, plus associated electronics for plotting and recording. The use of diamond results in an improvement of throughput in the interferometer by a factor of 2.[14]

Titanium alloys are used for manufacturing aircraft and space vehicle components essential to the safety of the craft and subject to severe dynamics and static loads in addition to shock loads at high temperatures. High-speed steels containing a high percentage of cobolt and tools tipped with K20-grade carbide have been found suitable for the machining of titanium alloy. The use of natural diamond tools is restricted because of the limited size of the cutting edge and poor shock resistance when used for interrupted cutting. The use of polycrystalline diamond as a cutting tool material makes possible substantial improvements in production techniques involving the machining of titanium alloys.[15]

Heavy metals and acids are used extensively in the production processes of diamond polishing and processing plants. The handling and disposal of the materials represent a potential health hazard. Problems associated with the handling of toxic wastes are described.[16]

Abstracts relative to properties of diamond-hard materials, machines, and patents were published monthly in the Industrial Diamond Review. Each issue, January to December 1977, contained from 11 to 25 pages of abstracts and patent information.

ARTIFICIAL ABRASIVES

Five firms produced crude fused aluminum oxide in the United States and Canada in 1977. Operators of plants in both countries were: The Carborundum Co., Div. of Kennecott Copper Corp., Norton Co., and General Abrasive Co., Div. of Dresser Industries, Inc. The Exolon Co. and Unicorn Abrasives of Canada, Ltd., Div. of Fusion du Saquenay (Simonds Canada Abrasive Co. Ltd.) operated plants in Canada. The production of white, high-purity material was 26,967 tons and production of regular material was 158,775 tons. Of the combined output of white and regular material, 13% was used for nonabrasive applications principally in the manufacture of refractories. The production was 63% of the rated capacity of the furnaces used to produce fused aluminum oxide. Stocks were reported as 15,140 tons for December 31, 1977.

One firm, General Abrasive Co., Div. of U.S. Industries, produced fused alumina zirconia abrasive in the United States and in Canada; and three firms, The Carborundum Co., Norton Co., and Exolon Co., operated plants in Canada. All production was reportedly used for abrasive applications. The output was 59% of the capacity of the furnaces assigned to the production of fused alumina zirconia. Stocks were reported as 212 tons for December 31, 1976.

Six firms in the United States and Canada produced silicon carbide in 1976. The Carborundum Co. operated plants in both countries. Electro-Refractories & Abrasives Canada, Ltd.; Exolon Co.; Norton Co.; and General Abrasive Co., Div. of Dresser Industries, operated in Canada. These five companies produced crude for abrasive, refractory, and other nonabrasive uses. Satellite Alloy Corp. operated in the United States and produced crude for nonabrasive applications. Production by the six firms was virtually at capacity and 31% was reportedly used for abrasive applications. Nonabrasive use was 69% of the output and was mostly for refractory and metallurgical applications. Stocks were reported as 8,888 tons for December 31, 1976.

In the Stockpile Report to the Congress by the General Services Administration, the inventory of crude fused aluminum oxide in

Table 12.—Producers of metallic abrasives in 1977

Company	Location	Product shot and/or grit
Abbott Ball Co	West Hartford, Conn	Steel.
Abrasive Materials, Inc	Hillsdale, Mich	Steel and stainless steel cut wire.
Abrasive Metals Co	Pittsburgh, Pa	Chilled iron and annealed iron.
The Carborundum Co., Pangborn Div	Butler, Pa	Steel.
Cleveland Metal Abrasive Co	Birmingham, Ala	Do.
Do	Cleveland, Ohio	Do.
Do	Howell, Mich	Chilled iron.
Do	Springville, N.Y	Do.
Do	Toledo, Ohio	Steel.
Durasteel Co	Mt. Pleasant, Pa	Do.
Ervin Industries, Inc	Adrian, Mich	Chilled iron and steel.
Globe Steel Abrasive Co	Mansfield, Ohio	Chilled and annealed iron.
Metal Blast, Inc	Cleveland, Ohio	Do.
National Metal Abrasive Co	do	Steel.
Pellets, Inc	Tonowanda, N.Y	Steel and stainless steel cut wire.
Steel Abrasives, Inc	Hamilton, Ohio	Chilled and annealed iron.
Wheelabrator-Frye Inc	Mishakawa, Ind	Steel.

calendar year 1977 was reduced to 248,868 tons, with 73,544 tons uncommitted excess; the stock of aluminum oxide grain was unchanged at 50,905 tons with the goal increased to 75,000 tons; and the stock of silicon carbide crude was 80,619 tons with the goal increased to 306,628 tons.

Metallic abrasives were produced by 13 firms in the United States in 1976. Steel shot and grit comprised 85% of the total quantity sold or used; chilled iron shot and grit, 12%; and annealed iron shot and grit, 3%. The amounts from Michigan were 28% of the total sold or used, the highest of the producing States. Ohio, Pennsylvania, Indiana, Virginia, Alabama, Wisconsin, and Connecticut followed in quantity sold or used. Three companies recycled material: Copperweld Steel Co. of Glassport, Pa.; Industeel Corp. of Pittsburgh, Pa.; and Kohler Co. of Sheboygan, Wis.

TECHNOLOGY

The Carborundum Co. will add 16,000 tons of new capacity for silicon carbide by early 1978. Process improvements are claimed to double the tonnage produced per square foot of building space. The expansion will include new and significantly larger furnaces and transformers. A materials handling system with vacuum equipment will minimize pollution. The Carborundum Co. claims to be the world's largest manufacturer of silicon carbide.[17]

A new plant to produce 27,560 short tons per year of silicon carbide will be built near Hennepin, Ill., by Electroschmelzwerk Kempten Gmbh of Munich, Germany a subsidiary of Wacker-Chemie. Construction of the facility has started and is scheduled to come onstream in 1979.[18]

The Carborundum Co. began construction of a research and development and pilot production facility devoted exclusively to alpha-phase silicon carbide. Primary focus of the new facility will be the development of ceramic parts to replace ductile metals in turbines and diesel engines where metal alloys have reached their temperature limits. Other applications include heat exchangers and other types of vehicular engines. The process consists of mixing a powder of alpha-phase silicon carbide with a plastic resin, injecting it into a mold by techniques long used in the plastics industry, then firing it in an electric furnace at 2,000°C or more to burn out the plastic and sinter the part. The final density of the part is more than 98% of its theoretical maximum, with an average grain size of 7 micrometers and no open porosity. Volume shrinkage is about 40%, but final dimensions are within 1% to 2% of the final desired value. The strength of the material is essentially constant up to 1,650°C, the maximum limit of the testing equipment. The average size of the powder is 0.4 micrometer and Carborundum is reported to have built a production facility for this material.[19]

Fans, spouts, feed screws, sprockets, and other high-temperature furnace componets are fabricated from recrystallized silicon carbide by Industrial Ceramics Div., Norton Co. Parts fabricated are said to feature high strength, lightweight, high thermal shock resistance, corrosion resistance, and high thermal conductivity. Applications at temperatures up to 1,550°C are predicted in heat-treating, annealing, powder metallurgy sintering, brazing, and forging.[20]

A solid-reductant, direct-reduction process can accommodate a wide variety of iron ores or pellets, reductants or fuels while turning out product of high quality. The Kimglor-Metor reduction unit consists of a vertical-shaft furnace surrounding six silicon carbide reactors that reduce the iron ore or pellets in the presence of a solid reductant at about 1,050°C. The system features low capital and operating costs and it is intended for small-producer markets.[21]

Cylindrical brushes made of nylon fibers impregnated with silicon carbide grain are being used to clean carbon and rust deposits from steel mesh conveyor belts used in glassware annealing lehrs.[22]

---

[1]Physical scientist, Division of Nonmetallic Minerals.

[2]Industrial Minerals. Italian Rutile. No. 117, June 1977, pp. 10, 12.

[3]Pentarich, P. Garnets in Tires Promoted as Stud Substitute. The Oregonian. Portland, Oreg. Nov. 8, 1977, Sec. A, p. 9.

[4]Mining Engineering. Industry Newswatch. V. 29, No. 6, June 1977, p. 21.

[5]Mining Magazine. Panorama. V. 136, No. 5, May 1977, p. 335.

[6]Mining Journal. Sierra Leone. Problems for Mining. V. 228, No. 7392, Apr. 22, 1977, p. 304.

[7]Mining Journal. Production, Kimberly Flooding. V. 289, No. 7403, July 8, 1977, p. 31.

[8]Industrial Diamond Review. News. December 1977, p. 26.

[9]U.S. Consulate, Lubumbashi, Zaire. State Department Airgram, A-5, Feb. 17, 1977, p. 10.

[10]Iron Age. Technology. V. 221, No. 23, June 6, 1977, pp. 67-70.

[11]Oil and Gas Journal. Diamond Composites Used in New Bits. V. 75, No. 16, Apr. 18, 1977, pp. 71-72.

[12]Wedlake, R. J. Diamond Synthesis. Industrial Diamond Review, June 1977, pp. 196-199.

[13]Holzapfel, W. B., W. Dieterick, and R. Keller. Diamond Anvil Techniques in High Pressure Physics. Industrial Diamond Review, June 1977, pp. 201-203.

[14]Industrial Diamond Review. A Novel Use of Diamond Micron Powders for Far Infra-red Filters. May 1977, p. 157.

[15]Bex, P. A. Syndite for the Machining of Titanium Alloys. Industrial Diamond Review, August 1977, pp. 276-277.

[16]Meiger, G. Health and Environmental Protection in a Diamond Polishing Factory. Industrial Diamond Review, October 1977, p. 348.

[17]Chemical Marketing Reporter. V. 211, No. 8, Feb. 21, 1977, p. 5.

[18]American Metal Market and Metalworking News. Silicon Carbide Plant in Illinois Being Built by Germany's ESK. V. 86, No. 7, Jan. 11, 1978, p. 8.

[19]Chemical and Engineering News. Technology, Carborundum Plans Silicon Carbide R&D Facility. V. 55, No. 41 Oct. 10, 1977, p. 36.

[20]Metal Progress. New Products. Ceramic Furnace Fixtures Handle High Temperatures. V. 111, No. 5, May 1977, p. 103.

[21]Chemical Engineering. Process Technology Sponge-Iron Process Combines Flexibility, Low Costs. V. 84, No. 9, Apr. 25, 1977, pp. 78-79.

[22]The Glass Industry. Belt Cleaning Brush Switch Improves Annealing Operation. V. 58, No. 10, October 1977, p. 31.

Table 13.—Crude artificial abrasives produced in the United States and Canada

(Thousand short tons and thousand dollars)

Kind	1973	1974	1975	1976	1977
Silicon carbide[1]	162	163	134	159	192
Value	$25,471	$33,872	$31,842	$45,953	$53,814
Aluminum oxide (abrasive grade)[1]	196	241	141	191	185
Value	$27,339	$40,906	$28,368	$43,356	$48,819
Aluminum zirconium oxide	22	25	17	20	20
Value	$6,223	$9,839	$8,506	$11,383	$11,281
Metallic abrasives[2]	266	301	236	250	243
Value	$49,775	$91,061	$72,864	$75,372	$72,740
Total	646	730	528	620	641
Value	$108,808	$175,678	$141,580	$176,064	$186,654

[1]Figures include material used for refractories and other nonabrasive purposes.
[2]Shipments for U.S. plants only.

Table 14.—Production, shipments, and annual capacities of metallic abrasives in the United States, by product

Year and product	Manufactured		Sold or used		Annual capacity[1] (short tons)
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	
1976:					
Chilled iron shot and grit	26,556	$5,433	34,025	$8,015	124,550
Annealed iron shot and grit	21,109	4,598	21,688	5,699	52,540
Steel shot and grit	188,717	48,125	193,300	61,054	320,670
Other[2]	798	451	851	604	2,140
Total	237,180	58,607	249,864	75,372	499,900
1977:					
Chilled iron shot and grit	22,533	4,481	28,934	6,238	86,600
Annealed iron shot and grit	7,372	1,244	8,308	1,940	25,600
Steel shot and grit	191,316	49,215	205,612	64,282	305,100
Other[2]	27	140	78	280	--
Total	221,248	55,080	242,932	72,740	417,300

[1]The total quantity of the various types of metallic abrasives that a plant could have produced during the year, working three 8-hour shifts per day, 7 days per week, allowing for usual interruptions, and assuming adequate fuel, labor, and transportation.
[2]Includes cut wire shot.

Aluminum

By John W. Stamper[1] and Christine M. Moore[2]

Domestic primary aluminum production was 7% above that in 1976. Demand as measured by net shipments of aluminum ingot and mill products to domestic industry increased 5% compared with the 1976 level. Exports decreased 15% from the 1976 level, and imports of crude and semicrude aluminum including scrap increased 12%. Domestic primary aluminum production capacity remained at 5.2 million tons in 1977.

World production of primary aluminum increased 9% during 1977, but world production capacity increased only 2.5%. Power interruptions caused production cutbacks during the year in the United States as well as in Ghana, the Netherlands, and Taiwan.

Legislation and Government Programs.— There were no shipments of aluminum from Government inventories during 1977. Stocks held at yearend totaled 1,687 short tons.

Table 1.—Salient aluminum statistics

(Thousand short tons and thousand dollars)

	1973	1974	1975	1976	1977
United States:					
Primary production	4,529	4,903	3,879	4,251	4,539
Value	$2,206,440	$3,005,640	$2,976,427	r$3,785,397	$4,683,949
Price: Ingot, average cents per pound	25.3	34.1	39.8	44.6	51.6
Secondary recovery	1,040	993	980	1,155	1,271
Exports (crude and semicrude)	561	524	440	484	411
Imports for consumption (crude and semicrude)	614	629	550	749	836
Aluminum industry shipments[1]	6,873	6,394	4,555	r5,956	6,315
Consumption, apparent	5,825	5,428	r3,907	r5,113	5,472
World: Production	13,364	14,516	r13,387	r13,771	15,049

rRevised.
[1]To domestic industry.

DOMESTIC PRODUCTION

Primary.—Primary aluminum production was 4,538,710 short tons, compared with 4,251,395 tons in 1976. Production capacity of domestic primary aluminum remained at 5,193,000 tons during 1977.

Operating levels at several smelters were reduced due to weather-caused electrical power shortages. Three potlines of the Aluminum Company of America (Alcoa) smelter at Evansville, Ind., were shut down when the coal distribution system froze. One potline at the Alcoa smelter at Alcoa, Tenn., was shut down due to a drought caused power reduction by the Tennessee Valley Authority. Reynolds Metals Co. shut down one 25,000-ton-per-year potline at its Jones Mills, Ark., smelter due to natural gas shortages.

A prolonged drought forced the Bonneville Power Administration to withdraw interruptible power used by its commercial customers, and Alcoa shut down a 23,000-ton-per-year potline at its Vancouver, Wash., smelter. The Anaconda Aluminum Co. facility at Columbia Falls, Mont., cut production by 27,000 tons per year. The Kaiser Aluminum & Chemical Corp. (Kaiser) primary smelter at Mead, Wash., stopped production in two potlines. Other primary aluminum smelters affected included Intalco Aluminum Corp. at Ferndale, Wash., and Martin Marietta Aluminum Inc., at The Dalles, Oreg., and Goldendale, Wash.

Alumax, Inc., owned 50% by AMAX, Inc., 45% by Mitsui & Co. Ltd., and 5% by Nippon Steel Corp., announced plans to build a 197,000-ton-per-year primary aluminum smelter in Berkley County, S.C. The $400 million facility would use alumina from Australia, and power would be supplied by the South Carolina Public Service Authority. Construction was scheduled to start in 1978.

Alumax began construction of a third 88,000-ton-per-year potline at the Eastalco Aluminum Co. smelter at Frederick, Md. The expansion, scheduled for completion in 1980, would increase capacity of the plant to 264,000 tons per year.

Anaconda Aluminum Co. announced plans to expand its Sebree, Ky., smelter by 60,000 tons per year to 180,000 tons per year by 1979.

Kaiser completed construction of a $32 million dry-scrubbing air pollution control facility at its Chalmette, La., primary aluminum smelter.

Reynolds announced plans to utilize alternate energy sources during the year at its 125,000-ton-per-year primary smelter at Jones Mills, Ark., in order to reduce the burden on electric utility companies during peak periods and to reduce the plant requirements for natural gas during periods of high consumer demand for natural gas. The plan was to be implemented by late 1978.

Alcan Aluminium Ltd., withdrew its offer to purchase the Revere Copper & Brass Inc. smelter and sheet mill facility at Scottsboro, Ala.

Under a jointly sponsored contract, Alcoa and the U.S. Energy Research and Development Administration (ERDA) agreed to build a $5 million pilot plant near Pittsburgh, Pa., to develop a process to produce an aluminum-silicon alloy by direct reduction. The process would use low-grade aluminum-bearing ores and would reduce energy consumption in the aluminum reduction process by using coal.

Secondary.—Aluminum recovery from purchased scrap, calculated from reports to the Bureau of Mines, was 1,271,226 tons, 10% higher than the quantity recovered in 1976. The Bureau estimated that full coverage of the industry would indicate a total consumption of purchased aluminum-based scrap of 1,854,000 tons in 1977. On this basis, aluminum recovery would total 1,494,000 tons, and total metallic recovery would be 1,605,000 tons.

Alcoa extended its contract to purchase aluminum scrap from the Ames, Iowa, municipal resource-recovery facility. Alcoa also announced plans to double the recovery capacity of its Alcoa, Tenn., aluminum can reclamation center. Completion was scheduled for 1979. Apex International Alloys, Inc., a subsidiary of Alumax, closed its Carson, Calif., secondary smelter. Kaiser began an aluminum can reclamation operation at Edison, N.J. Reynolds announced plans to expand the capacity of its Sheffield, Ala., secondary smelter to 100,000 tons per year.

Table 2.—Consumption of and recovery from purchased new and old aluminum scrap in 1977[1]

(Short tons)

Class	Consumption	Calculated recovery	
		Aluminum	Metallic
Secondary smelters	841,258	665,505	717,423
Primary producers	425,733	366,965	393,168
Fabricators	137,720	120,344	128,638
Foundries	105,387	90,545	96,985
Chemical producers	58,117	25,780	26,678
Total	1,568,215	1,269,139	1,362,892
Estimated full industry coverage	1,854,000	1,494,000	1,605,000

[1]Excludes recovery from other than aluminum-base scrap.

Table 3.—Aluminum recovered from purchased scrap processed in the United States, by kind of scrap and form of recovery

(Short tons)

Kind of scrap	1976	1977	Form of recovery	1976	1977
New scrap:			Unalloyed	1,685	1,743
Aluminum-base	[1]813,907	[2]857,651	Aluminum alloys	1,080,300	1,218,100
Copper-base	83	84	In brass and bronze	77	90
Zinc-base	238	260	In zinc-base alloys	1,308	1,389
Magnesium-base	140	249	In magnesium alloys	446	567
			Dissipative forms[3]	71,202	49,337
Total	814,368	858,244	Total	1,155,018	1,271,226
Old scrap:					
Aluminum-base	[1]339,209	[2]411,488			
Copper-base	65	47			
Zinc-base	1,070	1,129			
Magnesium-base	306	318			
Total	340,650	412,982			
Grand total	1,155,018	1,271,226			

[1]Aluminum alloys recovered from aluminum-base scrap in 1976, including all constituents, were 868,301 tons from new scrap and 370,113 tons from old scrap and sweated pig, a total of 1,238,414 tons.

[2]Aluminum alloys recovered from aluminum-base scrap in 1977, including all constituents, were 915,205 tons from new scrap and 447,687 tons from old scrap and sweated pig, a total of 1,362,892 tons.

[3]Includes recovery in deoxidizing ingot assuming 85% aluminum content in such ingot.

Table 4.—Stocks, receipts, and consumption of purchased new and old aluminum scrap and sweated pig in the United States in 1977[1]

(Short tons)

Class of consumer and type of scrap	Stocks Jan. 1[r]	Net receipts[2]	Consumption	Stocks Dec. 31
Secondary smelters:				
New scrap:				
Solids and clippings	14,626	274,347	266,810	22,163
Borings and turnings	7,198	141,479	139,165	9,512
Foil	142	1,895	1,604	433
Dross and skimmings	9,954	127,687	128,766	8,875
Other	868	22,933	23,502	299
Total new scrap	32,788	568,341	559,847	41,282
Old scrap:				
Castings, sheet, clippings	11,185	135,875	135,777	11,283
Aluminum cans	509	18,249	15,925	2,833
Other[3]	4,363	32,643	32,871	4,135
Total old scrap	16,057	186,767	184,573	18,251
Sweated pig	29,539	86,110	96,838	18,811
Total all classes	78,384	841,218	841,258	78,344
Primary producers, foundries, fabricators, chemical plants:				
New scrap:				
Solids and clippings	45,467	379,877	373,481	51,863
Borings and turnings	214	17,385	17,202	397
Foil	1,167	6,032	5,653	1,546
Dross and skimmings	530	47,906	47,915	521
Other	1,595	68,120	66,909	2,806
Total new scrap	48,973	519,320	511,160	57,133
Old scrap:				
Castings, sheet, clippings	1,533	58,140	58,322	1,351
Aluminum cans	5,544	122,277	116,737	11,084
Other[3]	385	24,013	22,066	2,332
Total old scrap	7,462	204,430	197,125	14,767
Sweated pig	1,232	18,268	18,672	828
Total all classes	57,667	742,018	726,957	72,728
Total of all scrap consumed:				
New scrap:				
Solids and clippings	60,093	654,224	640,291	74,026
Borings and turnings	7,412	158,864	156,367	9,909
Foil	1,309	7,927	7,257	1,979
Dross and skimmings	10,484	175,593	176,681	9,396
Other	2,463	91,053	90,411	3,105
Total new scrap	81,761	1,087,661	1,071,007	98,415
Old scrap:				
Castings, sheet, clippings	12,718	194,015	194,099	12,634
Aluminum-copper radiators	3,881	18,278	18,998	3,161
Aluminum cans	6,053	140,526	132,662	13,917
Other	867	38,378	35,939	3,306
Total old scrap	23,519	391,197	381,698	33,018
Sweated pig	30,771	104,378	115,510	19,639
Total all classes	136,051	1,583,236	1,568,215	151,072

[r]Revised.
[1]Includes imported scrap. According to the reporting companies 8.46% of total receipts of aluminum-base scrap, or 133,875 short tons, was received on toll arrangements.
[2]Includes inventory adjustment.
[3]Includes data on aluminum-copper radiators.

Table 5.—Production and shipments of secondary aluminum alloys by independent smelters

(Short tons)

	1976		1977	
	Production	Net shipments	Production	Net shipments
Die-cast alloys:				
13% Si, 360, etc. (0.6% Cu, maximum)	73,323	71,535	82,325	83,580
380 and variations	375,383	372,804	413,364	416,661
Sand and permanent mold:				
95/5 Al-Si, 356, etc. (0.6% Cu, maximum)	20,045	20,202	24,487	24,306
No. 12 and variations	8,179	8,219	W	W
No. 319 and variations	44,053	43,642	48,674	49,761
F-132 alloy and variations	15,163	15,047	15,771	15,778
Al-Mg alloys	1,260	1,154	1,355	1,249
Al-Zn alloys	14,675	15,022	18,328	17,671
Al-Si alloys (0.6% to 2.0% Cu)	4,272	4,129	4,548	4,748
Al-Cu alloys (1.5% Si, maximum)	3,970	3,830	3,050	3,315
Al-Si-Cu-Ni alloys	W	W	3,573	3,673
Other	2,893	2,899	3,684	3,616
Wrought alloys: Extrusion billets	59,254	59,245	87,979	87,500
Destructive and other uses: Steel deoxidation:				
Grades 1, 2, 3, and 4	29,486	28,450	27,714	28,524
Miscellaneous:				
Pure (97.0% Al)	1,685	2,250	W	W
Aluminum-base hardeners	2,763	2,952	2,548	2,574
Other[1]	20,675	20,213	28,933	29,309
Total	677,079	671,593	766,333	772,265
Less consumption of materials other than scrap:				
Primary aluminum	23,140	--	26,403	--
Primary silicon	38,243	--	40,239	--
Other	3,685	--	4,712	--
Net metallic recovery from aluminum scrap and sweated pig consumed in production of secondary aluminum ingot[2]	612,011	--	694,979	--

W Withheld to avoid disclosing company proprietary data; included in "Miscellaneous," and "Other categories."
[1]Includes data withheld (other die-cast alloys, "No. 12 and variations," "Other sand and permanent mold," " Pure (97.0% Al)," "Other miscellaneous").
[2]No allowance made for melt-loss of primary aluminum and alloying ingredients.

CONSUMPTION

The Bureau of Mines estimate of apparent aluminum consumption in end products such as automobiles, cans, air conditioning equipment, and residential siding, as shown in table 6, increased 7% from 5,113,000 tons (revised) in 1976 to 5,472,000 tons in 1977.

Domestic consumption as measured by net shipments of aluminum ingot and mill products to domestic industry was 6% higher in 1977 than in 1976. Shipments to the building and construction industry, the largest user of aluminum, increased 5% to 1,539,000 tons. Transportation applications were the second largest use of aluminum, increasing 18% from the level in 1976 to 1,448,000 tons. Shipments to the containers and packaging industry increased 8%, and shipments to electrical markets increased 2% compared with those of 1976.

The average quantity of aluminum used in 1977 model automobiles was about 100 pounds per unit compared with 87 pounds per unit in 1976. Estimates indicated that approximately 114 pounds would be required per unit in 1978 models.

It was estimated that approximately 750 tons of aluminum was used in solar energy collector plates in 1977 and that aluminum consumption by this industry could reach 10,000 tons in 1980.

Table 6.—Apparent aluminum supply and consumption in the United States

(Thousand short tons)

	1973	1974	1975	1976	1977
Primary production	4,529	4,903	3,879	4,251	4,539
Change in stocks:[1]					
Aluminum industry	+248	-395	-421	r+179	-23
Government	+730	+511	+2	+9	--
Imports	614	629	550	749	836
Secondary recovery:[2]					
New scrap	977	978	r899	1,062	1,074
Old scrap	265	304	r337	409	531
Total supply	7,363	6,930	r5,246	r6,659	6,957
Less total exports	561	524	440	484	411
Apparent aluminum supply available for domestic manufacturing	6,802	6,406	r4,806	r6,175	6,546
Apparent consumption [3]	5,825	5,428	r3,907	r5,113	5,472

rRevised.

[1]Positive figure indicates a decrease in stocks; negative figure indicates an increase in stocks.

[2]Metallic recovery from purchased, tolled, or imported new and old aluminum scrap expanded for full industry coverage.

[3]Apparent aluminum supply available for domestic manufacturing less recovery from purchased new scrap (a measure of consumption in manufactured end products).

Table 7.—Distribution of end use shipments of aluminum products

Industry	1976 Quantity (thousand short tons)	1976 Percent of total	1977 Quantity (thousand short tons)	1977 Percent of total
Building and construction	r1,470	r23.0	1,539	23.1
Transportation	r1,230	r19.3	1,448	21.7
Containers and packaging	1,285	20.2	1,389	20.8
Electrical	r656	r10.3	668	10.0
Consumer durables	518	8.1	531	7.9
Machinery and equipment	452	7.1	460	6.9
Other markets	306	4.8	298	4.5
Statistical adjustment	r+39	r.6	-18	-.3
Total to domestic users	r5,956	93.4	6,315	94.6
Exports	r418	6.6	363	5.4
Total	6,374	100.0	6,678	100.0

rRevised.

Source: The Aluminum Association, Inc.

Table 8.—Net shipments of aluminum wrought[1] and cast products by producers

(Short tons)

	1976	1977
Wrought products:		
Sheet, plate, foil	3,178,127	3,423,149
Rolled and continuous-cast rod and bar; wire	492,652	467,623
Extruded rod, bar, pipe, tube, shapes; drawn and welded tubing and rolled structural shapes	1,070,683	1,197,998
Powder, flake, paste	66,187	60,561
Forgings (including impacts)	50,108	60,644
Total	4,857,757	5,209,975
Castings:		
Sand	109,824	113,373
Permanent mold	188,678	219,633
Die	605,240	652,292
Other	18,848	19,178
Total	922,590	1,004,476
Grand total	5,780,347	6,214,451

[1]Net shipments derived by subtracting the sum of producers' domestic receipts of each mill shape from the domestic industry's gross shipment of that shape.

Source: U.S. Department of Commerce.

Table 9.—Distribution of wrought products

(Percent)

	1976	1977
Sheet, plate, foil:		
Non-heat-treatable	54.4	53.8
Heat-treatable	3.1	4.1
Foil	7.9	7.7
Rolled and continuous-cast rod and bar; wire:		
Rod, bar, wire	3.7	2.3
Cable and insulated wire	6.4	6.7
Extruded products:		
Rod and bar	.7	.8
Pipe and tubing	2.0	1.8
Shapes[1]	17.4	18.3
Tubing:		
Drawn	1.0	1.0
Welded, non-heat-treatable[2]	1.0	1.1
Powder, flake, paste	1.4	1.2
Forgings (including impacts)	1.0	1.2
Total	100.0	100.0

[1]Includes a small amount of rolled structural shapes.
[2]Includes a small amount of heat-treatable welded tube.

Source: U.S. Department of Commerce.

STOCKS

Metal inventories held at reduction and other processing plants as reported by the U.S. Department of Commerce, Bureau of Domestic Commerce (BDC) increased slightly from 2,815,324 short tons at yearend 1976 to 2,842,718 tons at yearend 1977.

PRICES

The price of 99.5% pure aluminum ingot as quoted by the American Metal Market was increased from 48.0 cents per pound at the beginning of the year to 51.0 cents per pound on March 28. On July 5, the price quoted was increased 2.0 cents per pound to 53.0 cents per pound where it remained at yearend.

The range of prices of smelters' secondary aluminum ingot as quoted in the American Metal Market rose from 47.0 to 57.0 cents per pound at the beginning of the year to 50.0 to 64.0 cents per pound at yearend. The price of secondary scrap increased from a range of 22.5 to 30.0 cents per pound on January 2 to 27.5 to 36.0 cents per pound at yearend.

FOREIGN TRADE

Exports of crude and semicrude aluminum including scrap decreased 15% during 1977. Major recipients of ingot shipments were Canada (22%) and Venezuela (10%). Japan imported 52% of U.S. scrap shipments, and Canada received 18%. Exports of plates, sheets, and bars were received by Canada (46%) and the United Kingdom (13%).

Imports of crude and semicrude aluminum including scrap increased 12% from 748,624 tons in 1976 to 835,554 tons in 1977. Canada was the major source of metal and alloy imports, supplying 75%. Imports of metal from Ghana were 16% of the total. Imports of scrap increased 5% from those of the previous year, and principal sources were Canada (47%) and the U.S.S.R. (36%).

Table 10.—U.S. exports of aluminum, by class

Class	1976		1977	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Crude and semicrude:				
Ingots, slabs, crude	152,366	$118,644	97,771	$94,498
Scrap	108,958	63,245	101,663	64,060
Plates, sheets, bars, etc	203,843	261,759	190,118	284,199
Castings and forgings	5,611	21,232	6,895	27,432
Semifabricated forms, n.e.c	12,937	31,016	14,509	33,840
Total	483,715	495,896	410,956	504,029
Manufactures:				
Foil and leaf	14,785	31,921	13,174	29,475
Powders and flakes	8,440	11,445	3,615	4,883
Wire and cable	26,419	32,576	23,279	32,695
Total	49,644	75,942	40,068	67,053
Grand total	533,359	571,838	451,024	571,082

Table 11.—U.S. exports of aluminum, by class and country

Country	1976						1977					
	Ingots, slabs, crude		Plates, sheets, bars, etc.[1]		Scrap		Ingots, slabs, crude		Plates, sheets, bars, etc.[1]		Scrap	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Argentina	4,636	$3,713	492	$2,008	--	--	8	$5	506	$2,994	49	$42
Australia	35	82	1,372	2,429	--	--	45	86	1,587	3,323	--	--
Belgium-Luxembourg	280	236	401	993	1,612	$651	9	15	1,233	2,812	679	439
Brazil	2,215	2,144	3,772	6,547	3,390	1,856	5,326	5,706	2,879	5,373	8,072	4,664
Canada	19,864	15,254	102,150	127,611	9,750	4,524	21,560	18,211	97,155	145,583	17,791	11,239
Chile	1,283	1,260	135	567	13	16	1,374	1,328	--	--	51	61
China, People's Republic of	41,170	25,641	255	811	--	--	5,523	5,311	8	19	--	--
Colombia	215	247	516	795	--	--	625	788	498	812	--	--
Denmark	49	121	4,857	6,527	20	6	11	31	3,417	4,901	--	--
El Salvador	1,921	1,836	582	649	--	--	1,027	1,131	159	259	--	--
France	9,536	7,701	4,577	8,111	56	29	4,838	4,651	4,106	7,908	--	--
Germany, Federal Republic of	909	898	9,021	13,987	11,964	5,650	2,527	2,470	7,903	15,198	9,599	5,388
Ghana	24	44	187	320	--	--	7,653	5,637	198	306	--	--
Guinea	--	--	2,000	2,609	--	--	--	--	1,068	1,572	--	--
India	4	8	6	61	--	--	--	--	26	64	74	67
Iran	20	12	776	1,487	--	--	552	546	2,012	3,329	--	--
Ireland	--	--	890	1,594	--	--	--	--	823	1,567	--	--
Israel	156	205	3,003	5,752	--	--	66	123	1,486	3,396	--	--
Italy	237	524	4,013	8,550	3,816	1,789	140	315	7,603	12,941	1,758	989
Jamaica	291	117	466	714	--	--	211	113	1,021	1,554	--	--
Japan	22,024	17,481	4,684	9,479	65,664	42,399	6,149	6,144	2,075	4,976	52,600	36,678
Korea, Republic of	1,262	1,188	796	1,138	1,750	945	1,789	1,697	1,062	2,199	1,315	691
Mexico	17,813	14,861	27,583	32,038	348	86	9,193	9,229	15,369	23,058	416	82
Netherlands	73	169	4,188	7,007	316	106	164	379	6,738	12,487	510	335
Nigeria	--	--	36	197	--	--	--	--	395	717	--	--
Norway	16	31	1,504	1,243	--	--	20	58	102	335	--	--
Pakistan	--	--	46	88	3,596	2,684	--	--	10	14	773	576
Panama	893	765	99	162	--	--	516	529	158	328	--	--
Peru	77	69	19	81	510	390	285	318	25	98	545	546
Philippines	6,244	5,544	204	570	52	36	6,849	7,112	169	595	90	94
Saudi Arabia	3	2	1,122	2,452	--	--	49	39	1,455	2,604	--	--
Singapore	166	170	361	699	--	--	120	137	769	1,680	7	2
South Africa, Republic of	43	35	3,871	5,733	58	28	22	61	3,284	5,254	113	70
Spain	18	38	949	1,700	1,452	500	20	26	857	1,715	2,306	776
Sweden	13	19	577	1,292	42	26	2,996	2,965	469	1,318	--	--
Switzerland	1,680	1,466	74	323	--	--	987	1,051	290	690	8	3
Taiwan	13,354	10,630	947	1,700	3,485	895	3,847	3,748	517	1,151	4,613	1,105
Thailand	473	436	120	286	60	20	15	37	275	620	118	71
United Kingdom	915	1,004	26,898	39,753	384	207	558	1,111	27,949	42,578	59	53
Venezuela	2,321	2,148	3,955	6,152	1	1	10,194	9,868	6,975	10,520	1	1
Other	r2,133	r2,545	r4,887	r9,792	619	401	2,503	3,522	8,891	18,622	116	88
Total	152,366	118,644	222,391	314,007	108,958	63,245	97,771	94,498	211,522	345,470	101,663	64,060

[1] Includes plates, sheets, bars, extrusions, forgings, and unclassified semifabricated forms.

Table 12.—U.S. imports for consumption of aluminum, by class

Class	1976		1977	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Crude and semicrude:				
Metals and alloys, crude	575,350	$439,570	670,200	$631,601
Circles and disks	8,475	10,166	7,681	10,994
Plates, sheets, etc., n.e.c	67,042	69,884	57,697	77,205
Rods and bars	11,563	14,563	9,586	13,644
Pipes, tubes, etc	480	1,699	495	1,893
Scrap	85,714	46,166	89,895	63,168
Total	748,624	582,048	835,554	798,505
Manufactures:				
Foil	4,924	14,395	4,882	16,432
Leaf	([1])	114	([1])	109
Flakes and powders	285	501	707	860
Wire	928	1,180	1,249	1,706
Total	6,137	16,190	6,838	19,107
Grand total	754,761	598,238	842,392	817,612

[1]1976—Aluminum leaf not over 30.25 square inches in area, 1,401,194 leaves, and aluminum leaf over 30.25 square inches in area, 42,803,390 square inches; 1977 aluminum leaf not over 30.25 square inches in area was 1,121,786 leaves and aluminum leaf over 30.25 square inches in area was 76,728,151 square inches.

Table 13.—U.S. imports for consumption of aluminum, by class and country

Country	1976						1977					
	Metals and alloys, crude		Plates, sheets, bars, etc.[1]		Scrap		Metals and alloys, crude		Plates, sheets, bars, etc.[1]		Scrap	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Austria	--	--	2,350	$2,759	--	--	--	--	3,176	$4,399	--	--
Bahrain	5,318	$3,946	--	--	--	--	9,279	$7,910	--	--	--	--
Belgium-Luxembourg	953	658	25,055	26,140	82	$50	20	31	24,126	31,143	652	$495
Canada	380,995	292,835	3,607	5,843	39,896	22,269	500,222	467,795	8,274	12,822	42,562	26,902
France	6,620	5,154	9,036	9,878	901	585	5,773	4,464	5,274	6,909	552	510
Germany, Federal Republic of	418	806	1,272	1,844	2,850	1,499	1,436	2,382	1,229	2,575	688	515
Ghana	89,806	69,691	(2)	(2)	--	--	105,637	104,078	--	--	--	--
Hong Kong	--	--	1,039	1,108	--	--	--	--	842	1,075	--	--
India	2,049	1,300	26	28	(2)	1	55	37	16	22	--	--
Italy	--	--	3,653	3,880	60	48	139	118	3,478	11,255	--	--
Jamaica	--	--	--	--	601	369	--	--	(2)	(2)	628	450
Japan	13,463	9,720	16,321	17,703	49	2	14	63	10,073	14,380	46	21
Mexico	312	142	96	221	1,322	494	65	36	373	599	1,581	692
Netherlands	19	15	1,432	2,648	--	--	2,827	2,878	3,010	6,587	7	11
Norway	15,503	13,000	4,800	4,224	377	305	12,473	12,006	1,503	1,545	7	3
Poland	--	--	--	--	1,542	860	--	--	17	22	896	683
Romania	797	484	964	896	--	--	--	--	1,040	1,152	--	--
South Africa, Republic of	3,353	2,166	--	--	26	14	1,328	1,248	--	--	--	--
Spain	4,228	2,885	4,193	4,053	552	343	--	--	2,464	2,506	--	--
Surinam	23,083	17,333	--	--	--	--	13,656	11,884	--	--	--	--
Sweden	1,706	1,110	180	336	--	--	--	--	300	540	579	504
Switzerland	1,249	1,040	74	157	364	146	1,122	1,734	18	57	--	--
Taiwan	--	--	301	290	--	--	5,511	5,104	118	121	1	5
U.S.S.R	195	132	--	--	32,401	16,392	--	--	--	--	32,537	25,069
United Kingdom	9,126	5,881	1,149	1,229	3,396	2,081	10,397	9,660	84	158	6,364	5,390
Venezuela	--	--	--	--	567	297	--	--	1,799	1,736	559	275
Yugoslavia	15,382	11,169	11,499	12,485	--	--	134	96	7,690	10,355	1,378	1,067
Other	780	603	513	590	728	411	112	77	555	778	858	576
Total	575,350	439,570	87,560	96,312	85,714	46,166	670,200	631,601	75,459	110,736	89,895	63,168

[1]Includes circles, disks, bars, plates, sheets, pipes, etc.
[2]Less than 1/2 unit.

WORLD REVIEW

World production of primary aluminum in 1977 increased 9% from the 1976 level. Stocks of primary aluminum held by members of the International Primary Aluminum Institute (IPAI), which represents the bulk of inventories held outside the centrally controlled economies, increased 8% from yearend 1976.

World primary aluminum production capacity increased 2.5% from the 1976 level to 17.8 million tons. Significant capacity expansions were completed in Argentina, Australia, the People's Republic of China, the U.S.S.R., India, Turkey, and Venezuela. Plans for additional capacity in 15 countries were being considered during the year.

Argentina.—Aluminio Argentino S.A. (Aluar) increased the capacity of its Puerto Madryn primary aluminum smelter to 154,000 tons per year.

Australia.—Alcan Australia Ltd. announced plans to expand its Kurri-Kurri smelter by 25,000 tons per year to 75,000 tons per year. The new potline was scheduled to come onstream in 1979.

Comalco Aluminium (Bell Bay) Ltd. commissioned half of the fourth potline at its Bell Bay, Tasmania, smelter. The capacity of the facility at yearend was 123,000 tons per year.

Brazil.—Cia. Vale do Rio Doce (CVRD) continued planning for an 88,000-ton-per-year primary aluminum smelter at Santa Cruz, near Rio de Janeiro. Construction of the $270 million project was scheduled to begin in early 1978. Alumina would initially be supplied from Australia and the Eurallumina S.p.A. refinery in Italy. Reynolds Metals Co. was expected to supply technology for the facility.

Nippon Amazon Aluminium Co. (NALCO), a consortium of 32 Japanese firms, was formed to help finance the Alunorte, S.A., 800,000-ton-per-year alumina refinery and the Albras S.A. 320,000-ton-per-year primary aluminum smelter at Belem. Mitsui Aluminium Industry Co. reportedly would supply technical assistance for the smelter, which was scheduled to begin production in 1982.

Pechiney Ugine Kuhlmann reportedly would provide technical assistance for an 88,000-ton-per-year primary aluminum reduction facility at Pernambuco. Cost of the smelter was estimated at $240 million.

Companhia Brasileira de Aluminio (CBA) announced that production at its Sorocaba aluminum smelter would increase to 88,000 tons per year in 1978 when a $120 million expansion was completed. The facility was scheduled to be expanded to 132,000 tons per year by 1982.

Canada.—Alcan Aluminium Ltd. announced plans to build a 63,000-ton-per-year primary aluminum smelter at La Baie, Quebec. The $200 million facility was scheduled to come onstream in 1981. Alumina would be supplied by Alcan's plant at Arvida, Quebec. Two potlines, each with a capacity of 63,000 tons per year, may be added later.

Kaiser reportedly began studies for a primary smelter at Whitehorse, Yukon Territory. The project was contingent on the development of additional hydroelectric facilities. The 180,000-ton-per-year smelter was tentatively scheduled to start production in 1985.

Costa Rica.—The Government of Costa Rica sought participation by several Japanese and United States firms in an integrated aluminum project. Reportedly included in the plans were a 600,000-kilowatt hydroelectric power station, a 660,000-ton-per-year alumina refinery, and a 330,000-ton-per-year aluminum smelter.

Dubai.—Dubai Aluminium Co. (Dubal) signed an agreement with Alcoa of Australia Ltd. to purchase 200,000 tons of alumina per year over a 10-year period. Dubal planned to build a 150,000-ton-per-year primary smelter at Jebel Ali, which was scheduled to come onstream in 1979. Expansion to 200,000 tons per year in the early 1980's was planned. Nissho-Iwai Co., Ltd. withdrew from the project, and Alcan reportedly was interested in becoming a partner.

Egypt.—An agreement was reached for the U.S.S.R. to supply alumina to the Nag Hamadi primary aluminum smelter. Expansion of the smelter to 166,000 tons per year was planned.

France.—Pechiney Ugine Kuhlmann announced plans to expand the production capacity of its Lannemezan primary aluminum smelter to 91,000 tons per year and to expand the St. Jean de Maurienne facility to 120,000 tons per year by early 1981.

Germany, Federal Republic of.— Plans to expand its Innwerke, Toging, smelter to 78,000 tons per year were announced by Vereinigte Aluminium-Werke A.G. (VAW).

The $85 million project was scheduled to be completed in 1981.

Ghana.—A power failure shut down three of the Volta Aluminium Co.'s five potlines at its 220,000-ton-per-year primary aluminum smelter at Tema.

India.—The Government-owned Bharat Aluminium Co. increased the production capacity of its Korba primary smelter to 83,000 tons per year. Hindustan Aluminium Co., owned by the Indian Government (73%) and Kaiser (27%), increased the capacity of its Renukoot facility to 110,000 tons per year.

Iran.—Iranian Aluminium Co. continued plans to expand its 55,000-ton-per-year primary aluminum smelter at Arak to 132,000 tons per year by 1980. Alcan Aluminium Ltd. undertook a feasibility study for an aluminum smelter to be located at Qeshm or Bandar Abbas. The 300,000-ton-per-year facility reportedly would use alumina from India and natural gas as a power source.

Italy.—The Italian aluminum industry reorganized into two large groups, one group would handle primary aluminum production and the other would handle the manufacture of semifinished products.

Japan.—Stocks of primary aluminum held by producers increased from about 103,000 tons at yearend 1976 to 318,000 tons at yearend 1977. The production rate at yearend was 71.3% of the rated capacity of 1,616,000 tons per year.

Sumikei Aluminium Co. began production at its Sakata primary smelter. Primary aluminum production was scheduled to reach 90,000 tons per year by 1979. The firm is a subsidiary of Sumitomo Light Metal Industries Ltd.

Nippon Light Metal Co. Ltd. scrapped 132 pots at its Kambara primary smelter, reducing capacity by 8,000 tons per year to 116,000 tons per year.

Libya.—Plans continued for a $900 million primary aluminum smelter in Libya to be built with Yugoslav assistance. Energoinvest, Jadral, and Progress-Invest were reportedly considering the project, which would include a thermal powerplant and a petroleum coke facility. Alumina would be supplied by Yugoslavia.

Malaysia.—Reynolds Metals agreed to study two proposals for primary aluminum smelters. In Sarawak State, plans reportedly included a 110,000-ton-per-year smelter and hydroelectric facilities at Bintulu. The $300 million smelter would use alumina from Western Australia. Sabah State invited Reynolds to undertake a feasibility study for a primary smelter and a hydroelectric plant at Labuan.

Netherlands.—An explosion and fire at the Holland Aluminium N.V. primary aluminum smelter at Delfzijl shut down the 196,000-ton-per-year facility for 6 weeks.

New Zealand.—New Zealand Aluminium Smelters Ltd. agreed to pay a 400% price increase for power. The 165,000-ton-per-year Bluff smelter was owned 50% by Comalco Ltd., 25% by Showa Denko K.K., and 25% by Sumitomo Chemical Co. Ltd.

Norway.—A/S Ardal og Sunndal Verk (ASV) completed modernization of its Ardal primary aluminum facility, increasing the capacity by 15,000 tons per year to 184,000 tons per year.

Lista Aluminiumverk A/S announced plans to add a fourth 25,000-ton-per-year potline at its Lista, Farsund, facility. Government approval was pending for additional hydroelectric power. The plant is owned by Alcoa (50%) and Elkem Spigerverket A/S (50%).

Norsk Hydro A/S applied to the Government for additional power in order to increase the capacity of its Karmoy smelter to 185,000 tons per year. Construction of the $90 million expansion was scheduled to start in 1978 with production startup scheduled for 1980.

Taiwan.—A typhoon caused power interruptions that severely damaged the Taiwan Aluminium Corp.'s older smelter at Kaohsiung. Production startup was slowed at the new 60,000-ton-per-year smelter.

Trinidad.—The Government of Trinidad announced plans to build a 75,000-ton-per-year aluminum smelter without the participation of Guyana and Jamaica.

Turkey.—The capacity of the primary aluminum smelter at Seydisehir was reportedly increased to 96,000 tons per year.

Venezuela.—Aluminio del Caroni S.A. (Alcasa) completed the expansion of its smelter at Ciudad Guayana to 132,000 tons per year.

New Venalum, comprised of Corporacion Venezolana de Guayana (80%), and a Japanese consortium consisting of Showa Denko K.K., Sumitomo Metal Mining Co., Mitsubishi Metal Corp., Marubeni Corp., and Kobe Steel Ltd., agreed to distribute the production. The Japanese consortium would receive up to 165,000 tons of the annual production of 310,000 tons when the project is completed. Startup of the first 77,000-ton-per-year potline was scheduled for early 1978.

Yugoslavia.—Startup of Energoinvest's primary aluminum smelter at Mostar in Bosnia Hercegovina was scheduled for 1980. The 92,000-ton-per-year facility, which was designed by Pechiney Ugine Kuhlmann, would use alumina produced at the site.

Plans were announced to expand the Sibenik smelter to 110,000 tons per year by 1981. The German Democratic Republic reportedly agreed to finance the project.

Table 14.—Aluminum: World production,[1] by country

(Thousand short tons)

Country	1975	1976	1977[p]
North America:			
Canada	978	698	1,060
Mexico	44	47	47
United States	3,879	4,251	4,539
South America:			
Argentina	[r]27	48	[e]45
Brazil	134	153	[e]185
Surinam	[r]46	49	[2]64
Venezuela	64	51	[e]52
Europe:			
Austria	98	98	101
Czechoslovakia	48	44	44
France	422	424	429
German Democratic Republic[e]	65	65	65
Germany, Federal Republic of	747	768	818
Greece	[r]150	148	[e]140
Hungary	77	78	79
Iceland	68	72	82
Italy	210	228	[e]287
Netherlands	288	282	266
Norway	656	658	693
Poland[3]	113	114	[e]115
Romania[4]	225	228	230
Spain	[r]232	232	233
Sweden	85	91	90
Switzerland	87	86	88
U.S.S.R.[e]	1,690	1,760	1,810
United Kingdom	340	369	385
Yugoslavia	[r]183	218	218
Africa:			
Cameroon	57	64	61
Egypt	2	65	98
Ghana	158	162	169
South Africa, Republic of	84	86	86
Asia:			
Bahrain	128	135	134
China, People's Republic of[e]	[r]220	220	280
India	184	234	203
Iran	56	34	23
Japan[5]	1,117	1,013	1,310
Korea, Republic of	20	19	19
Taiwan	31	28	33
Turkey	18	41	35
Oceania:			
Australia	236	256	273
New Zealand	120	154	160
Total	[r]13,387	13,771	15,049

[e]Estimate. [p]Preliminary. [r]Revised. NA Not available.
[1]Output of primary unalloyed ingot unless otherwise specified.
[2]Exports.
[3]Includes secondary unalloyed ingot.
[4]Includes primary alloyed ingot.
[5]Includes production of superpurity aluminum (99.99% Al), apparently included in the reported total unalloyed ingot production, as follows, in short tons: 1975—3,274; 1976—4,251; 1977—NA.

Table 15.—Aluminum: World capacity, by country[1]

(Thousand short tons)

Country	1975	1976	1977
North America:			
Canada	1,175	1,175	1,175
Mexico	50	50	50
United States	5,021	5,193	5,193
South America:			
Argentina	40	66	154
Brazil	140	187	198
Surinam	73	73	73
Venezuela	55	55	132
Europe:			
Austria	102	101	101
Czechoslovakia	72	72	72
France	448	452	452
German Democratic Republic	88	94	94
Germany, Federal Republic of	832	841	841
Greece	160	160	160
Hungary	69	69	69
Iceland	84	84	84
Italy	340	321	321
Netherlands	293	293	293
Norway	733	768	780
Poland	122	122	122
Romania	132	132	132
Spain	238	240	240
Sweden	95	94	94
Switzerland	105	104	104
U.S.S.R	2,140	2,555	2,695
United Kingdom	399	403	403
Yugoslavia	221	199	199
Africa:			
Cameroon	61	61	61
Egypt	110	110	110
Ghana	169	220	220
South Africa, Republic of	88	88	88
Asia:			
Bahrain	132	132	132
China, People's Republic of	270	270	300
India	289	330	363
Iran	55	55	55
Japan	1,492	1,627	1,616
Korea, Republic of	20	20	20
Taiwan	42	r77	77
Turkey	66	66	96
Oceania:			
Australia	254	256	274
New Zealand	123	165	165
Total	16,398	r17,380	17,808

rRevised.

[1]Detailed information on the individual aluminum reduction plants is available in a 2-part report which can be obtained from Chief, Division of Finance, Bureau of Mines, Bldg. 20, Federal Center, Denver, Colo. 80225. Part One of "Primary Alumimum Plants, Worldwide," which costs $9.70 details location, ownership, and production capacity for 1976-83, and sources of energy and aluminum raw materials for foreign and domestic primary aluminum plants, including those in centrally planned economies. Part Two, which costs $2.55, summarizes production capacities for 1976-83 by smelter and country.

TECHNOLOGY

Developmental research on a new process that promises to reduce the amount of energy needed to produce aluminum was begun under a cost-sharing agreement between the Department of Energy (DOE) and Alcoa. The DOE share under the agreement was expected to be approximately $3 million, with Alcoa contributing about $2 million. The agreement called for constructing a small-scale pilot unit to explore the feasibility of making aluminum-silicon alloy from ores by a direct reduction process similar to that used in blast furnaces in the iron and steel industry. This process does not require the use of electricity in contrast to the conventional (Hall-Heroult) aluminum-making method.

According to DOE, ores containing aluminum mixed with a coal-derived fuel are heated in a closed furnace, producing ferrosilicon (used in the steel industry), and an aluminum-silicon alloy. Carbon monoxide (CO) is a byproduct. DOE indicated that successful application in commercial-scale production depended upon experience gained from the unit and subsequent units to be built at the Alcoa Laboratories near Pittsburgh. The project was expected to take 5 to 7 years to complete. If the process appears commercially feasible, it would be made available to others.

Demand for aluminum-silicon alloy by the auto industry is expected to grow because this material offers an important means of reducing overall weight, and thus, fuel consumption of passenger cars and trucks. A commercially-pure form of aluminum can also be obtained from the aluminum-silicon alloy, according to DOE, using technology being developed by Alcoa as a part of the agreement.

The byproduct, carbon monoxide, reportedly is an important part of the energy economics of the new process because it has value as a fuel or as a chemical feedstock.

In addition to the potential energy savings, the new process is based on coal, an abundant and domestically available fuel source; a high proportion of lower-grade aluminum ores, which are abundant in the United States, can be used; and the capital needed for aluminum plant construction was expected to be reduced.

Alcoa also continued to develop its new process for electrolytically producing aluminum metal in a chloride bath, at a semicommercial facility at Palestine, Tex.

---

[1]Physical scientist, Division of Nonferrous Metals.
[2]Mineral specialist, Division of Nonferrous Metals.

Antimony

By John A. Rathjen[1]

With the exception of domestic mine production, exports, and secondary virtually all phases of the antimony industry registered decreases in 1977. Reported consumption of primary antimony dropped 1,514 tons to a total of 13,823 tons during the year. Secondary smelter production totaled 30,601 tons, up from 19,799 tons produced in 1976. Imports of antimony in all forms declined 39% to 13,335 tons during 1977. The most noticeable shortfall was in ores and concentrates, which dropped from 10,023 tons of contained antimony in 1976 to 3,438 tons in 1977. This severe cutback was attributed to the phaseout and closing of NL Industries, Inc.'s smelter at Laredo, Tex., and the continued pattern of importing crude antimony oxide as an alternate to smelting ore domestically.

Domestic mine production of antimony in 1977 rose to 610 tons from 283 tons in 1976 and reflected termination of a year-long strike at the Sunshine mine in Kellogg, Idaho.

Legislation and Government Programs.—Government stocks of antimony remained at 40,728 tons. On October 1, 1976, the Federal Preparedness Agency (FPA) of the General Services Administration (GSA) established a new goal for antimony of 20,130 tons. This action created a surplus of 20,570 tons, but Congressional approval is required for disposal. Antimony remained on the list of commodities eligible for exploration assistance under the program administered by the Office of Minerals Exploration (OME). However, funds for exploration projects have not been requested from Congress since fiscal year 1974.

Federal income tax laws under the Tax Reform Act of 1969 provided a percentage depletion allowance of 22% for domestic production and 14% for U.S. production from foreign sources.

Table 1.—Salient antimony statistics

(Short tons)

	1973	1974	1975	1976	1977
United States:					
Production:					
Primary:					
Mine	545	661	886	283	610
Smelter[1]	17,206	16,657	12,189	14,618	12,827
Secondary	24,062	23,570	17,964	19,799	30,601
Exports of metal and alloys	515	871	340	341	742
Imports for consumption (antimony content)	21,265	22,119	18,706	21,770	13,335
Consumption[1]	20,613	18,041	12,987	15,337	13,823
Price: New York, average cents per pound	68.50	181.76	176.58	165.26	178.00
World: Production	76,920	79,113	[r]77,114	[r]76,576	78,977

[r]Revised.
[1]Includes primary antimony content of antimonial lead produced at primary lead refineries.

DOMESTIC PRODUCTION

MINE PRODUCTION

Domestic mine production of primary antimony in 1977 was 610 tons, an increase of 327 tons from the total mined in 1976. Primary antimony was produced at two domestic mines. The Sunshine mine, operated by the Sunshine Mining Co. in the Coeur d'Alene district of Idaho, produced 446 tons, an increase of 313 tons over the 1976 total. The increase was attributed to a return to work after a prolonged strike which ended in March 1977. Antimony was produced at the Sunshine operations as a byproduct of the treatment of tetrahedrite, a complex silver-copper-antimony sulfide, one of the principal ore minerals in the Kellogg area.

The United States Antimony Corp. (USAC), at Thompson Falls, Mont., also increased production to 164 tons in 1977, compared with 150 tons in 1976. The upturn, late in the year, was credited to an improvement of mining techniques and power distribution along with improved materials handling. Stibnite, the most common of the antimony minerals, was the primary source of antimony from the Babbitt, Bardot, and Black Jack mines, operated by USAC at Thompson Falls.

Antimony is also produced as a byproduct in smelting of primary lead from domestic concentrates. Antimonial lead produced in this process during 1977 was 598 tons, a 68% increase compared with 1976 output. Two primary lead refiners reported production in 1977.

Table 2.—Antimony mine production and shipments in the United States

(Short tons)

Year	Antimony concentrate	Antimony	
		Produced	Shipped
1973	2,468	545	494
1974	3,217	661	593
1975	4,505	886	966
1976	1,111	283	310
1977	3,496	610	534

SMELTER PRODUCTION

Primary.—Production of primary antimony products in 1977 was 12,827 tons, a decline of 12% from the output recorded in 1976. With the exception of residues, all of the categories were lower than in 1976. The largest decline was in production of antimony metal, which totaled 1,877 tons, a drop of 39% from 1976. This reduction was attributed to the closing of the antimony smelter at Laredo, Tex., which was operated by NL Industries. The lack of proper raw material, obsolescence, and reduced demand for antimony metal were factors that contributed to closing the plant. Antimony metal was also produced at the Kellogg works of the Sunshine Mining Co. for consumption in the battery industry.

The pattern of antimony oxide production changed slightly as two new plants were brought onstream. McGean Chemical Co. Inc. started up a new plant near Cleveland, Ohio, which was to be capable of producing antimony trioxide from ores and concentrates, metal, and imported crude oxide. The Chemetron Corp. moved its antimony oxide facilities to LaPorte, Tex., from Cleveland, Ohio. Harshaw Chemical Co. continued production of antimony oxide at Gloucester City, N.J., and M&T Chemicals Inc. produced oxide at Baltimore, Md. ASARCO Incorporated had a small production of antimony oxide at its Perth Amboy, N.J. plant, although it was announced that this plant was being closed.

Sodium antimonate, which is used in the glass industry for color television tubes, was produced at Thompson Falls, Mont., by USAC.

ASARCO continued work on a new antimony smelter at El Paso, Tex. The plant will treat byproduct antimony from the Coeur mine in Idaho and should be fully operational in 1978.

Secondary.—Production of antimony from secondary sources increased 10,802 tons to a total of 30,601 tons in 1977. Of this, 26,580 tons, or 87% of the total metal, was recovered by treating battery scrap. Other items such as cable sheathing, drosses, old bearings, and type metal provided the balance of secondary production. As the automotive industry continued its shift to maintenance-free (MF) batteries there was a buildup of residual antimony at the secondary lead smelters. New refining technology was being studied that should make this recycled metal available in the future.

Table 3.—Primary antimony produced in the United States

(Short tons of antimony content)

Year	Class of material produced					Total
	Metal	Oxide	Sulfide	Residues	Byproduct antimonial lead	
1973	2,859	11,273	92	1,839	1,143	17,206
1974	3,030	10,445	54	2,066	1,062	16,657
1975	3,254	7,890	--	595	450	12,189
1976	3,102	10,628	--	191	697	14,618
1977	1,877	9,907	--	277	766	12,827

Table 4.—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	Percent
1973	15,455	731	412	24	1,167	7.6
1974	12,513	658	404	35	1,097	8.8
1975	6,029	268	182	117	567	9.4
1976	6,743	355	342	33	730	10.8
1977	7,557	598	168	134	900	11.9

[1]Includes primary residues and a small quantity of antimony ore.
[2]Includes foreign base bullion and small quantities of foreign antimony ore.

Table 5.—Secondary antimony produced in the United States, by kind of scrap and form of recovery

(Short tons of antimony content)

Kind of scrap	1976	1977	Form of recovery	1976	1977
New scrap:			In antimonial lead[1]	16,498	26,580
Lead-base	2,116	4,037	In other lead alloys	3,294	4,013
Tin-base	26	24	In tin-base alloys	7	8
Total	2,142	4,061	Total	19,799	30,601
			Value (millions)	$65.4	$108.9
Old scrap:					
Lead-base	17,642	26,526			
Tin-base	15	14			
Total	17,657	26,540			
Grand total	19,799	30,601			

[1]Includes 33 tons of antimony recovered in antimonial lead from secondary sources at primary plants in 1976 and 134 tons in 1977.

CONSUMPTION AND USES

Domestic consumption of primary antimony in 1977 dropped 1,514 tons to a total of 13,823 tons. A decline in use for metal and nonmetal products was partially offset by a gain in consumption of antimony trioxide as a flame retardant.

Antimony metal used in manufacture of starting-lighting-ignition (SLI) batteries for the automotive industry continued a decline that began several years ago with the introduction of MF batteries. Increased use of antimony in ammunition, solder, and type metal was not sufficient to compensate for the loss in batteries, and the total consumption of antimony metal in 1977 was 3,847 tons, a drop of 1,053 tons from the 1976 consumption.

Nonmetal products totaled 4,211 tons in 1977, 674 tons less than in 1976. All of the use patterns were down with the exception of consumption in plastics, which increased 226 tons during the year. Use of antimony in plastics was increasing because of its dual ability to react as a mordant or stabilizer in conjunction with attendant flame-retardant properties.

Antimony oxide consumed directly as a flame retardant increased 213 tons to a total of 5,765 tons in 1977. Use in plastics, adhesives, and rubber cumulatively was 320 tons higher than in 1976, but the increase was tempered by less consumption in pigments, textiles, and paper, which together used 107 tons less than in 1976.

Table 6.—Industrial consumption of primary antimony in the United States

(Short tons of antimony content)

Year	Class of material consumed						
	Ore and concentrate	Metal	Oxide	Sulfide	Residues	Byproduct antimonial lead	Total
1973	582	5,824	10,970	255	1,839	1,143	20,613
1974	1,032	4,362	9,457	62	2,066	1,062	18,041
1975	369	4,229	7,311	33	595	450	12,987
1976	640	3,375	10,397	37	191	697	15,337
1977	160	2,625	9,959	36	277	766	13,823

STOCKS

Yearend industry stocks of antimony dropped sharply in 1977 to 8,591 tons, as compared with 15,070 tons at the close of 1976. All categories registered a downturn with the exception of antimonial oxides and antimonial residues where a nominal gain of 41 tons was reported. The largest shortfall was in holdings of ore and concentrate, which dropped to 1,869 tons, a decline of 6,030 tons from the total inventory at yearend. This sharp reduction in raw material stocks was attributed to the continuing shift from smelting antimony domestically to the purchase of semifinished products from abroad. The growing dependence on secondary lead smelters as a source of antimony was also a factor in reduction of primary raw material inventories in 1977.

Table 7.—Industrial consumption of primary antimony in the United States, by class of material produced

(Short tons of antimony content)

Product	1973	1974	1975	1976	1977
Metal products:					
Ammunition	122	121	239	63	138
Antimonial lead	8,027	7,251	4,568	3,861	2,936
Bearing metal and bearings	527	476	402	405	265
Cable covering	12	16	23	19	16
Castings	65	31	18	24	13
Collapsible tubes and foil	12	18	9	23	16
Sheet and pipe	97	69	60	74	56
Solder	191	205	133	188	220
Type metal	134	107	75	79	83
Other	104	135	120	164	104
Total	9,291	8,429	5,647	4,900	3,847
Nonmetal products:					
Ammunition primers	18	11	14	13	13
Fireworks	5	11	10	12	9
Ceramics and glass	1,917	1,384	989	1,260	1,547
Pigments	644	460	321	415	400
Plastics	2,920	1,431	1,091	1,277	1,503
Rubber products	693	664	458	578	473
Other	2,219	1,268	658	1,330	266
Total	8,416	5,229	3,541	4,885	4,211
Flame retardant:[1]					
Plastics		2,711	2,501	3,777	3,972
Pigments		172	92	183	149
Rubber	2,906	252	172	199	219
Adhesives		231	126	141	246
Textiles		980	748	1,055	997
Paper		37	160	197	182
Total	2,906	4,383	3,799	5,552	5,765
Grand total	20,613	18,041	12,987	15,337	13,823

[1]Flameproofing chemicals and compounds shown separately by use starting in 1974.

Table 8.—Industry stocks of primary antimony in the United States, December 31

(Short tons of antimony content)

Stocks	1973	1974	1975	1976	1977
Ore and concentrate	5,585	6,275	8,364	7,899	1,869
Metal	1,540	809	1,380	1,662	1,359
Oxide	2,074	3,732	3,886	4,560	4,576
Sulfide	31	35	32	31	24
Residues and slags	526	549	921	475	516
Antimonial lead[1]	322	294	374	443	247
Total	10,078	11,694	14,957	15,070	8,591

[1]Inventories from primary sources at primary lead refineries only.

PRICES

The New York price for RMM brand 99.5% antimony metal remained firm at \$1.78 per pound through 1977. This quotation was calculated from a base price of \$1.75 per pound f.o.b. the NL Industries smelter at Laredo, Tex., with a freight differential of 3 cents per pound for New York delivery. The New York dealer price for foreign metal was quoted in a range of \$1.00 to \$1.55 per pound in January but dropped steadily through the year to \$1.10 to \$1.15 per pound in December. The decline was attributed primarily to a drop in demand for antimony metal in the automotive storage battery industry. The industry quotation for antimony trioxide was $1.80 per pound in January and remained firm until August 3, when Harshaw Chemical Co. reduced its antimony trioxide price by 16 cents per pound to a new base price of $1.64 per pound. The Metals Week quotation for antimony trioxide was published in a range of $1.64 to $1.80 per pound where it remained for the balance of the year. The European Market quotation for lump ore, on a 60% antimony basis, dropped from a range of $25.50 to $27.50 per metric ton unit, c.i.f., during the first half of 1977, to a range of $17.50 to $20, same basis, for the remainder of the year.

Table 9.—Antimony price ranges in 1977

Type of antimony	Price per pound
Domestic metal[1]	$1.75-$1.78
Foreign metal[2]	1.00- 1.55
Antimony trioxide[3]	1.64- 1.80

[1]RMM brand, f.o.b., Laredo, Tex.
[2]Duty-paid delivery, New York.
[3]Quoted in Metals Week.

FOREIGN TRADE

Imports of antimony in all forms totaled 13,335 tons (metal content), a decline of 39% from the 1976 total. The largest loss was in the category of ores and concentrates, which dropped to 3,438 tons in 1977 as compared with 10,023 tons received in 1976.

Table 10.—U.S. imports for consumption of antimony, by country

Country	1976		1977	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Antimony metal, including needle or liquated:[1]				
Belgium-Luxembourg	392	$611	55	$146
Bolivia	236	743	666	2,081
Canada	1	36	1	50
Chile	14	36	110	291
China, People's Republic of	209	613	483	1,137
Germany, Federal Republic of	1	16	(2)	15
Italy	22	70	--	--
Japan	44	131	--	--
Malaysia	11	30	--	--
Mexico	273	443	222	405
Netherlands	--	--	51	104
South Africa, Republic of	--	--	214	443
Spain	41	108	43	85
Thailand	99	284	--	--
United Kingdom	230	462	25	90
Yugoslavia	551	1,532	111	269
Total	2,124	5,115	1,981	5,116
Antimony oxide:				
Belgium-Luxembourg	350	965	376	1,110
Bolivia	110	293	744	1,997
Chile	--	--	20	37
China, People's Republic of	1,288	3,441	391	1,211
France	1,464	4,198	1,300	3,853
Germany, Federal Republic of	22	69	78	214
Italy	20	53	73	184
Japan	597	1,638	228	641
Netherlands	50	143	22	76
South Africa, Republic of	6,005	1,504	4,693	1,405
Switzerland	(2)	(2)	20	83
Taiwan	82	218	11	34
United Kingdom	1,623	4,507	1,685	4,305
Total	11,611	17,029	9,641	15,150

[1]Includes needle or liquated (value in thousands): 1976-Belgium-Luxembourg 18 tons ($53), the United Kingdom 23 tons ($76); 1977—Belgium-Luxembourg 25 tons ($66), the Republic of South Africa 214 tons ($443), the United Kingdom 20 tons ($71).
[2]Less than 1/2 unit.

The decline was attributed to closing of the NL Industries smelter at Laredo, Tex., and a continuing changeover to importation of crude antimony oxide in lieu of smelting foreign ores domestically. Imports of antimony oxide were 9,641 tons (gross weight), a decline of 1,970 tons from the 1976 level. Metal imports including liquated totaled 1,981 tons during 1977 and were 143 tons under the 1976 level.

Three countries supplied 80% of antimony oxide imports during 1977: The Republic of South Africa, 4,693 tons (includes crude antimony oxide imported for further refining); the United Kingdom, 1,685 tons; and France, 1,300 tons. A sharp drop in receipts from the People's Republic of China was partially offset by increased shipments from Bolivia, the Federal Republic of Germany, and Italy. Receipts of antimony ores and concentrates in 1977 were 3,438 tons (metal content), a 66% decline from the 1976 total. All of the principal suppliers recorded lower imports. The Republic of South Africa, with 959 tons, reflected a 78% drop from the 1976 total; Bolivia at 757 tons (including Bolivian antimony shipped via Antofagasta, Chile) was 68% lower; Mexico, 869 tons, was down 43%; and Canada, 823 tons, was 25% lower than in 1976.

Total imports of refined metal dropped 143 tons to 1,981 tons in 1977. A sharp decline in receipts from Belgium-Luxembourg, Mexico, the United Kingdom, and Yugoslavia, which cumulatively shipped 1,033 tons less in 1977 than in 1976, was partially offset by a combined increase in receipts of 1,259 tons from Bolivia (includes Bolivian antimony shipped via Antofagasta, Chile) and the People's Republic of China.

Exports of antimony, metal, alloys, and scrap totaled 742 tons in 1977, a rise of 401 tons over shipments in 1976. The largest customers were the United Kingdom, 244 tons, 33%; Bulgaria, 123 tons, 17%; Japan, 78 tons, 11%; India, 70 tons, 9%; and Canada, 68 tons, 9%. The balance was shipped in small parcels to 15 additional countries.

Table 11.—U.S. imports for consumption of antimony ore, by country

Country	1976			1977		
	Gross weight (short tons)	Antimony content (short tons)	Value (thousands)	Gross weight (short tons)	Antimony content (short tons)	Value (thousands)
Bolivia	3,179	1,992	$3,820	499	312	$675
Canada	1,756	1,091	1,949	1,267	823	1,701
Chile	711	411	804	687	445	938
China, People's Republic of	--	--	--	8	6	17
Colombia	219	91	112	70	24	26
Guatemala	949	474	384	--	--	--
Mexico	6,625	1,513	2,458	3,869	869	1,493
South Africa, Republic of	7,495	4,446	7,378	1,642	959	1,982
Thailand	11	5	6	--	--	--
Total	20,945	10,023	16,911	8,042	3,438	6,832

Table 12.—U.S. imports for consumption of antimony

Year	Antimony ore			Needle or liquated		Antimony metal[1]		Antimony oxide	
	Gross weight (short tons)	Antimony content (short tons)	Value (thousands)	Gross weight (short tons)	Value (thousands)	Gross weight (short tons)	Value (thousands)	Gross weight (short tons)	Value (thousands)
1975	20,736	8,320	$14,535	74	$255	2,112	$5,677	9,908	$12,588
1976	20,945	10,023	16,911	41	129	2,083	4,986	11,611	17,029
1977	8,042	3,438	6,832	259	580	1,722	4,536	9,641	15,150

[1]Does not include alloy containing 83% or more antimony.

Table 13.—Antimony: World production (content of ore unless otherwise indicated), by country

(Short tons)

Country	1975	1976	1977[p]
North America:			
Canada[e] [1]	2,020	2,535	2,340
Guatemala	944	1,235	[e]1,250
Honduras	114	129	77
Mexico[2]	3,458	2,806	[e]3,000
United States[3]	886	283	610
South America:			
Argentina	3	2	2
Bolivia	[4]13,136	[5]16,873	[5]16,707
Brazil	--	39	[e]40
Peru (recoverable)	305	665	[e]670
Europe:			
Austria (recoverable)	561	588	564
Czechoslovakia[e]	[r]770	[r]770	830
Greece	237	243	--
Italy	1,113	1,112	909
Spain	88	168	357
U.S.S.R.[e]	8,300	8,500	8,700
Yugoslavia	2,406	2,228	[e]2,300
Africa:			
Algeria	66	66	[e]66
Morocco	1,160	1,560	1,553
Rhodesia, Southern[e]	330	330	330
South Africa, Republic of	17,553	11,890	12,930
Asia:			
Burma	[r]306	524	734
China, People's Republic of[e]	13,000	13,000	13,000
Korea, Republic of	44	11	--
Malaysia (Sarawak)	275	275	[e]275
Pakistan[e]	144	43	[e]45
Thailand	3,454	4,047	5,238
Turkey	4,010	4,771	[e]4,900
Oceania: Australia[6]	2,431	1,883	[e]1,550
Total	[r]77,114	76,576	78,977

[e]Estimate. [p]Preliminary. [r]Revised.
[1]Partly estimated on the basis of reported value of total production.
[2]Antimony content of ores for export plus antimony content of antimonial lead and other smelter products.
[3]Production from antimony mines; excludes a small amount produced as a byproduct of domestic lead ores.
[4]Production by COMIBOL plus exports by medium and small mines and so-called "other producers."
[5]Total national production.
[6]Antimony content of antimony concentrates, lead concentrates, and zinc concentrates.

WORLD REVIEW

World mine production of antimony in 1977 increased slightly to 78,977 tons. The principal producers continued at levels consistent with former years with minor declines more than offset by increased production from developing countries. Bolivia continued as the world's largest producer in 1977 with a total of 16,707 tons. The People's Republic of China and the Republic of South Africa retained strong positions as suppliers of antimony to the world market, with an estimated combined production of about 25,930 tons.

Australia.—Production of antimony in Australia in 1977 was estimated at 1,550 tons, a decline of 333 tons from output in 1977. Increased production by Vam Ltd. at its Hillgrove mines near Armidale in New South Wales was offset by disappointing results at the Blue Spec antimony-gold mine near Nullagine in the Pilbara region of Western Australia. The Blue Spec mine, which reopened in 1976, was to be operated at recovery levels of 80% for antimony and 75% for gold. In actual practice the factors were only 59.7% for antimony and 44.7% for gold; as a result the project has been declared uneconomical, and it was announced that the mine would be closed early in 1978.

Vam Ltd. was planning a substantial increase in antimony production with the opening of a fourth mine, Garibaldi, in New South Wales. Proven ore reserves are 23,000 tons assaying up to 5% antimony, and there are 100,000 tons of inferred reserves.

Bolivia.—Bolivia continued as the world's largest antimony producer in 1977 with a total output of 16,707 tons. Much of the production was utilized at the new smelter operated by Empresa Nacional de Fundiciones (ENAF), where metal and oxide were produced for export. Metal production assayed in a range of 99.5% to 99.6% antimony, and trioxide was 99.85% pure. Concentrates and cobbed ore not consumed at the smelter were exported to traditional markets including the United States, Europe, and Japan.

Canada.—Two companies continued as the principal producers of antimony metal in Canada. Cominco Ltd. at its lead smelter and refinery at Trail, British Columbia, and Brunswick Mining and Smelting Corp. at its lead smelter near Belledune, New Brunswick, produced byproduct antimonial lead in their refining operations.

Antimony was mined and concentrated in Canada by Consolidated Durham Mines and Resources Ltd. at its Lake George property near Fredrickton, New Brunswick. The main ore is stibnite, which is upgraded to a premium grade 66% antimony concentrate with less than 0.50% arsenic and lead combined. The concentrates were shipped to Europe and the United States.

Con-Am Resources Ltd. announced a three-phase study of its antimony prospect in the Wheaton River district of the Yukon Territory. Previous investigations have indicated a reserve of 175,000 tons of 3% to 5% stibnite. Reconstruction of access roads and adits prior to additional core drilling and metallurgical testing will be the main thrust of the ongoing study.

China, People's Republic of.—China maintained its position as the world's second-ranking producer with an estimated 13,000 tons in 1977. A review of international commerce and activity at the Canton Fair seemed to indicate a production level somewhat lower than these current estimates. China's reserves of antimony ore, which are believed to contain an excess of 2 million tons of metal, are the largest known world resource. Most of the deposits are in southwestern Hunan Province with other occurrences reported in the Provinces of Kweichow, Kwangsi, Kwangtung, and Yunan.

South Africa, Republic of.—The third-ranking world producer of antimony in 1977 was the Republic of South Africa with 12,930 tons. A single company, Consolidated Murchison Limited, which operated in the Letaba district of the Transvaal, produced all of the antimony mined and treated during the year. A number of separate deposits were mined along the Murchison Range, of which the Gravelotte section proved to be the most productive. Antimony was produced as a concentrate and in the form of high-grade cobbed ore. The major portion of the company's production was exported and sold in Europe and North America. Prior to export, a significant percentage of the antimony concentrate was treated by Antimony Products (Proprietary) Ltd. for the production of crude antimony oxide.

Research and exploration programs continued throughout the year in an effort to improve gold recovery and expand the current reserve at the mine.

Thailand.—Thailand was the fifth largest world producer of antimony in 1977 with 5,238 tons of metal content mined during the year. Antimony was produced in the north, central, and southern regions of Thailand. There were many small producers, and mining was frequently intermittent, reflecting the price of metal in the world market. The largest producing Provinces in the north were Phrae and Lampang, minor quantities came from Chiang Rai, Chiang Mai Tak, Lamphum, and Sukhothai. In the central area ore was produced in the Provinces of Kanchana Bari, Chanthaburi, Rayong, and Rat Buri, and in the south, there was production in Nakhon Si Thammarat, and Surat Thani Provinces.

Yugoslavia.—The Rajiceva Gora antimony mine and mill on Kopaonik Mountain in Serbia, operated by Rudarsko Topionicki Bazen Zajaca (RTB-Zajaca), started regular production following 12 months of trial production. Output should reach 300,000 tons of ore by 1979. Reserves of antimony ores at Rajiceva Gora were estimated to be between 10 and 15 million tons. The grade of the ore was not made public.

Exploration in the general area of Rujevac, in Serbia, has led to the discovery of important reserves of lead, zinc, and antimony ores. Development of a new mine was to start during 1979. In the vicinity of Kriva Palanka, Serbia, exploration for bentonite by geologists of Bentomak, a local producer of bentonite, have led to discovery of antimony ore. During exploration work, about 13,000 tons of ore was produced; it was considered that the deposit could justify construction of a mine and mill.

A decision to build Yugoslavia's first antimony oxide plant, of 400 tons per year capacity, was taken by RTB-Zajaca. The location of the facility was not announced, but it was believed it would be at Zajaca, where the only Yugoslav antimony smelter was in operation.

---

[1]Mineral specialist, Division of Nonferrous Metals.

Asbestos

By R. A. Clifton[1]

Shipments of asbestos (mostly chrysotile) in 1977 from mines in the United States decreased 11% from those in 1976. Imports were 8% lower than those in 1976 because U.S. demand continued to lag well below the peak year of 1973.

Canadian production in 1977 was 8% lower than that for 1976, and shipments from Canada to the United States were 6% less than those in 1976. Imports from the U.S.S.R. were 1% of total U.S. imports, and those from the Republic of South Africa accounted for 4%.

Table 1.—Salient asbestos statistics

	1973	1974	1975	1976	1977
United States:					
Production (sales) short tons	150,036	109,091	98,654	114,842	101,704
Value thousands	$16,288	$13,759	$14,220	$23,693	$25,267
Exports and reexports (unmanufactured) short tons	66,442	61,723	36,447	46,923	37,637
Value thousands	$9,342	$9,192	$10,667	$12,791	$11,731
Exports and reexports of asbestos products (value) do	$40,777	$60,396	$60,776	$60,572	$78,822
Imports for consumption (unmanufactured) short tons	792,473	766,164	538,553	657,851	607,022
Value thousands	$98,914	$123,822	$111,011	$142,145	$145,146
Released from stockpile (unmanufactured) short tons	6,761	28,851	6,877	552	207
Consumption, apparent[1] do	882,908	845,825	607,637	726,322	671,543
World: Production do	4,613,717	4,582,320	[r]4,562,624	[r]5,623,211	5,878,829

[r]Revised.
[1]Measured by quantity produced, plus imports, plus stockpile releases, minus exports.

Legislation and Government Programs.—Again, no date was set by the Occupational Safety and Health Administration (OSHA) for the public hearings mandatory for the proposed revisions to its asbestos standard for manufacturing. The proposal for a permissible-exposure level of 0.5 fibers per cubic centimeter (0.5f/cc) is well into its third year without the hearings.

On March 18, 1977, President Carter signed Public Law 95-12. This act repealed the Byrd Amendment, which had exempted strategic minerals from the economic sanctions in force against Southern Rhodesia.

The Consumer Products Safety Commission (CPSC) banned all consumer patching compounds and artificial emberizing materials that contain respirable free-form asbestos. The ban on emberizing materials became effective December 15, 1977, and that on patching compounds becomes effective January 16, 1978, for all such compounds manufactured after that date.

On November 10, 1977, the Environmental Protection Agency (EPA) gave advance notice of intention to propose an asbestos standard for the production and use of crushed stone.

Under a new State law, all California firms manufacturing asbestos products or using asbestos in their processes had to register that fact prior to September 1, 1977.

As shown in table 2, there was little change in stockpile inventories in 1977. Crocidolite was sold from the stockpile at $301 per ton.

Table 2.—Stockpile goals and Government inventories as of December 31

(Short tons)

	Stock-pile goals	Total inventories 1976	Total inventories 1977	Sales of excesses, 1977
Amosite	26,291	42,623	42,416	207
Chrysotile	--	[1]10,960	[1]10,960	--
Crocidolite	--	2,474	2,474	--
Total	--	[r]56,057	55,850	207

[r]Revised.
[1]Adjusted figure, Federal Preparedness Agency.

Environmental Impact.—Isolating the impact of environmental considerations on the demand for asbestos is difficult because of the many interacting variables. It is demonstrable, however, that in the past, asbestos consumption has risen with rising construction activity and declined with each decrease in construction activity. This is shown in figure 1, and is true for the 9 years preceding 1977. The sudden divergence in that year of the paths of new construction and asbestos consumption is quite likely the result of lessened demand brought on by the environmental problems associated with asbestos. Indications are that future asbestos consumption in the United States may have a nongrowth pattern, and that environmental considerations will be a causative factor.

DOMESTIC PRODUCTION

Mines in the United States shipped 11% less asbestos in 1977 than in 1976. Value was 7% higher than in 1976. Four States produced asbestos: California was the leader, with 74%, followed by Vermont, Arizona, and North Carolina. Total output was 101,704 tons valued at $25,267,000.

Output from the copperopolis mine made Calaveras Asbestos Corp. California's leading producer. At yearend, two mines were also active on the Joaquin Ridge near Coalinga. Atlas Asbestos Corp. worked its Santa Cruz mine in Fresno County and Union Carbide Corp. operated its Santa Rita mine in San Benito County, both on the ridge.

The Vermont Asbestos Group's Lowell mine in Orleans County, Vt., is no longer the mine with the highest production of asbestos in the United States. Its output was less than that of the Calaveras Corp. mine. The Lowell mine is owned and operated by an employee group which, though successful in its operation, is considering selling it.

Arizona production in 1977 was below the 1976 level. The Jaquays Mining Corp. in Gila County had the only active asbestos mine in the State.

Powhatan Mining Co.'s mine in North Carolina was active, and a few tons of anthophyllite was mined and shipped in 1977. U.S. asbestos producers and mine sites follow:

State and company	County	Mine	Type of asbestos
Arizona: Jaquays Mining Corp	Gila	Chrysotile	Chrysotile.
California:			
Atlas Asbestos Corp	Fresno	Santa Cruz	Do.
Calaveras Asbestos Corp	Calaveras	Copperopolis	Do.
Union Carbide Corp	San Benito	Santa Rita	Do.
North Carolina: Powhatan Mining Co	Yancey	Hippy	Anthophyllite.
Vermont: Vermont Asbestos Group	Orleans	Lowell	Chrysotile.

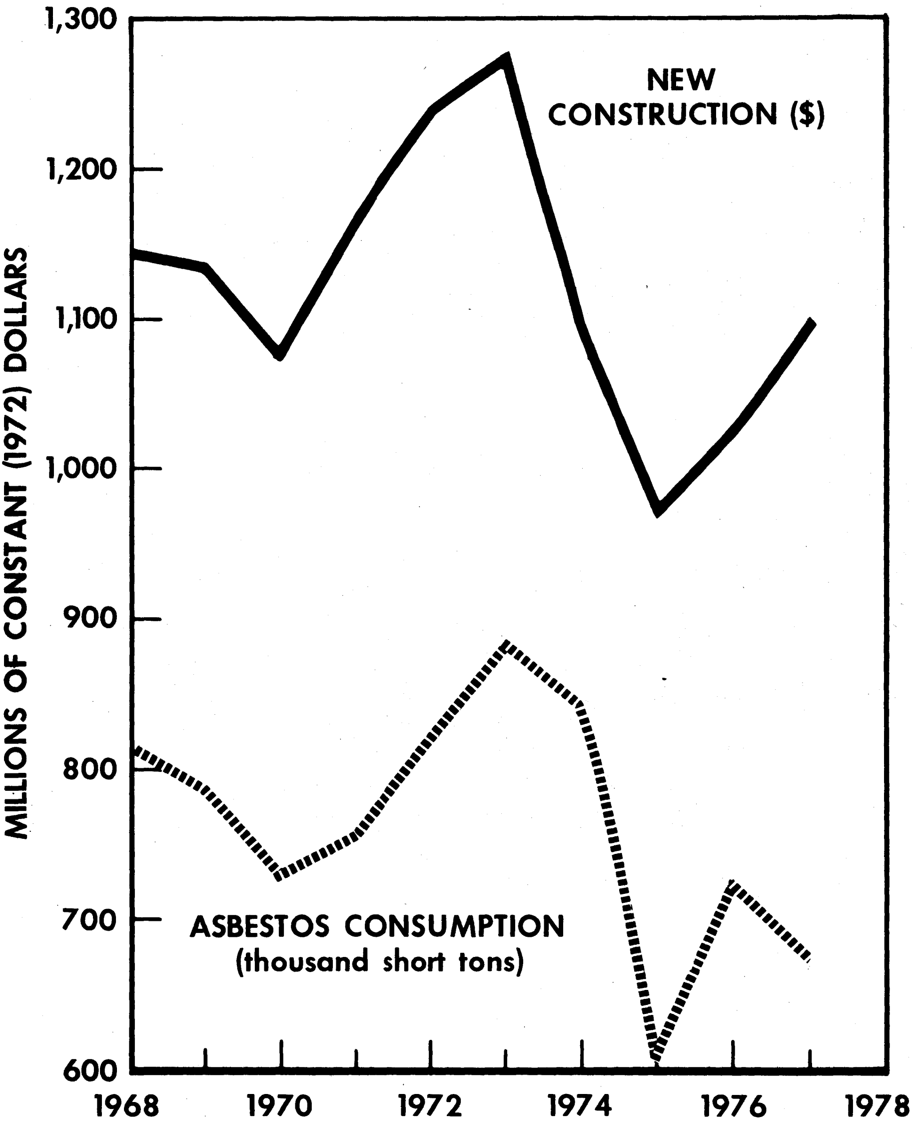


Figure 1.—Value of new construction versus asbestos consumption.

Table 3.—U.S. asbestos distribution by end use, grade, and type, 1977

(Short tons)

	Chrysotile											
	Grades 1 & 2	Grade 3	Grade 4	Grade 5	Grade 6	Grade 7	Grade 8	Total chrysotile	Crocidolite	Amosite	Anthophyllite	Total asbestos
Asbestos-cement pipe	--	--	86,500	41,600	3,000	--	--	131,100	25,400	3,000	--	159,500
Asbestos-cement sheet	--	--	8,000	14,100	11,200	9,000	--	42,300	--	1,200	--	43,500
Flooring products	2,700	--	--	67,500	100	84,100	--	154,400	--	--	--	154,400
Roofing products	--	--	300	3,600	14,900	44,500	--	63,300	100	--	--	63,400
Packing and gaskets	300	3,100	3,900	13,800	1,500	5,000	--	27,600	100	--	--	27,700
Insulation:												
Thermal	--	1,700	500	400	8,400	5,500	--	16,500	--	--	--	16,500
Electrical	--	200	--	2,200	1,000	300	--	3,700	--	--	--	3,700
Friction products	100	1,600	2,500	30,100	10,900	45,400	300	90,900	--	--	700	91,600
Coatings and compounds	--	--	200	400	1,100	34,100	--	35,800	--	--	--	35,800
Plastics	--	100	--	1,100	--	5,900	--	7,100	900	--	--	8,000
Textiles	1,100	8,400	200	--	--	--	--	9,700	--	--	--	9,700
Paper	--	--	1,700	1,200	16,200	4,800	--	23,900	500	--	--	24,400
Other	100	200	1,000	4,000	7,000	19,000	--	31,300	--	--	2,000	33,300
Total	4,300	15,300	104,800	180,000	75,300	257,600	300	637,600	27,000	4,200	2,700	671,500

CONSUMPTION AND USES

The end use data on asbestos fiber as reported by respondents to the Bureau of Mines questionnaire remain difficult to analyze. Patterns of use that may be indicative of trends are not apparent. The data may represent a major market readjustment that started with the economic recession and Canadian strike in 1975 and was complicated by the environmental picture, or the lack of clarity may be due to inconsistency of reporting. If the former is true, then the readjustment period is still taking place. Three-fourths of the end uses showed increases in asbestos consumption; the others decreased. The asbestos used in asbestos cement pipe increased 14% and that in asbestos cement sheet, 92%. Further increases were in flooring products (36%), packing and gaskets (38%), thermal insulation (150%), electrical insulation, (61%), coatings and compounds (80%), and textiles (31%). The asbestos used in roofing products in 1977 was reported at just 25% of that in 1976, asbestos used in plastics was only 37% of the 1976 level, and in paper, 79%.

Asbestos cement pipe, which represented 24% of the total asbestos consumption, and flooring products, which represent 23%, were the largest end uses of asbestos. Friction products totaled 14%, and roofing products, the 1976 leader, was fourth at 9%. Other major asbestos-using end products were asbestos cement sheet (6%), coatings and compounds (5%), packing and gaskets, as well as paper (4%), insulation (3%), plastics and textiles (1% each), and other end uses (6%).

The following, from a Canadian trade publication, indicates the amount of asbestos used in some of the end products and its contribution to the cost of the article:[2]

Product	Weight-percent	Approximate percent of cost
Asbestos waterproofing products and antileak joints	50-70	15-20
Friction material (molded)	50-60	15
Friction material (woven)	70	30
Asbestos textiles (cloth, yarn)	85-90	40
Asbestos papers (felts)	80-90	60
Asbestos finished sheets	10-15	30
Asbestos pipes	16	45
Asbestos-vinyl tiles	8-14	6

PRICES

Quoted prices for Quebec asbestos, all chrysotile, were raised 14% during 1977. The last rise was effective on July 1, 1977. British Columbia asbestos chrysotile prices rose 12.8% on that date.

Prices for Vermont chrysotile asbestos rose 4% on January 1, 1977. Arizona prices did not increase during 1977. The latest prices are still those that went into effect on July 1, 1976, and quotations, f.o.b. Globe, are shown below:

Grade	Description	Per short ton
Group 1	Crude	$3,000
Group 2	do	1,800
AAA	do	1,300
Group 3	Nonferrous filtering and spinning	$750- 840
Group 4	Nonferrous plastic and filtering	750- 840
Group 7	White shorts	100- 200

As of January 1, 1977, Vermont chrysotile asbestos, f.o.b. Morrisville, was priced as follows:

Grade	Description	Per short ton
4T	Fiber	$477
5D through 5R	do	$314- 369
6D	Waste	228
7D through 7T	Shorts	95- 182
7TF	Floats (shorts)	82
8S	Shorts	62
Hooker No. 1	Packaged in 50-pound woven polyvinyl bags	1,110
Hooker No. 2	Packaged in 100-pound woven polyvinyl bags	555

Quotations for Canadian (Quebec) chrysotile, f.o.b. mine, as of July 1, 1977, follow:

Grade	Description	Per short ton
Group 1	Crude	Can$3,300-Can$4,000
Group 2	do	1,800- 2,175
Group 3	Spinning fiber	850- 1,700
Group 4	Asbestos-cement fiber	530- 700
Group 5	Paper fiber	315- 400
Group 6	Waste, stucco, or plaster	245- 275
Group 7	Refuse or shorts	90- 200

Prices for chrysotile asbestos from British Columbia and the Yukon Territory, Canada, effective July 1, 1977, f.o.b. Vancouver, follow:

Grade	Description	Per short ton
	CASSIAR MINE	
C-1	Crude	Can$3,621
AAA	Nonferrous spinning fiber	2,000
AA	do	1,600
A	do	1,050
AC	do	913
AK	Asbestos-cement fiber	770
AS	do	670
AX	do	580
AY	do	420
AZ	do	320

Grade	Description	Per short ton
	CLINTON MINE	
CP	Asbestos-cement fiber	Can$730
CT	do	650
CY	do	420
CZ	do	320

African asbestos producers privately negotiate sales, thereby ruling out market quotations. The following tabulation shows the average value per short ton of South African imports, regardless of grade, calculated from U.S. Department of Commerce data:

Type	1973	1974	1975	1976	1977
Amosite	$188	$228	$395	$461	$534
Crocidolite	213	251	427	518	528
Chrysotile	234	282	940	235	440

The increased demand for and the shortage of most types of asbestos, and the increased mining costs resulted in price increases in almost all categories. Other price rises were expected early in 1978.

FOREIGN TRADE

There was a 23% increase from 1976 to 1977 in the value of exports of asbestos products manufactured in the United States. The number of articles exported increased.

Major groupings of exported products and their share of the total value were textiles and yarns, 22%; friction products, packing and gaskets, and asbestos-cement products, 17% each; insulation products, 5%; and other products, 22% (table 4).

In 1977, 62% of the cost of imported asbestos was recovered by exporting and reexporting fibers and products.

In 1977, the United States imported 90% of its asbestos consumption. This was slightly below the 1976 percentage. Canada provided more than 94% of the imports, the Republic of South Africa provided 4%, the U.S.S.R. provided 1%, and four other countries provided the remainder. Chrysotile, with 98%, dominated the imported types. The dollar value of imported fibers was 2% higher than that in 1976.

Table 4.—Countries importing U.S. asbestos products in 1977, by type

(Thousand dollars)

	Canada	Germany, Federal Republic of	Mexico	Australia	United Kingdom	Other	Total
Friction products	10,436	927	62	121	153	3,398	15,097
Packing and gaskets	3,602	266	552	469	326	9,725	14,940
Asbestos-cement products	1,934	1,825	32	58	54	11,782	15,685
Textiles and yarn	4,282	1,767	4,939	718	162	8,200	20,068
Insulation products	1,103	13	93	40	49	3,373	4,671
Other	2,458	5,148	498	273	726	10,487	19,590
Total	23,815	9,946	6,176	1,679	1,470	46,965	90,051

Table 5.—U.S. exports and reexports of asbestos and asbestos products

Products	1976		1977	
	Quantity	Value (thousands)	Quantity	Value (thousands)
EXPORTS				
Unmanufactured:				
Crude and spinning and nonspinning fibers ---- short tons	21,470	$7,179	17,906	$7,433
Waste and refuse ---- do	24,847	5,461	19,484	4,268
Total ---- do	46,317	12,640	37,390	11,701
Products:				
Gaskets and packing ---- do	2,460	11,330	3,784	14,940
Brake linings ---- do	6,239	11,536	6,381	12,968
Clutch facings, including linings ---- number	1,007,551	1,660	1,110,280	2,129
Textiles and yarn ---- short tons	7,522	7,907	8,782	11,323
Shingles and clapboard ---- do	10,610	3,547	7,206	2,484
Articles of asbestos cement ---- do	15,151	6,326	24,454	13,201
Protective clothing	NA	898	NA	1,312
Insulation, heat and sound	NA	4,819	NA	4,671
Manufactures, n.e.c	NA	12,253	NA	15,322
Total	XX	60,276	XX	78,350
REEXPORTS				
Unmanufactured:				
Crude and spinning and nonspinning fibers ---- short tons	606	151	--	--
Waste and refuse ---- do	--	--	247	30
Total ---- do	606	151	247	30
Products:				
Gaskets and packing ---- do	4	19	12	126
Brake linings ---- do	221	251	197	197
Clutch facings, including linings ---- number	28,143	23	720	7
Textiles and yarn ---- short tons	--	--	8	35
Shingles and clapboard ---- do	12	3	--	--
Articles of asbestos cement	--	--	--	--
Manufactures, n.e.c	--	--	NA	107
Total	XX	296	XX	472

NA Not available. XX Not applicable.

Table 6.—U.S. imports for consumption of asbestos from specified countries, by grade

(Short tons)

Grade	1976			1977		
	Canada	Republic of South Africa	Southern Rhodesia	Canada	Republic of South Africa	Southern Rhodesia
Chrysotile:						
Crude	635	1,745	3,451	134	3,810	2,451
Spinning fibers	5,872	61	247	6,685	3,764	--
All other	611,068	6,557	--	561,985	2,360	345
Crocidolite (blue)	--	10,177	--	71	11,968	--
Amosite	20	1,554	--	1	582	--
Total	617,595	20,094	3,698	568,876	22,484	2,796

Table 7.—U.S. imports for consumption of asbestos (unmanufactured), by class and country

Year and country	Crude (including blue fiber)		Textile fiber		All other		Total	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
1976								
Australia	99	$46	--	--	--	--	99	$46
Canada	655	272	5,872	$4,613	611,068	$121,977	617,595	126,862
Germany, Federal Republic of	--	--	--	--	1,909	383	1,909	383
Hong Kong	--	--	--	--	2	(1)	2	(1)
Mexico	378	209	--	--	1,091	146	1,469	355
Rhodesia, Southern	3,451	2,099	247	208	--	--	3,698	2,307
South Africa, Republic of	13,476	6,932	61	38	6,557	2,616	20,094	9,586
U.S.S.R	--	--	--	--	12,421	2,324	12,421	2,324
United Kingdom	564	282	--	--	--	--	564	282
Total	18,623	9,840	6,180	4,859	633,048	127,446	657,851	142,145
1977								
Canada	206	90	6,685	6,224	561,985	124,940	568,876	131,254
Mexico	--	--	--	--	3,615	139	3,615	139
Rhodesia, Southern	2,451	2,368	--	--	345	199	2,796	2,567
South Africa, Republic of	16,360	7,721	3,764	309	2,360	1,273	22,484	9,303
Sweden	--	--	--	--	1	(1)	1	(1)
Taiwan	--	--	--	--	312	7	312	7
U.S.S.R	--	--	2,190	443	6,748	1,433	8,938	1,876
Total	19,017	10,179	12,639	6,976	575,366	127,991	607,022	145,146

[1]Less than 1/2 unit.

WORLD REVIEW

Industrial Minerals magazine discussed the asbestos market, the recession, and environmental factors by describing the "uniqueness" of a mineral that maintains a reasonably strong demand in spite of an intensive campaign to either ban or limit its use at a time of industrial recession.[3]

The world market for asbestos is apparently in a period of transition away from the older, longer established trends. Canada has been supplanted as the world's number one producer and the United States as the number one consumer; the Soviet Union enjoys premiership in both areas.

Consumption growth rates in the more developed countries are, at least for now, on the decline, but consumption is increasing in developing countries. This is indicated by the 8% reduction in U.S. consumption and 12% reduction in British imports, but world production rose 4.5% from 1976 to 1977.

There is even the possibility that there are trend changes among the grades of choice in the marketplace. During much of 1977, there were inventories of the spinning grades available from producers; during part of that time, shorts (grade 7) were also available. Demand for the cement grades, however, continued to exceed supply throughout the world.

Australia.—Although production for the year ended June 1977 more than doubled the record high set in 1972, the future of the Woodsreef Mines Ltd. mine at Barraba, New South Wales, still does not seem assured. New on-site reserves of fibers have been found, and the Baryugil property remains promising, but the receivership has not been vacated.

Canada.—The eight companies that produce and ship asbestos in Canada reported a 7% decrease in shipments to the United States and Western Europe. The Canadian Government established an emission standard of 2 fibers per cubic centimeter of air for air surrounding crushing, drying, milling, and storage operations of the asbestos mining industry. The standard will become effective on December 31, 1978.

In Quebec, the Provincial government's interest in the asbestos industry was greatly clarified by the end of 1977. Instead of the industrywide takeover reported earlier, only one company (Asbestos Corp. Ltd.) is now targeted for acquisition by the new $Can250,000,000 crown corporation, Société Nationale de l'Amiante, being proposed in the legislature. Asbestos Corp. Ltd., with 35% of the Province's production capacity, is not a willing seller. Improvement of the industry's health and safety standards remains a goal of the Government, as does job creation, by having more provincial manufacturing of asbestos -containing products.

In this regard, a study financed by the Quebec Asbestos Mining Association isolated five product areas as the most promising for local manufacturing: Molded friction products, asbestos-cement pipe, asbestos-cement sheet, asbestos papers, and asbestos flooring felts. Details of the second phase of the study were unavailable at yearend, but the study was not expected to promise much hope of achieving the Government's goal of 20% of Quebec fibers being used in local manufacture.

United Asbestos Inc. was placed in default by its bondholders and bank in March, and the mine at Midlothian, Ontario, closed. At yearend, Woodsreef Minerals, Ltd., was studying the property relative to acquisition, and was doing some testing at its facility in Australia.

Asbestos Corp. Ltd. closed its Normandie mine in September, reserves were depleted.

Canadian Johns-Manville Co., Ltd., at first reconsidered, then reinstituted its announced plan to spend $77 million over the next 5 years for facility development at its Jeffrey mine in Asbestos, Quebec.

Carey-Canadian Mines Ltd. completed a $3 million air purification plant for its 230,000-ton-per-year-capacity mill. The company employed 550 people at its open pit mine and mill.

Cassiar Asbestos Corp. Ltd. announced formation of its own marketing department, closure in 1978 of its Clinton mine, and resumption of exploration of its Kutcho Creek deposit in northern British Columbia.

Among the asbestos properties either undergoing exploration or awaiting development or financing decisions are Abitibi Asbestos Mining Co. Ltd. and its property at Amos, Quebec; Great Northern Pulp and Paper Group Ltd. and its Daffodil property in Deloro Township, Ontario; Hollinger Mines Ltd. and its discovery in Newton Township near Timmins, Ontario; McAdam Mining Corp. Ltd. and its own chrysotile property at Roberge Lake, McCorkill Township, near Chibougamau, Quebec, and a joint exploration with Campbell Chibougamau Mines Ltd. on its discovery at McKenzie Bay, Roy Township, Quebec; and Pathfinder Resources Ltd. and its 750-acre Lili property in Cleveland Township, Quebec.

Greece.—In January 1977, Cerro Corp. sold its rights in the Zindanion asbestos mines near Kozani to the Government's Hellenic Industrial Development Bank (ETVA). The bank's own company, Asbestos Mines of Northern Greece, Mining Society Anonyme, will carry out the Government's priority for development of the mine. In November, the company applied formally to the Government for a $68 million investment to establish a 100,000-ton-per-year asbestos plant. A Canadian consulting firm has been retained as technical advisor for plant construction, and at yearend, the firm was conducting site-selection tests.

Japan.—An article discussed the role of asbestos in Japanese industry.[4] As seen in the following tabulation, Japan, like the United States, is largely dependent on foreign sources for its asbestos.

	Short tons				
	1972	1973	1974	1975	1976
Production	13,088	7,489	4,654	4,184	6,988
Imports:					
Canada	107,083	130,637	123,994	62,443	130,773
South Africa, Republic of	90,932	101,782	112,621	90,567	87,676
U.S.S.R	37,379	42,284	58,933	65,681	49,293
Italy	17	--	30	1,258	11,974
United States	4,173	7,179	5,782	4,086	9,157
Australia	11,546	27,329	14,297	4,204	3,947
China, People's Republic of	45	69	1,265	1,092	2,034
Cyprus	861	--	--	--	--
Mozambique	485	--	1,820	--	--
Total	252,521	309,280	318,742	229,331	294,854
Exports	688	233	163	1,958	3,202
Apparent consumption[1]	264,921	316,536	323,233	231,557	298,640

[1]Measured by quantity produced, plus imports, minus exports.

The source countries are of interest, with the exception of 1975, the major suppliers share of the Japanese market has not varied widely in several years. In 1975, the year of the Canadian strike, Canada's share dropped from a nominal 45%-50% of the market to 27%; the U.S.S.R. rose from a nominal 14%-17% share to an alltime high of 29%. The Republic of South Africa's share is normally about 30% of the market, and the United States captures 2% to 3%. Canada, the Republic of South Africa, and the U.S.S.R. had more than 90% of the market in 1976.

Usage of asbestos in Japan differs significantly from that in the United States, and is undergoing changes. It is reported that currently, asbestos-cement sheet uses between 50% and 60% of the total consumption of asbestos. This is down from 66% of the 1973 level of consumption. In 1973, 88% of the consumption went into asbestos-cement products. Two reports of product composition seem noteworthy: One states that a few thousand tons of reprocessed asbestos is used each year in asbestos-cement sheets; this is the only report of asbestos recycling use. The other reports that the chrysotile-to-crocidolite ratio in asbestos-cement pressure pipe is always 1:1, which is a higher than normal usage of crocidolite.

Kenya.—Under contract to the Kenyan Government, a joint Kenyan-Austrian team is geologically surveying and mapping a 20,000-square-mile area near Taita-Taveta which is known to have reserves of asbestos and other minerals.

Oman.—Exploration of an asbestos discovery in the northern mountains near Saham continued. The Government hopes to use the fibers in its new 36,000-ton-per-year-capacity asbestos-cement pipe factory.

South Africa, Republic of.—Although the South African asbestos industry is experiencing larger yearend inventories than anticipated, its growth continued. The inventories forced some layoffs in both amosite and crocidolite production personnel. The asbestos production-machinery industry received a 1-million-Rand order for a milling plant in Turkey. South Africa remains firmly in third place among the world's asbestos producers.

Swaziland.—Havelock Asbestos Mines Ltd. announced that, without further adjacent ore body acquisition, its reserves would be exhausted by 1988. The fact that the Swaziland Government is a 40% partner with Turner and Newall Ltd. in the venture may prove helpful.

United Kingdom.—Imports of asbestos into the United Kingdom were 12% less in 1977 than in 1976, and it was a general rather than patterned, decrease. Each supplying country lost some market. The major supplying countries were Canada, with 69%; Swaziland, with 12%; the Republic of South Africa, with 11%; Cyprus, with 6%; and Italy, with 1%. The Asbestos Advisory Committee (ACA) issued the following interim recommendation for exposure to asbestos: 0.2 fiber per cubic centimeter of air for exposure to crocidolite measured over a 10-minute period; and 2.0 fibers per cubic centimeter for other types of asbestos when averaged over a 4-hour period.

U.S.S.R.—The following tabulation is based on planned production data supplied by the Johns-Manville Corp. after some of its officers visited and consulted with Soviet officials during the summer of 1977:

Complex	Thousand short tons		
	1976	1981	1986
Uralasbest:			
Groups 1-6	1,700	1,700	1,700
Group 7	500	500	500
Dzhetygara	725	850	850
Tuvaasbest	100	250	250
Kiembayev	--	275	550
Total	3,025	3,575	3,850

The Molodezhyy asbestos deposit complex was designed in 1974 for construction when the western section of the Baykal-Amur railway is built.

The following, also based on data from Johns-Manville, shows expected U.S.S.R. export distribution, in thousand short tons:

Year	Eastern Europe	Market economy countries	Total exports
1976	275	325	600
1981	375	375	750
1986	500	450	950

Of real interest is that of the planned 825,000-ton increase in production by 1986; less than half is scheduled for export, and only 125,000 tons of the increase is destined for market economy countries.

Table 8.—Asbestos: World production, by country

(Short tons)

Country[1]	1975	1976	1977[p]
North America:			
Canada (shipments)	1,163,673	1,693,250	1,700,000
Mexico	29	1	--
United States (sold or used by producers)	98,654	114,842	101,704
South America:			
Argentina	1,238	980	972
Brazil	81,547	102,187	[e]105,000
Europe:			
Bulgaria	24,251	[e]22,000	22,000
Finland[2]	3,073	--	--
Italy	[r]162,034	181,649	[e]170,000
U.S.S.R.[e]	2,090,000	2,520,000	2,710,000
Yugoslavia	[r]13,451	14,330	9,994
Africa:			
Egypt	528	1,208	[e]1,210
Rhodesia, Southern[e]	180,000	180,000	220,000
South Africa, Republic of	391,001	407,679	419,059
Swaziland[3]	45,436	46,128	[e]50,000
Asia:			
China, People's Republic of[e]	165,000	190,000	220,000
Cyprus	39,015	38,050	[e]38,600
India	[r]21,999	24,965	22,375
Japan	5,084	8,491	[e]8,800
Korea, Republic of	4,790	5,249	6,812
Taiwan	1,915	940	[e]660
Thailand	--	16	[e]16
Turkey	17,081	10,557	[e]11,000
Oceania: Australia	[r]52,825	60,689	60,627
Total	4,562,624	5,623,211	5,878,829

[e]Estimate. [p]Preliminary. [r]Revised.

[1]In addition to the countries listed, Czechoslovakia, North Korea, and Romania also produce asbestos, but output is not officially reported, and available general information is inadequate for the formulation of reliable estimates of output levels.

[2]Includes asbestos flour.

[3]Exports.

TECHNOLOGY

Environmental Research.—At least three papers in 1977 commented on the lack of specificity in the light optical method of identifying asbestos.[5] Because this method is the only one in present OSHA and MESA (Mining Enforcement and Safety Administration) regulations for use in the working environment, enforcement of the regulations is difficult. The National Institute for Occupational Safety and Health (NIOSH) document, for example, states, "This technique is not specific for asbestos fibers or any other fiber type." These papers demonstrate the need for further research in this area. The Rohl document proposes another method of identification, using electron microscopy to count all fibers, including the very short fibers, but acknowledges that the scientific community does not yet know anything of the biological activity of short chrysotile fiber.[6] Another paper reporting on such research describes both the transmission electron microscope (TEM) and the scanning electron microscope (SEM) as equally capable of counting asbestos fibers in circumstances where specificity is not required.[7]

There has been much research aimed at producing asbestos-dust-monitoring equipment for the workplace, and some sophisticated instruments have been developed by at least four companies. One, using beta ray attenuation, has been selected by the Quebec Asbestos Mining Association for both site and personal monitoring. These instruments are also nonspecific for asbestos, and are not useful for identifying asbestos among other particulate matter.

In a health-related matter, a National Academy of Sciences (NAS) publication states that, ". . . evidence of the toxicity of ingested particles of asbestos minerals is not conclusive. Further research is necessary to resolve this problem."[8] While the foregoing report was being written, a U.S. Army group was writing another, demonstrating that if the fibers in Lake Superior were asbestos, and if they represented a health hazard, the standard U.S. Army Water Purification Equipment (ERDLater Unit) could be used to completely remove them.[9] The process is interesting: A positively charged cationic polyelectrolyte is added to the water. The electrolyte neutralizes the negatively charged single particles, which then aggregate or "bridge" on the long chain polymer. The resulting larger aggregates are easily filtered out when passed through diatomite.

The effort to isolate the health effects of the various types of asbestos continued. It was made difficult by the fact that most asbestos workers in the manufacturing segment of the industry were probably exposed to two or more types if they worked in that environment long enough to have passed the long "latent" stage of the asbestos-related diseases. The importance of this work lies in the fact that some evidence clearly indicates that at least crocidolite is much more dangerous than chrysotile. Some interesting evidence comes from the Journal of Occupational Medicine, in which a 30-year historical cohort mortality study was made of workers exposed only to chrysotile asbestos.[10] The data demonstrate a favorable mortality experience, and the author concludes that the study suggests that the hazard of chrysotile in asbestos-products manufacturing is minimal and that the study is consistent with what is known of the relative dangers of crocidolite, amosite, and chrysotile, with chrysotile being the least dangerous.

Substitutes.—Although synthesis research on asbestos is still being done, environmental problems involving asbestos have aroused interest and research into finding substitutes. A comprehensive research paper in a leading journal reemphasized that no economic route to asbestos synthesis has been found.[11] The high temperatures (300° to 400° C), hydrothermal pressure, and long time (up to 30 days) for synthesis of submicroscopic chrysotile demonstrate the impracticality, so far, of this approach.

Industrial Minerals magazine, in a midyear comment, hypothesized that due to the essential nature of asbestos-containing products, limitation on asbestos usage would be possible only when acceptable alternatives exist.[12] The appearance of true alternatives in some areas, such as alkali-resistant glass fiber for reinforcing cement, is acknowledged, but they are said to have a long way to go on both technical and economic grounds. In August, Turner and Newall Ltd. of the United Kingdom announced a new research unit with a first-year budget of $1.3 million for the sole purpose of accelerating the development of asbestos substitutes.

DuPont Co. announced plans for a multimillion dollar Nafion intermediates plant at Fayetteville, N.C., to start production of four intermediate materials necessary to the production of its Nafion perfluorosulfonic acid copolymers. Films of these copolymers are finding increasing use as asbestos replacements in chlorine-caustic diaphragm cells. Japan's planned replacement of all of its mercury cells with asbestos or membrane diaphragms by March 1978 may be delayed by 2 to 3 years owing to the need to evaluate fully the technologic and economic feasibility.

Some uses of alkali-resistant glass fiber being proposed as an asbestos substitute were discussed in an article in The Glass Industry.[13] The two advantages cited were higher impact strength and shatter resistance, plus the lack of known health hazard. Limitations of cost, fiber strength, durability, and incompatibility with asbestos-cement machinery were not discussed. A later announcement by the British firm, Stelmo International Ltd., of three installations being built in Iran may overcome one of these, at least partially. Stelmo claims that the plants are fully automated and can produce glass-fiber-reinforced cement sheets at high speed. A West German design team developed an experimental structure having a load-bearing hyperbolic paraboloid roof in which glass fibers replace the reinforcing steel.[14]

Cape Board and Panels Ltd., a subsidiary of Cape Asbestos Fibers Ltd., developed a new fire-resistant, noncombustible, insulating board comparable to its Asbestolux, but containing no asbestos. Details are sketchy, but probably cellulose fibers and vermiculite in a calcium silicate binder may be major ingredients.

General.—The Quebec Natural Resources Department announced a new method of extracting magnesium from asbestos tailings. However, query of the researchers revealed that although the work looked promising, the announcement was premature.

Asbestos is among the minerals amenable to the photometric sorting technique developed by Rio Tinto Zinc Ltd. This method uses electronic processing of reflectance measurements to actuate air jets, thereby deflecting selected pieces of ore to another conveyor.

Asbestos cement is the material of choice in building hyperbolic cooling towers. It was used in building Europe's largest towers at the Gösgen nuclear power station in the Federal Republic of Germany. This 499-foot-high tower can reduce the temperature by 14° C of 114,000 cubic meters of water per hour at the station's rated output.

Asbestos-cement pressure pipe was also the material of choice to carry the cooling water necessary for underground transportation of power at a 380-kilovolt range from a West Berlin power station to substations around the city.

---

[1]Physical scientist, Division of Nonmetallic Minerals.

[2]Bulletin of the Quebec Asbestos Mining Association. V. 2, No. 2, February 1978, p. 7.

[3]Industrial Minerals. Asbestos—Now and To Come. No. 119, August 1977, p. 7.

[4]Harbin, P. The Industrial Minerals of Japan, Part II. Ind. Miner., No. 119, August 1977, pp. 15-39.

[5]National Bureau of Standards. A report on the Fiber Content of Eighty Industrial Talc Samples Obtained From, and Using the Procedures of the Occupational Safety and Health Administration. May 1977, 31 pp.

Rohl, A. N., A. M. Langer, and I. J. Selikoff. Environmental Asbestos Pollution Related to Use of Quarried Serpentine Rock. Science, v. 196, No. 4299, June 17, 1977, pp. 1319-1322.

Zumwalde, R. D., and J. M. Dement. Review and Evaluation of Analytical Methods for Environmental Studies of Fibrous Particulate Exposures. NIOSH Rept. 77-204, May 1977, 66 pp.

[6]Second work cited in footnote 5.

[7]Gerber, R. M., and R. C. Rossi. Evaluation of Electron Microscopy for Process Control in the Asbestos Industry. Aerospace Corp. Rept. EPA-600/2-77-059, February 1977, 45 pp.

[8]National Academy of Sciences. Drinking Water and Health. Summary Rept., 1977, 65 pp.

[9]Schmitt, R. P., D. C. Lindston, and T. F. Shannon. Decontaminating Lake Superior of Asbestos Fibers. Environmental Sci. and Technol., v. 11, No. 5, May 1977, pp. 462-465.

[10]Weiss, W. Mortality of a Cohort Exposed to Chrysotile Asbestos. Occupational Medicine, v. 19, No. 11, November 1977, pp. 737-740.

[11]Yada, K., and K. Iishi. Growth and Microstructure of Synthetic Chrysotile. Am. Mineral., v. 62, Nos. 9-10, September-October 1977, pp. 958-965.

[12]Work cited in footnote 3.

[13]Jones, J. Glass Fiber Reinforced Cement. Glass Ind., v. 58, No. 6, June 1977, pp. 26-28.

[14]Engineering News-Record. Glass Fiber Reinforces Self-Supporting Concrete Roof. V. 198, No. 17, Apr. 28, 1977.

Barite

By Stanley K. Haines[1]

Domestic production of barite reached an alltime high of 1.49 million tons in 1977, an increase of 21% over that of 1976. Nevada, with production of 1.16 million tons, was the leading producing State. Other principal producing States were Arkansas and Missouri. Imports of crude barite continued to increase, reaching 955,000 tons in 1977. Oil- and gas-well drilling activity remained high and pushed total consumption of crushed and ground barite to 2.57 million tons, also a record high. Of the total crushed and ground barite, 91% was consumed in drilling muds.

Table 1.—Salient barite and barium-chemical statistics

(Thousand short tons and thousand dollars)

	1973	1974	1975	1976	1977
United States:					
Barite:					
Primary (sold or used by producers)	1,104	1,106	1,318	1,234	1,494
Value	$16,688	$16,822	$21,200	$28,689	$30,264
Exports	68	61	57	41	50
Value	$2,884	$2,518	$2,871	$2,871	$3,436
Imports for consumption	716	729	634	905	955
Value	$7,596	$8,680	$8,541	$17,677	$18,055
Crushed and ground (sold or used by producers)	1,571	1,637	1,807	2,204	2,593
Value	$54,473	$64,394	$73,075	$93,283	$110,409
Barium chemicals (sold or used by producers)	62	56	43	52	56
Value	$13,899	$15,751	$15,556	r$19,698	$23,151
World: Production	4,945	5,109	r5,419	5,666	5,892

rRevised.

DOMESTIC PRODUCTION

U.S. production increased 21% in quantity and 5% in value to 1,494,000 tons of primary barite valued at $30,264,000. This output was 13% higher than the previous record set in 1975. Primary barite is the first marketable product, and includes crude or run-of-mine barite, flotation concentrates, and other beneficiated material such as washer, jig, or magnetic separation concentrates.

Barite was produced at 30 mines: 13 in Nevada, 9 in Missouri, 2 each in Arkansas and Georgia, and 1 each in Idaho, Illinois, Montana, and Tennessee. Nevada remained the leading producing State with 78% of the total quantity and 61% of the total value. The other producing States in descending order of production were Missouri, Arkansas, Georgia, Montana, Illinois, Idaho, and Tennessee.

Run-of-mine barite sold or used by producers represented 38% of total production, down from 48% in 1976; other beneficated material was 57% compared with 44% in 1976; and flotation concentrate was 5% compared with 8% in 1976.

The leading producers of domestic barite for use in well drilling were (in alphabetical order) Baroid Div., NL Industries, Inc., with mines in Arkansas, Missouri, and Nevada; Dresser Minerals Div., Dresser Industries, Inc., with mines in Missouri, and Nevada; IMCO Services Div., Halliburton Co., with mines in Nevada; and Minerals Div., Milchem, Inc., with mines in Missouri and Nevada.

Barite for chemical, glass, and filler uses was sold by C. R. Wood Co., Inc.; Dresser Minerals Div., Dresser Industries, Inc.; Industrial Chemical Div., FMC Corp.; IMCO Services Div., Halliburton Co.; New Riverside Ochre Co.; De Lore Products, Industrial Chemicals Div., NL Industries, Inc.; Paga Mining Co.; Minerals, Pigments, and Metals Div., Pfizer, Inc.; and Standard Slag, Inc.

Imported and/or domestic barite was ground at 41 plants in 12 States. Texas with eight plants and Louisiana with seven had the heaviest concentration of grinding plants, due to the availability of port facilities for imported barite and the close proximity to areas of high drilling activity. Other States with grinding plants were Missouri, with six operations; Nevada and Utah, five each; Arkansas, California, and Georgia, two each; and Alaska, Illinois, Montana, and Tennessee, one each.

In May 1977, IMCO Services dedicated a new barite beneficiation plant near Battle Mountain, Nev. The plant has a capacity of 225,000 tons per year of drilling-mud-grade barite. Ore comes from the Mountain Springs mine of FMC Corp. The beneficiation plant is the first in the United States to include three distinct concentration techniques-jigging, tabling, and flotation.

IMCO also initiated its mining plan for the Clipper mine and associated jigging plant south of Battle Mountain, Nev. The ore was mined by a contractor and fed through a plant containing three Bendelari three-cell jigs. The capacity of the Clipper plant is 150,000 tons per year. The barite will be ground in the grinding plant at Battle Mountain, Nev., or at Houston, Tex.[2]

Tom Norris, Inc., operating under contract to NL Baroid, completed assembly of a jigging plant at NL Baroid's Rossi mine outside of Battle Mountain, Nev. The two Bendelari jigs provide an upgraded feed for the flotation plant 30 miles away.[3]

Table 2.—Barite sold or used by producers in the United States, by State

(Thousand short tons and thousand dollars)

State	1976		1977	
	Quantity	Value	Quantity	Value
Missouri	124	3,860	117	4,061
Nevada	900	18,379	1,158	18,329
Other States[1]	210	6,451	219	7,874
Total	1,234	[2]28,689	1,494	30,264

[1]Includes Arkansas, Georgia, Idaho, Illinois, Montana, and Tennessee.
[2]Data do not add to total shown because of independent rounding.

CONSUMPTION AND USES

Total consumption of barite in 1977 reached a record high of 2,592,000 tons, an increase of 18% over that of 1976. Barite for use as a weighting agent in oil- and gas-well drilling fluids continued as the dominant end use, accounting for 92% of total consumption or 2,372,000 tons. This was an increase of 19% over 1976, and corresponds closely with the increase of 18% in total drilling footage from 181.7 million feet in 1976 to 215.0 million feet in 1977. The average depth drilled was 4,626 feet in 1977, with an average of 22 pounds of barite consumed per foot of drilling.

Barite for use in barium chemicals increased 4% to 81,000 tons in 1977. The largest increase in consumption was in the end use for other filler, from 14,000 tons in 1976 to 31,000 tons in 1977. Paint usage of barite remained about the same as in 1976, at 50,000. Other uses declined 22% to 59,000 tons and included filler in rubber and plastics; flux, oxidizer, and decolorizer in glass manufacture; and miscellaneous uses such as ballast for ships, heavy concrete aggregate, and other unspecified uses.

The data in table 3 are mainly for ground barite, but include the relatively small quantity of crushed barite used primarily in the barium-chemical industry. In 1977, apparent consumption was less than reported consumption. The heavy demands for drilling mud caused most producers to ship all the barite they could produce plus draw down any stocks.

Barite is the principal raw material used in the production of barium chemicals. Producers of barium chemicals in 1977 were J. T. Baker Chemical Co., Phillipsburg, N.J.; Chemical Products Corp., Cartersville, Ga.; Industrial Chemical Div., FMC Corp., Modesto, Calif.; Mallinckrodt, Inc., St. Louis, Mo.; and Chemical Div., Sherwin-Williams Co., Coffeyville, Kans. Sherwin-Williams also produced lithopone. Total production of barium chemicals increased 8%. Sales of barium carbonate increased 2% to 35,700 tons in 1977. The average value was $300.73 per ton in 1977 compared with $138.82 per ton in 1976. Barium carbonate was used in the manufacture of television picture tubes (for screen control), in brick and tile, in barium ferrite manufacture, and for many other purposes.

Table 3.—Crushed and ground barite sold, by use[1]

(Thousand short tons)

Use[2]	1976		1977	
	Quantity	Percent of total	Quantity	Percent of total
Barium chemicals[3]	78	4	81	3
Filler or extender:				
Paint	50	2	50	2
Rubber	W	--	W	--
Other filler	14	1	31	1
Well drilling	1,986	90	2,372	92
Other uses	76	3	59	2
Total	2,204	100	2,593	100

W Withheld to avoid disclosing company proprietary data; included with "Other uses."
[1]Includes imported barite.
[2]Uses reported by producers of ground and crushed barite, except for barium chemicals.
[3]Quantities reported by consumers.

Table 4.—Barium chemicals produced and sold by producers in the United States in 1977[1]

Barium chemical	Plants[2]	Production (short tons)	Sold by producers	
			Quantity (short tons)	Value (thousands)
Barium carbonate	4	35,300	35,700	$10,736
Barium chloride	3	W	W	W
Barium hydroxide	3	W	W	W
Black ash	2	W	W	W
Blanc fixe	1	W	W	W
Other barium chemicals	4	29,600	20,400	12,415
Total	6	64,900	56,100	23,151

W Withheld to avoid disclosing company proprietary data; included with "Other barium chemicals."
[1]Only data reported by barium-chemical plants that consume barite are included.
[2]A plant producing more than one product is counted only once.

PRICES

Prices for barite remained constant, according to the Engineering and Mining Journal. The prices listed in table 5 are from trade publications; they serve as a general guide but do not necessarily reflect actual transactions.

The average value per ton of crude barite was \$20.26, a decrease of \$2.99 per ton from that of 1976. The drop in average value may be partially attributed to the continued increase in production of Nevada barite, which is cheaper to mine and process than ore of other areas. The average value per ton of crushed and ground barite was \$42.60, compared with \$42.56 in 1976.

Table 5.—Barite price quotations in 1977

Item	Price per short ton[1]
Barite:[2]	
Chemical, filler, glass grades, f.o.b. shipping point, carload lots:	
Handpicked, 95% $BaSO_4$, not over 1% Fe	\$46.50- \$55.00
Magnetic or flotation, 96% $BaSO_4$, not over 0.5% Fe	60.00- 70.00
Water-ground, 99.5% $BaSO_4$, 325 mesh, 50-pound bags	60.00- 80.00
Drilling-mud grade:	
Ground, 83%-93% $BaSO_4$, 3%-12% Fe, specific gravity 4.20-4.30, f.o.b. shipping point, carload lots	71.00- 78.00
Crude, imported, specific gravity 4.20-4.30, c.i.f. Gulf ports	19.00- 28.00
Barium chemicals:[3]	
Barium carbonate:	
Precip., bulk, carload lots, freight equalized	250.00- 275.00
Electronics grade, bags, same basis	255.00
Barium chloride:	
Purified cryst., 400 pound drums, at works (per pound)	1.24
Technical cryst., bags, carload lots works	300.00
Anhydrous, bags, carload lots, same basis	400.00
Barium sulfate:	
USP X-ray diagnosis grade, powder, 250-pound drums, 1,250-pound lots (per pound)	.25
Barium sulfide (black ash) drums, carload lots, works	115.00- 150.00

[1]Unless otherwise noted.
[2]Engineering and Mining Journal. V. 178, No. 12, December 1977, pp. 46-47.
[3]Chemical Marketing Reporter. V. 213, No. 26, Dec. 26, 1977, p. 27.

FOREIGN TRADE

Exports of barite increased 21% to about 50,000 tons in 1977. The average value of the exports was \$69.34 per ton. Canada remained the leading recipient of these exports with 31,000 tons. Barite, primarily ground material, was shipped principally from the following customs districts: Seattle, Wash. (38%); Laredo, Tex. (19%); Detroit, Mich. (10%); New Orleans, La. (10%); and Great Falls, Mont. (10%).

Imports of crude barite increased 6% to 955,000 short tons valued at \$18.91 per ton. The principal source countries and the average values per ton were Peru, \$17.68; Ireland, \$12.60; and Mexico, \$17.69.

Most of the crude barite imported was drilling-mud-grade and entered the United States through the following customs districts: New Orleans, La. (47%); Laredo, Tex. (18%); Galveston, Tex. (17%); Houston, Tex. (11%); and Port Arthur, Tex. (7%).

Ground barite imports increased to 19,000 tons valued at \$121,000 in 1977. Mexico was the leading source country. Imports of natural ground witherite were 1,036,000 pounds valued at \$102,600 in 1977. These data are open to question since there has been no reported production of witherite since 1969. These imports, mainly from the Federal Republic of Germany, were probably precipitated (manufactured) barium carbonate.

Imports of barium chemicals increased 47% to 25,000 tons in 1977. Barium carbonate and blanc fixe, the major compounds imported increased 186% and 10%, respectively. The leading source country for lithopone, hydroxide, carbonate, and blanc fixe was the Federal Republic of Germany. The People's Republic of China was the leading source for chloride and nitrate.

The large increase in imports of barium carbonate was the indirect result of the closing of Kaiser Industries' strontium carbonate plant in Canada. The FMC Corp. chemicals plant at Modesto, Calif., increased strontium carbonate production to meet the demand resulting from Kaiser's shutdown. Since barium and strontium chemicals are made with the same equipment, FMC cut back on production of barium carbonate. U.S. consumers found the Federal Republic of Germany ready to supply their needs through exports to the United States.

Table 6.—U.S. exports of natural barium sulfate and carbonate

Country	1976		1977	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Argentina	97	$4	394	$19
Australia	20	4	--	--
Belize	--	--	500	44
Brazil	287	21	146	15
Cameroon	--	--	600	61
Canada	26,382	1,875	31,485	1,782
Chile	--	--	33	1
Colombia	212	9	--	--
Costa Rica	34	1	--	--
Dominican Republic	--	--	28	1
El Salvador	123	17	--	--
France	--	--	51	11
Germany, Federal Republic of	57	3	--	--
Guatemala	9,064	543	--	--
Hong Kong	--	--	40	2
Israel	600	53	--	--
Italy	--	--	66	3
Jamaica	39	2	--	--
Japan	49	24	27	4
Korea, Republic of	--	--	148	6
Mexico	704	32	10,782	1,021
Netherlands	14	1	88	4
Netherlands Antilles	--	--	204	16
New Zealand	--	--	638	67
Paraguay	351	27	1,101	88
Peru	5	1	--	--
Philippines	174	11	33	7
South Africa, Republic of	130	6	79	6
Switzerland	44	2	--	--
Taiwan	52	2	147	6
Trinidad and Tobago	2,500	220	2,500	220
Venezuela	125	13	199	28
Zaire	--	--	262	24
Total	41,063	2,871	49,551	3,426

Table 7.—U.S. exports of lithopone

Year	Quantity (short tons)	Value (thousands)
1975	1,833	$1,060
1976	779	937
1977	435	698

Table 8.—U.S. imports for consumption of barite, by country

(Thousand short tons and thousand dollars)

Country	1976 Quantity	1976 Value	1977 Quantity	1977 Value
Crude barite:				
Canada	62	861	78	1,429
Chile	12	283	27	770
France	27	1,079	--	--
German Democratic Republic	(1)	1	--	--
Germany, Federal Republic of	4	77	--	--
Greece	17	385	17	242
Ireland	199	2,328	211	2,659
Malaysia	--	--	3	42
Mexico	106	1,605	115	2,034
Morocco	101	3,078	74	2,339
Mozambique	18	561	--	--
Peru	210	3,246	267	4,721
Thailand	--	--	75	1,266
Turkey	149	4,173	88	2,553
Total	905	17,677	955	18,055
Ground barite:				
Belgium-Luxembourg	--	--	(1)	1
Canada	(1)	7	(1)	2
Colombia	(1)	2	(1)	1
Germany, Federal Republic of	(1)	(1)	(1)	1
Mexico	13	143	19	116
Total	13	152	19	121

[1]Less than 1/2 unit.

Table 9.—U.S. imports for consumption of barium chemicals

Year	Lithopone Quantity (short tons)	Lithopone Value (thousands)	Blanc fixe (precipitated barium sulfate) Quantity (short tons)	Blanc fixe Value (thousands)	Barium chloride Quantity (short tons)	Barium chloride Value (thousands)	Barium hydroxide Quantity (short tons)	Barium hydroxide Value (thousands)
1975	15	$6	5,443	$2,047	1,199	$358	2,595	$1,492
1976	69	25	7,971	2,643	3,425	690	2,422	1,090
1977	65	27	8,729	3,069	5,384	1,170	2,448	1,222

Year	Barium nitrate Quantity (short tons)	Barium nitrate Value (thousands)	Barium carbonate precipitated Quantity (short tons)	Barium carbonate precipitated Value (thousands)	Other barium compounds Quantity (short tons)	Other barium compounds Value (thousands)
1975	593	$233	681	$111	411	$196
1976	520	122	2,420	423	86	102
1977	899	197	6,911	1,391	395	286

Table 10.—U.S. imports for consumption of crude, unground, and crushed or ground witherite

Year	Crude, unground Quantity (short tons)	Crude, unground Value (thousands)	Crushed or ground Quantity (short tons)	Crushed or ground Value (thousands)
1975	1	(1)	84	$44
1976	6	$5	278	56
1977	--	--	518	103

[1]Less than 1/2 unit.

WORLD REVIEW

World barite production for 1977 increased 4% to 5.9 million tons. U.S. production was 25.4% of the world total.

Japan.—Barite ore reserves were estimated at 8 million tons of 24% $BaSO_4$. The principal producers were Dowa Industry Co., with mines at Fukazawa and Kosaka and a total capacity of 5,000 short tons per month, and Sakoi Chemical, with a mine in Hokkaido and a capacity of 1,100 short tons per month. Most of the domestic production was used for well drilling, with the remainder used for barium chemicals. Japan also imported between 11,000 and 22,000 tons of barite from the People's Republic of China, Thailand, and India.[4]

India.—Mining commenced on a barite deposit located near Mangampet in the Cuddapah District of Andhra Pradesh; reserves were estimated at over 55 million tons. Andhra Pradesh Mining Corp. shipped 12,000 tons to Abu Dhabi during the year.[5]

Iran.—IMCO Services formed a new company, Doreen/IMCO, to develop a barite mine near Keshan, 155 miles south of Tehran. The processing plant is expected to have an annual capacity of 120,000 tons per year or 30% of Iran's requirements.[6]

Ireland.—Shetlands Barytes Co. Ltd. set up a barite grinding plant with a capacity of 40,000 tons per year. The plant was set up in Shetlands due to its function as a major supply point for North Sea drilling activity.[7]

IMCO Services began operation of a jigging plant near Sligo to be operated by its Sligo Bay Barytes Co. subsidiary. The $600,000 plant will have an annual capacity of 50,000 tons and the product will be drilling-grade barite.[8]

Thailand.—Most of Thailand's barite production came from three Provinces, Chiang Mai in the north, Nakhon S. Thammarat in the south, and Loei in the northeast. In the north (435 miles from Bangkok), reserves of 6 million tons have been delineated. Production over the last 2 years has been depressed by the decline in drilling in Southeast Asia. About one-half of Thailand's barite is exported, with the majority going to Singapore and Indonesia.[9]

Endeavor Resources Ltd. of Australia sold its barite interests to NL Industries for about $1.1 million. Plans for a 120,000-ton-per-year barite operation were announced by Pand S Barite Mining Co. The operation is to be in Nakhon Si Thammarat Province.[10]

U.S.S.R.—Barite production reached about 495,000 tons in 1977, about 60% of domestic consumption. Imports were chiefly from North Korea, Yugoslavia, and Bulgaria. Georgia, Kazakhstan, and West Siberia continued to be the principal source areas of barite. Construction continued on a 45,000-ton-per-year complex at Khaishi in Svanetia, Georgia.[11]

---

[1]Physical scientist, Division of Nonmetallic Minerals.
[2]Jackson, D. New Plants Move IMCO Services Into Front Ranks of Nevada Barite Producers. Engineering and Mining Journal, v. 178, No. 7, July 1977, pp. 73-75.
[3]White, L. Nevada Barite Output Up Sharply in 70's. Engineering and Mining Journal, v. 178, No. 6, June 1977, pp. 157-158.
[4]Harben, P. The Industrial Minerals of Japan, Part 2. Industrial Minerals, No. 119, August 1977, p. 32.
[5]Seshardi, G. R. India. Min. Ann. Rev., June 1978, p. 437.
[6]Mining Engineering. Industry Newswatch. V. 29, No. 7, July 1977, p. 18.
[7]Industrial Minerals (London). No. 117, June 1977, p. 14.
[8]Engineering and Mining Journal. Exploration Roundup——In Europe. V. 178, No. 10, October 1977, p. 154.
[9]Industrial Minerals (London). The Industrial Minerals of Thailand. No. 117, June 1977, pp. 15-16, 21.
[10]Mining Annual Review. Thailand. June 1978, p. 454.
[11]Mining Annual Review. U.S.S.R. June 1978, pp. 576-577.

Table 11.—Barite: World production, by country

(Thousand short tons)

Country[1]	1975	1976	1977[p]
North America:			
Canada	90	111	[e]139
Mexico	331	298	[e]309
United States[2]	1,318	1,234	1,494
South America:			
Argentina	43	45	46
Brazil	59	56	[e]55
Chile	7	19	[e]22
Colombia	3	[e]3	[e]3
Peru	[e]255	365	[e]310
Europe:			
Austria	(3)	(3)	(3)
Czechoslovakia[e]	8	8	8
France	101	165	[e]165
German Democratic Republic[e]	34	34	34
Germany, Federal Republic of	273	289	[e]320
Greece[4]	[r]96	48	43
Ireland	325	356	[e]330
Italy	235	197	150
Poland	59	89	[e]94
Portugal	3	(3)	1
Romania[e]	128	128	130
Spain	85	[e]85	[e]90
U.S.S.R.[e]	380	440	495
United Kingdom	56	55	[e]55
Yugoslavia	67	62	[e]65
Africa:			
Algeria	75	[r e]71	[e]72
Egypt	1	(3)	1
Kenya	(3)	[e](3)	(3)
Morocco	[r]151	152	[e]154
South Africa, Republic of	1	2	3
Swaziland	(3)	[e](3)	(3)
Tunisia	[r]16	26	18
Asia:			
Afghanistan[5]	6	6	[e]6
Burma	17	15	17
China, People's Republic of[e]	275	300	330
India	193	215	347
Iran[5]	161	[e]190	[e]190
Japan	41	59	62
Korea, North[e]	[r]130	130	130
Korea, Republic of	2	5	3
Malaysia	1	7	13
Pakistan	5	10	[e]14
Philippines	4	4	6
Thailand	285	167	[e]110
Turkey	[r]73	208	45
Oceania: Australia	26	12	13
Total	[r]5,419	5,666	5,892

[e]Estimate. [p]Preliminary. [r]Revised.

[1]In addition to the countries listed, Bulgaria and Southern Rhodesia also produce barite, but available information is inadequate to make reliable estimates of output levels.

[2]Sold or used by producers.

[3]Less than 1/2 unit.

[4]Barite concentrates.

[5]Year beginning March 21 of that stated.

Bauxite and Alumina

By Horace F. Kurtz[1]

World bauxite production rose 6% and reached a record high level of over 81 million long tons in 1977. Producers in Australia and Jamaica provided most of the increase over the previous year. The production of alumina (aluminum oxide), the intermediate product between bauxite and aluminum metal, also was a new record, totaling over 32 million short tons in 1977. The increases in the output of bauxite and alumina largely reflected a continued growth in world demand for primary aluminum, the principal end use of these commodities.

In the United States, bauxite production increased slightly to nearly 2 million long tons. Alumina production rose about 4% to 6.65 million short tons, while imports of alumina increased 14% to over 4 million tons. Imports provided about 88% of the bauxite used by domestic alumina producers and 38% of the new supply (production plus imports) of alumina.

Legislation and Government Programs.—The Federal Preparedness Agency, General Services Administration (GSA), stockpile inventories at the end of 1977 included about 14.2 million long tons of metal-grade bauxite (excluding excess that had been sold), 173,000 tons of calcined refractory-grade bauxite, and no alumina. Stockpile goals at yearend were 0.5 million long tons of metal-grade bauxite, 2.1 million tons of refractory-grade bauxite, and 11.5 million short tons of alumina.

Table 1.—Salient bauxite statistics

(Thousand long tons and thousand dollars)

	1973	1974	1975	1976	1977
United States:					
Production, crude ore (dry equivalent)	1,879	1,949	1,772	1,958	1,981
Value	$26,635	$25,663	$25,083	$26,645	$28,018
Exports (as shipped)	12	16	19	15	25
Imports for consumption [1]	13,403	14,976	11,529	12,548	12,784
Consumption (dry equivalent)	16,650	16,904	12,388	13,817	14,299
World: Production	69,244	78,362	[r]73,610	[r]76,602	81,102

[r]Revised.
[1]Excludes calcined bauxite. Includes bauxite imported into the Virgin Islands.

DOMESTIC PRODUCTION

Bauxite production in the United States increased 1% to 1.98 million long tons (dry basis) in 1977. Output increased in all three producing States, Alabama, Arkansas, and Georgia. Arkansas again produced 85% of the total. All of the bauxite was mined at open pit operations, as the only underground mine active in recent years did not produce in 1977.

In Arkansas, bauxite was mined by Aluminum Co. of America (Alcoa), American Cyanamid Co., and Reynolds Mining Corp. in Saline County, and by Reynolds in Pulaski County. American Cyanamid calcined bauxite at its plant at Benton, Ark., and Porocel Corp. (owned by Engelhard Minerals & Chemicals Corp.) produced activated bauxite at its Berger plant.

In Alabama, the second largest producing State, bauxite was mined in the Eufaula district, Barbour and Henry Counties, by Abbeville Lime Co., A. P. Green Refractories Co. (U.S. Gypsum Co.), Harbison-Walker Refractories Co. (a division of Dresser Industries, Inc.), Mullite Co. of America (C-E Minerals Div. of Combustion Engineering Inc.), and Wilson-Snead Mining Co. (NL Industries, Inc.). Drying or calcining plants were operated by A. P. Green, Harbison-Walker, and Wilson-Snead.

Bauxite was mined in Sumter County, Ga., by American Cyanamid and Mullite Co. of America. Both companies operated processing plants near Andersonville, Ga.

The production of alumina (excluding aluminates) at the eight Bayer-process alumina plants in the United States and the one plant in the U.S. Virgin Islands increased about 4% to an estimated 6.87 million short tons (6.65 million tons calcined alumina equivalent) in 1977. The total production included an estimated 6.15 million tons of calcined alumina, 620,000 tons of commercial alumina trihydrate, and 100,000 tons of tabular, activated, and other alumina.

Shipments of alumina by producers totaled an estimated 6.79 million tons (6.57 million tons calcined equivalent) and were valued at $970 million. Calcined alumina shipments to primary aluminum plants totaled 5.8 million tons, or 88% of the calcined equivalent of total shipments. The chemical industry, including producers of aluminum fluoride fluxes for aluminum plants, received over half of the remaining tonnage, largely as hydrate. Other shipments of alumina went mainly to producers of abrasives, ceramics, and refractories.

Table 2.—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]
1975:						
Alabama and Georgia	302	[r]230	2,127	175	236	[r]6,117
Arkansas	1,862	1,543	22,956	1,883	1,599	[r]25,412
Total[2]	2,164	1,772	25,083	2,058	1,836	[r]31,529
1976:						
Alabama and Georgia	369	291	2,165	135	214	[r]8,909
Arkansas	2,013	1,667	24,481	2,035	1,728	27,580
Total[2]	2,382	1,958	26,645	[r]2,170	1,941	[r]36,489
1977:						
Alabama and Georgia	381	305	3,166	103	185	8,006
Arkansas	2,016	1,676	24,851	1,933	1,657	26,532
Total[2]	2,397	1,981	28,018	2,036	1,843	34,538

[r]Revised.
[1]Computed from values assigned by producers and from estimates of the Bureau of Mines.
[2]Data may not add to totals shown because of independent rounding.

Table 3.—Recovery of dried, calcined, and activated bauxite in the United States

(Thousand long tons)

Year	Crude ore treated	Total processed bauxite recovered[1]	
		As recovered	Dry equivalent
1976	360	172	284
1977	412	167	289

[1]Dried, calcined, and activated bauxite.

Table 4.—Percent of domestic bauxite shipments, by silica content

SiO_2 (Percent)	1973	1974	1975	1976	1977
Less than 8	6	2	4	6	2
From 8 to 15	61	72	62	50	54
More than 15	33	26	34	44	44

Table 5.—Production and shipments of alumina in the United States

(Thousand short tons)

Year	Calcined alumina	Other alumina [1]	Total: As produced or shipped	Total: Calcined equivalent
Production:[2]				
1973	6,834	734	7,568	7,344
1974	7,059	753	7,812	7,589
1975	5,223	624	5,847	5,660
1976[e]	5,900	700	6,600	6,400
1977[e]	6,150	720	6,870	6,650
Shipments:				
1973	6,822	738	[3]7,561	7,335
1974	7,051	745	7,796	7,575
1975	5,232	628	5,860	5,671
1976[e]	5,900	700	6,600	6,400
1977[e]	6,070	720	6,790	6,570

[e]Estimate.
[1]Trihydrate, activated, tabular, and other aluminas. Excludes calcium and sodium aluminates.
[2]Includes only the end product if one type of alumina was produced and used to make another type of alumina.
[3]Data do not add to total shown because of independent rounding.

Table 6.—Capacities of domestic alumina plants, December 31, 1977[1]

(Thousand short tons per year)

Company and plant	Capacity
Aluminum Co. of America:	
Bauxite, Ark	375
Mobile, Ala	990
Point Comfort, Tex	1,335
Total	2,700
Martin Marietta Aluminum, Inc.: St. Croix, V.I	520
Kaiser Aluminum & Chemical Corp.:	
Baton Rouge, La	1,025
Gramercy, La	800
Total	1,825
Ormet Corp.: Burnside, La	600
Reynolds Metals Co.:	
Hurricane Creek, Ark	840
Corpus Christi, Tex	1,385
Total	2,225
Grand total	7,870

[1]Capacity may vary depending upon the bauxite used.

CONSUMPTION AND USES

The consumption of bauxite in the United States (including the U.S. Virgin Islands) increased nearly 0.5 million long dry tons or about 3% in 1977. Consumption rose in each of the major bauxite consuming industries. About 88% of the bauxite used during the year came from foreign countries.

The production of alumina in various forms required 13.3 million long dry tons of bauxite or 93% of the total bauxite consumption. An estimated average of 2.01 long tons (dry basis) of bauxite was used to produce 1 short ton (calcined basis) of alumina. The two alumina plants in Arkansas used mainly bauxite mined in Arkansas, and the other seven alumina plants used only imported ore.

The refractories industry reported consumption of bauxite totaling 426,000 tons (dry weight basis), an increase of 6% over the previous year. (Data may exclude some bauxite blended with clay by producers and not reported as bauxite consumption.) Nearly all of the bauxite consumed in refractories was used in the calcined form, which weighs about 65% of the dry equivalent weight. Imports comprised 79% of the bauxite used in refractories. Refractory manufacturers reported receipts of about 90,000 tons (dry basis) of domestic bauxite and 325,000 tons of foreign ore. About 94% of the imported ore came from Guyana and nearly all of the remainder came from Surinam. The trends in domestic consumption and availability of refractory raw materials were reviewed.[2]

Five companies consumed imported calcined bauxite in the manufacture of artificial abrasives. Over 60% of the bauxite received by these companies came from Surinam. Australia and Guinea provided most of the remainder. Data on consumption by the abrasives industry include bauxite fused and crushed in Canada because much of the fused product is made into abrasive wheels and coated products in the United States. About 10% to 15% of this material is used for nonabrasive applications, principally refractories.

Bauxite consumption in the chemicals industry increased 6% to 195,000 tons in 1977. Guyana and the United States were the principal sources of bauxite for this industry. The production of commercial aluminum sulfate in the United States, according to the Bureau of the Census, decreased from 1.23 million short tons (revised) in 1976 to 1.16 million tons (preliminary) in 1977.

Other consumers of bauxite, in descending order of magnitude, included the cement, oil and gas, steel, and ferroalloys industries, and municipal waterworks.

Thirty-one U.S. primary aluminum plants consumed 8,701,000 short tons of calcined alumina, 7% more than the 8,117,000 tons consumed in 1976. Alumina consumption data for other uses were not available. A significant quantity was used to make aluminum fluoride and synthetic cryolite, which is also used in the production of primary aluminum.

Table 7.—Bauxite consumed in the United States by industry

(Thousand long tons, dry equivalent)

Year and industry	Domestic	Foreign	Total[1]
1976:			
Alumina	1,652	11,254	12,905
Abrasive[2]	--	260	260
Chemical	[3]67	[3]184	184
Refractory	87	314	401
Other	W	W	67
Total[1] [2]	1,806	12,012	13,817
1977:			
Alumina	1,589	11,750	13,339
Abrasive[2]	--	270	270
Chemical	[3]59	[3]205	195
Refractory	88	338	426
Other	W	W	69
Total[2]	1,736	12,563	14,299

W Withheld to avoid disclosing company proprietary data; included with "Chemical."

[1]Data may not add to totals shown because of independent rounding.

[2]Includes consumption by Canadian abrasive industry.

[3]Includes other uses.

Table 8.—Crude and processed bauxite consumed in the United States

(Thousand long tons, dry equivalent)

Type	Domestic origin	Foreign origin	Total[1]
1976:			
Crude and dried	1,669	11,433	13,102
Calcined and activated	137	578	715
Total	1,806	[1]12,012	13,817
1977:			
Crude and dried	1,602	11,950	13,552
Calcined and activated	134	613	747
Total	1,736	12,563	14,299

[1]Data may not add to totals shown because of independent rounding.

Table 9.—Production and shipments of selected aluminum salts in the United States, in 1976

(Thousand short tons and thousand dollars)

Item	Number of producing plants	Production	Total shipments including interplant transfers	
			Quantity	Value
Aluminum sulfate:				
Commercial (17% Al_2O_3)	67	1,230	1,157	84,843
Municipal (17% Al_2O_3)	2	W	XX	XX
Iron-free (17% Al_2O_3)	18	174	156	8,461
Aluminum chloride:				
Liquid (32°Bé)	5	W	W	W
Crystal (32°Bé)				
Anhydrous (100% $AlCl_3$)	6	35	29	20,483
Aluminum fluoride, technical	4	132	133	50,238
Aluminum hydroxide, trihydrate (100% $Al_2O_3 \cdot 3H_2O$)	6	488	W	W
Other inorganic aluminum compounds[1]	XX	XX	XX	40,162

W Withheld to avoid disclosing company proprietary data. 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 inventories in the United States increased about 2% to a total of 20.9 million long dry tons during 1977. Most of the increase was attributed to a buildup of bauxite stocks at alumina plants. Inventories at domestic bauxite producers rose 100,000 tons. GSA reports indicated that Government stockpiles were reduced over 200,000 tons during the year.

Government stockpiles at the end of 1977 consisted of 8,859,000 tons of Jamaica-type bauxite, 5,719,000 tons of Surinam-type bauxite, and 175,000 tons (270,000 tons, dry basis) of calcined refractory-grade bauxite. About 420,000 tons of the Surinam-type bauxite had been sold and was reported as excess.

Total inventories of calcined and other forms of alumina at plants producing alumina and primary aluminum metal increased from 1.44 million short tons (revised) to 1.67 million tons by the end of the year. The Government held no stocks of alumina except in the form of abrasive grain and crude fused aluminum oxide. These stockpiles were reduced 3% to 312,000 short tons.

Table 10.—Stocks of bauxite in the United States[1]

(Thousand long tons, dry equivalent)

Sector	Dec. 31, 1976	Dec. 31, 1977
Producers and processors	r518	618
Consumers[2]	r4,845	5,412
Government	15,066	14,849
Total[3]	r20,428	20,879

rRevised.
[1]Domestic and foreign bauxite; crude, dried, calcined, activated; all grades.
[2]Includes bauxite stockpiled by the U.S. Government during World War II and purchased by Reynolds Metals Co.
[3]Data may not add to totals shown because of independent rounding.

Table 11.—Stocks of alumina in the United States [1]

(Thousand short tons, calcined equivalent)

Sector	Dec. 31, 1976r	Dec. 31, 1977
Producers[e]	175	250
Primary aluminum plants	1,263	1,423
Total	1,438	1,673

eEstimate. rRevised.
[1]Excludes consumers stocks other than those at primary aluminum plants.

PRICES

Prices on most of the bauxite and alumina produced throughout the world are not quoted because the large tonnages used by the aluminum industry are usually obtained from affiliated companies or purchased under long-term negotiated contracts.

The Bureau of Mines estimated the average value of crude domestic shipments in 1977, f.o.b. mine or plant, at $11.60 per long ton. The average value of shipments of domestic calcined bauxite was estimated at $69 per ton. The Bureau's estimates of the value of shipments were based on incomplete data supplied by producers. Bauxite values among producers varied widely because of differences in grade.

The value of imported bauxite consumed at alumina plants in the United States was believed to have increased in 1977, but sufficient company data were not available to determine an average value. Engineering and Mining Journal published the following prices on super-calcined, refractory-grade bauxite imported from Guyana, car lots, per metric ton:

	January-February	March-November	December
F.o.b. Baltimore, Md	$117.28	$135.27	$138.42
F.o.b. Mobile, Ala	117.28	135.77	138.42

The estimated average value of domestic shipments of calcined alumina was $139 per short ton in 1977, compared with $128 (revised) in 1976. The average value of imported alumina (including small quantities of hydrate), as reported by the Bureau of the Census, was $124 per ton at port of shipment and $131 per ton at U.S. ports (c.i.f.). Exports of alumina from the United States and the Virgin Islands averaged $149 per ton.

Table 12.—Average value of U.S. imports of crude and dried bauxite in 1977[1]

(Per long ton)

Country[2]	Port of shipment (f.a.s.)	Delivered to U.S. ports (c.i.f.)
Dominican Republic	$29.62	$34.23
Guinea	20.27	28.15
Guyana	22.69	33.45
Haiti	26.67	30.66
Jamaica	27.95	30.95
Surinam	23.18	32.11
Other	9.93	14.97
Weighted average	25.73	30.74

[1]Not adjusted for moisture content.
[2]Excludes bauxite imported into the U.S. Virgin Islands.

Source: Based on data reported to U.S. Customs Service and compiled by the Bureau of the Census, U.S. Department of Commerce.

Table 13.—Market quotations on alumina and aluminum compounds

(Per short ton, in bags, carlots, freight equalized)

Compound	Dec. 31, 1976	Jan. 2, 1978
Alumina, calcined	$158	$207
Alumina, hydrated, heavy	118	130
Alumina, activated, granular, works	320-360	320
Aluminum sulfate, commercial, ground (17% Al_2O_3)	121	129
Aluminum sulfate, iron-free, dry (17% Al_2O_3)	140	140

Source: Chemical Marketing Reporter.

FOREIGN TRADE

Exports from the United States classified as "bauxite and concentrates of aluminum excluding alumina" totaled 25,000 long tons in 1977 and were valued at $2.34 million.

Canada received 65% of the total.

Alumina exports declined 18% to 944,000 short tons, including 37,000 tons of aluminum hydroxide. The total also included shipments of 326,000 tons of alumina to the U.S.S.R. and 38,000 tons to Norway from the alumina plant in the U.S. Virgin Islands. Most of the other exports were shipments from domestic alumina plants on the gulf coast to aluminum plants in Ghana, Mexico, and Canada.

Aluminum sulfate exports fell sharply from 51,000 short tons in 1976 to 12,000 tons, valued at $900,000, in 1977. About 7,000 tons were shipped to Canada. Exports of artificial corundum or fused aluminum oxide decreased about 2,000 tons to 20,000 tons, valued at $13.2 million. Canada, the largest recipient among 55 countries, received 9,000 tons. Exports classified as "other aluminum compounds" declined 7,000 tons to 34,000 tons, valued at $17.6 million. Much of the tonnage in this category was believed to be aluminum fluoride and synthetic cryolite shipped to other countries for use as a flux in making primary aluminum. About 9,000 tons was shipped to Ghana, 8,000 tons to Surinam, 5,000 tons to Canada, and 4,000 tons to Venezuela.

The United States imposed no duties on imports of bauxite, alumina, or aluminum hydroxide in 1977. All duties on these commodities were suspended in 1971.

Imports of crude, partially dried, and dried bauxite into the United States and the U.S. Virgin Islands increased 2% to 12.8 million long tons in 1977. Receipts from Surinam increased over 300,000 tons and showed the largest gain among supplying countries. Jamaica again provided nearly half (49%) of the total. Imports from Guinea provided 23% of the total, Surinam provided 15%, and Haiti, the Dominican Republic, and Guyana provided most of the remainder.

Calcined bauxite imports decreased 23% to 238,000 long calcined tons. Most of this tonnage was refractory-grade bauxite from Guyana. Additional calcined bauxite was imported into Canada for manufacture into crude fused aluminum oxide, much of which was subsequently used in abrasive and refractory products in the United States. This bauxite was imported into Canada principally from Surinam but also from Australia, Guinea, and other countries.

Alumina imports, including small quantities of aluminum hydroxide, increased 14% to a record high level of 4.15 million short tons, valued at $512 million at the port of shipment ($544 million, c.i.f.). Imports increased from all three of the principal supplying countries, Australia, Jamaica, and Surinam. Shipments from Australia, largely to aluminum plants in the Pacific Northwest, provided 69% of the total imports. Imports of crude aluminum oxide abrasive, virtually all of which came from Canada, totalled 180,000 short tons in 1977, compared with 174,000 tons in 1976.

Table 14.—U.S. exports of alumina,[1] by country

(Thousand short tons and thousand dollars)

Country	1975		1976		1977	
	Quantity	Value	Quantity	Value	Quantity	Value
Australia	2	896	2	862	2	757
Belgium-Luxembourg	1	598	1	413	1	872
Brazil	1	496	2	1,037	5	1,588
Canada	217	30,350	314	47,912	80	17,929
France	2	556	4	1,329	4	1,851
Germany, Federal Republic of	4	2,565	4	3,091	4	3,679
Ghana	156	15,112	243	29,410	237	29,183
Japan	4	4,329	2	2,879	2	2,765
Mexico	131	16,483	124	17,407	136	20,947
Netherlands	1	543	1	727	1	818
Norway	164	19,961	48	5,390	38	4,255
Poland	(2)	21	28	3,248	--	--
Sweden	1	442	29	3,420	60	8,027
U.S.S.R.	158	16,935	272	26,808	357	38,208
United Kingdom	4	2,181	6	2,509	5	2,198
Venezuela	104	9,812	73	9,503	2	1,363
Yugoslavia	69	7,258	--	--	--	--
Other	10	5,535	5	3,973	10	6,576
Total	1,029	134,073	1,158	159,918	944	141,016

[1]Includes exports of aluminum hydroxide: 1975—24,000 tons, 1976—35,000 tons, 1977—37,000 tons; includes alumina exported from the U.S. Virgin Islands to foreign countries: 1975—263,000 tons, 1976—309,000 tons, 1977— 364,000 tons.

[2]Less than 1/2 unit.

Table 15.—U.S. imports for consumption of bauxite, crude and dried, by country[1]

(Thousand long tons)

Country	1975	1976	1977
Australia	93	--	(2)
Dominican Republic[3]	742	509	574
Greece	26	--	56
Guinea	2,598	3,016	2,981
Guyana	295	635	374
Haiti	495	606	578
Jamaica[3]	5,396	6,185	6,254
Sierra Leone	27	53	79
Surinam	1,857	1,544	1,888
Other	--	(2)	(2)
Total	11,529	12,548	12,784

[1]Includes bauxite imported into the U.S. Virgin Islands from foreign countries: 1975—939,000 tons, 1976—902,000 tons, 1977—858,000 tons.
[2]Less than 1/2 unit.
[3]Dry equivalent of shipments to the United States.

Table 16.—U.S. imports for consumption of bauxite (calcined), by country

(Thousand long tons and thousand dollars)

Country	1975		1976		1977	
	Quantity	Value [1]	Quantity	Value [1]	Quantity	Value [1]
China, People's Republic of	14	350	11	861	--	--
Guyana	255	22,585	263	22,546	216	21,635
Surinam	64	2,291	33	1,790	21	1,755
Trinidad and Tobago[2]	15	1,463	(3)	25	--	--
Other	(3)	3	2	176	1	54
Total	348	26,692	309	25,398	238	23,444

[1]Value at foreign port of shipment as compiled by U.S. Bureau of the Census.
[2]Shipments probably originated in Guyana or Surinam.
[3]Less than 1/2 unit.

Table 17.—U.S. imports for consumption of alumina,[1] by country

(Thousand short tons and thousand dollars)

Country	1975		1976		1977	
	Quantity	Value[2]	Quantity	Value[2]	Quantity	Value[2]
Australia	2,154	201,748	2,751	284,497	2,855	318,760
Canada	21	3,289	14	2,504	23	4,260
France	11	14,563	10	13,734	9	13,539
Germany, Federal Republic of	4	2,126	6	3,485	28	6,995
Guyana	22	1,651	13	839	59	6,610
Italy	29	2,673	--	--	--	--
Jamaica	779	96,609	616	79,526	693	106,889
Japan	(3)	22	(3)	91	57	6,813
Surinam	487	46,969	210	18,699	421	47,750
Other	(3)	389	4	1,103	(3)	797
Total	3,507	370,039	3,624	404,478	4,145	512,413

[1]Includes small quantities of aluminum hydroxide; excludes shipments from the U.S. Virgin Islands to the United States: 1975—131,000 tons ($16,410,000), 1976—165,000 tons ($19,394,000), 1977—104,862 tons ($17,492,940).
[2]Value at foreign port of shipment as compiled by U.S. Bureau of the Census.
[3]Less than 1/2 unit.

WORLD REVIEW

The total bauxite production of the 27 producing countries throughout the world rose an estimated 6% to over 81 million long tons in 1977. Australia was by far the largest producer, accounting for about 32% of the world total. Australia increased output by nearly 2 million tons, Jamaica by over 1 million tons, and Indonesia and Greece by about 0.5 million tons each. France was the only country that showed a large decline in production. The bauxite industries of the Caribbean and northern South American countries were included in a review of mining activities in this area.[3]

World production of alumina gained an estimated 10% to 32.4 million short tons. The largest increase occurred in Canada where production had been curtailed by strikes in 1976. Major increases were also recorded in Australia, Jamaica, and Japan in 1977. Australia and the United States together produced 43% of the world total. World alumina capacity did not change significantly during the year.

At its annual ministerial meeting, the International Bauxite Association, an organization of 11 bauxite exporting countries, recommended a minimum c.i.f. price of $24 per metric ton ($24.39 per long ton) for "base-grade" bauxite in the North American market for 1978.

Australia.—Comalco Ltd., Nabalco Pty. Ltd., and Alcoa of Australia (W.A.) Ltd., accounted for virtually all of the bauxite and alumina produced in Australia, the world's largest producer of both commodities.

Comalco, owned by Kaiser Aluminum & Chemical Corp. (45%), Conzinc Riotinto of Australia, Ltd. (45%), and the public (10%), produced 9.9 million long tons of bauxite at its mines in the Weipa area of the Cape York Peninsula in Queensland. The mining and processing procedures and facilities at Weipa were described.[4] An expansion of bauxite production capacity to over 11 million tons was underway in 1977. Bauxite shipments during the year totaled about 9.3 million tons, of which 52% went to the affiliated alumina plant of Queensland Alumina Ltd. at Gladstone, 19% to Japan, and 29% to Italy and other countries. The production of calcined bauxite, largely for the abrasives industry, declined marginally in 1977. Alumina production by Queensland Alumina reached a record level of 2.34 million short tons.

Nabalco, owned by Swiss Aluminium Ltd. (Alusuisse) (70%) and Gove Alumina Ltd. (30%), produced bauxite at Gove, Northern Territory, both for export and for conversion to alumina at its adjacent plant. Bauxite production totaled about 5.1 million long tons, and alumina production exceeded the nominal capacity of 1.1 million short tons by 10%. The company decided to alter its alumina plant by 1980 to produce the sandy type rather than the floury type of alumina and to increase nominal capacity to 1.2 million tons.

Alcoa of Australia, owned by Aluminum Co. of America (51%) and three Australian mining companies (49%), mined bauxite in the Darling Range of Western Australia. All of the bauxite production was used in Alcoa's two alumina plants, located at Kwinana and Pinjarro, which had a combined annual capacity of about 3.75 million short tons. Alcoa withdrew from a proposed consortium to build an alumina plant at Wagerup, south of Pinjarra, and was expected to proceed with construction of a new plant at that location without other partners.

The consortium from which Alcoa withdrew as a potential partner, planned to proceed with its project, relocating the plant site to Worsley, Western Australia, and was reportedly seeking additional participants to join Reynolds Metals Co. and Alwest Pty. Ltd., owned by Dampier Mining Co. Ltd. and News Ltd. The proposed alumina plant would have an annual capacity of 0.9 to 1.1 million tons and would cost an estimated $650 million.

Alumax, Inc., was reported to be engaged in feasibility studies for the development of bauxite deposits on leases it held in the Mitchell Plateau area of Western Australia. The possibilities of a bauxite-alumina complex and the production of refractory-grade bauxite were reportedly under investigation.

Brazil.—Construction continued at the Trombetas River bauxite project of Mineração Rio do Norte S.A., and bauxite shipments were scheduled to begin early in 1979. The joint venture was to have an initial annual production capacity of 3.3 million long tons, and increases to 5 million tons and possibly 10 million tons were being considered. At yearend Rio do Norte was owned by Cia. Vale do Rio Doce (CVRD), 46%; Alcan Aluminium Ltd., 19%; Cia. Brasileira de Aluminio S.A., 10%; Reynolds Metals Co. 5%; and four European aluminum companies, 5% each. Rio Tinto Zinc (RTZ) sold its 5% interest in the venture to CVRD during the year. Construction of an alumina plant of 880,000 short tons capacity at the Trombetas shipping port has been proposed.

RTZ's Mineração Vera Cruz Ltda. was conducting exploration and feasibility studies on its large bauxite deposit in the

Paragominas area south of Belém during 1977. The Government approved an agreement for CVRD to purchase a 36% interest in Mineração Vera Cruz. Ethyl Corp. was reported to have sold its bauxite-kaolin concession in the Jari area of Amapa to Gulf & Western Industries, Inc. The bauxite at this site was reportedly less extensive than originally believed. Bauxite occurrences in the Amazon Basin were described.[5]

Cia. Mineira de Alumínio, owned 50% by Alcoa, undertook an expansion of its integrated facilities at Poços de Caldas, Minas Gerais, including an increase of 44,000 tons in the annual capacity of its alumina plant to a total capacity of 198,000 tons.

The Alunorte project, a proposal to construct an 880,000-ton-per-year alumina plant near Belém, was scheduled for initial production in 1982. Alunorte will be owned by CVRD, 60%, and 32 Japanese companies, 40%. The refinery was expected to use either Paragominas bauxite supplied by Vera Cruz or Trombetas bauxite supplied by Rio do Norte.

France.—Bauxite production in France declined for the fifth consecutive year and totaled less than 2 million long tons in 1977, the first time since 1963. Bauxite deposits and mining techniques in France were described.[6]

Greece.—Nucleonics Hellas S.A. announced the discovery of a gibbsitic bauxite deposit in the Florina area of northern Greece. The deposit was believed to contain 100 million tons, and proved reserves were reported at 25 million tons. Greek bauxite export quotas for 1978 were increased 26% to 2.9 million tons.

Guinea.—Guinea Bauxite Co. (CBG) was the largest of three bauxite producers in Guinea and produced 7.1 million long tons in 1977. CBG was owned by the Government of Guinea (49%) and Halco (51%), a consortium of aluminum producers owned by Alcoa (27%), Alcan (27%), Martin Marietta Aluminum, Inc. (20%), Pechiney Ugine Kuhlmann Group (PUK) (10%), Vereinigte Aluminium-Werke AG (VAW) (10%), and Alumetal S.p.A. (6%). CBG's mining operations at Sangaredi and the transportation and processing of bauxite from this mine were described in the literature.[7]

Friguia, also owned by the Government of Guinea (49%) and a consortium of aluminum producers, Frialco, (51%), produced bauxite entirely for its alumina plant located at Kimbo, the only alumina plant in Africa. Frialco was owned by Noranda Mines Ltd. (38.5%), PUK (36.5%), British Aluminium Co., Ltd. (10%), Alusuisse (10%), and VAW (5%).

The third bauxite producer was the Kindia Bauxite Office (OBK), owned by the Government of Guinea and operated with the U.S.S.R. assistance. Production was believed to have been about 2.5 million tons, most of which was exported to the U.S.S.R. The Government and the U.S.S.R. signed a protocol in January for increased assistance by the U.S.S.R. in the exploration of bauxite deposits in Guinea. More intensive exploration was to be carried out in the Kindia, Gaoual, Pata, and Labé regions.

Alusuisse reported that prospecting had been completed for a feasibility study on the development of the Ayékoyé bauxite deposits, located near the CBG concession. The study was for a proposed large bauxite-alumina complex to be constructed by a joint venture of the Governments of Guinea, Egypt, Iraq, Kuwait, Libya, Saudi Arabia, and the United Arab Emirates.

Guyana.—The Government-owned bauxite producing companies, Guyana Bauxite Co. Ltd. (Guybau) and Berbice Mining Enterprise (Bermine), were merged into one company, Guyana Mining Enterprise, Ltd. (Guymine), which will operate as a subsidiary of the Government-owned Bauxite Industry Development Co. Ltd. (BIDCO). A paper was presented describing the production of specialty grades of bauxite in Guyana, the world's largest producer of refractory-grade bauxite.[8]

India.—The Government of India was considering the construction of two export oriented 660,000-ton-per-year alumina plants to be located on India's east coast. The plants would be based on huge bauxite deposits still being explored in the States of Orissa and Andhra Pradesh. It was reported that the U.S.S.R. had agreed to prepare a feasibility study for bauxite mining and an alumina plant in Andhra Pradesh and indicated its desire to take half of the plant's output in return for financing. A feasibility study for construction of an alumina-aluminum complex in Orissa was expected to be awarded to one of the major international aluminum companies. This project was expected to have excess alumina available for export even if an aluminum smelter is constructed.

Ireland.—In November, Alcan Aluminium Ltd., Billiton B.V. (a company within the Royal-Dutch Shell group), and The Anaconda Company announced agreement to construct an 880,000-short-ton-per-year alumina plant on Aughinish Island in the Shannon River estuary, County Limerick. The plant will be operated by Aughinish Alumina Ltd., 40% of which will be owned by Alcan, 35% by Billiton, and 25% by Anaconda. This project was launched in 1974 by Alcan with different partners but deferred in 1975 because of the world recession.

Construction of the plant was to begin in 1978, and production was expected to start in 1982. The plant will employ approximately 800 people and will be based on the use of imported bauxite, probably from Guinea and Brazil. The total cost of construction was estimated to be in excess of $500 million. It will be possible to expand alumina capacity at this location up to a maximum of 2.6 million tons per year.

Jamaica.—Bauxite and alumina were produced by affiliates of five North American aluminum companies, Alcan, Alcoa, Anaconda, Kaiser, and Reynolds. In addition to the bauxite produced to supply the four alumina plants operated during the year, Jamaican bauxite was exported to the United States by Alcoa, Kaiser, and Reynolds. Total bauxite exports increased 1% to 6.25 million long tons (dry basis) in 1977. Exports of alumina increased 25% to 2.24 million short tons. An agreement was signed by the Government of Jamaica to sell 1.1 million short tons of alumina to Venezuela over a 7-year period beginning in mid-1978. Reportedly, the Government will purchase the alumina from Alcan.

The Government established the bauxite production levy rate for 1977 at 7.5% of the average realized price of aluminum ingot. A base levy, which assumed a price of 51 cents per pound for primary aluminum, was set at $17.79 per ton of bauxite. The past use of Jamaican bauxite lands and current government land use policies were reviewed.[9]

Kaiser and the Jamaican Government signed an agreement in February to form a bauxite mining partnership under terms similar to those reached in a preliminary agreement in 1974. The Government was to purchase 51% of the mining assets of Kaiser Bauxite Co. at book value over a 10-year period, and a new mining company, Kaiser Jamaica Bauxite Co., was to be created. Kaiser also agreed to sell to the Government all of its bauxite land and other lands not needed for plant operations. In return, Kaiser was assured of mining leases to provide a 40-year supply of bauxite for its two alumina plants in Louisiana and an initial production levy rate of 7.5%, with provisions for adjustments of that rate. In April, Reynolds and the Government signed a similar agreement, under which the Government would purchase all of Reynolds land holdings and a 51% interest in the mining assets of Reynolds Jamaica Mines Ltd. Reynolds was also assured of a 40-year supply of bauxite and an initial production levy of 7.5%. The new joint mining venture was to be called Jamaica Reynolds Bauxite Partners.

Total production at the Ewarton and Kirkvine alumina plants, owned by Alcan Jamaica Ltd., increased 5% to 887,000 short tons. Talks between the Government and Alcan regarding ownership of land and bauxite reserves and Government participation in Alcan's equity continued during 1977.

The bauxite mine and alumina plant of Revere Jamaica Alumina, Ltd., have remained closed since August 1975. In a suit filed by Revere against the Government, a Jamaican Court ruled that the bauxite production levy imposed on Revere was valid but that no levy was payable for a year (1976) in which there was no production.[10] The Overseas Private Investment Corp. (OPIC), a U.S. Government insurance agency, reportedly denied a claim by Revere for expropriation compensation regarding its facilities in Jamaica. However, Revere continued to press its claim through arbitration proceedings, asserting that the Jamaican production levy was in effect expropriation.

Japan.—Japan was completely dependent on imports for its supply of aluminum raw materials and was the world's second largest importer of bauxite. Bauxite receipts in 1977 totaled 5,234,000 long tons, of which 3,423,000 tons came from Australia, 1,189,000 tons from Indonesia, 513,000 tons from Malaysia, and 109,000 tons from Guyana and other countries. An additional 1,027,000 short tons of alumina was imported for use in making aluminum. Virtually all of the alumina came from Australia. During the year, Nippon Light Metal Co., Ltd. was converting its alumina plant at Tomakomai from the production of floury-type alumina to sandy-type alumina.

Solomon Islands.—A feasibility study was completed on the development of a bauxite-alumina complex in the Solomon Islands based on bauxite resources of 50 to 60 million tons on Rennell and Wagina

Islands. A request by Mitsui Mining and Smelting Co. Ltd., that the project be deferred was rejected by the Government, and the future of the project was uncertain. Mitsui was to have had a 50% interest in the project, and Pacific Aluminium Ltd., a subsidiary of Conzinc Riotinto of Australia, Ltd., and the Government would each have had a 25% interest.

Surinam.—Metallurgical and special grades of bauxite were mined by Surinam Aluminum Co. (Suralco), an Alcoa subsidiary, in the Moengo area of eastern Surinam and by Suralco and N.V. Billiton Mij. Suriname in the Paranam area. Suralco also produced alumina and aluminum and converted bauxite to alumina for Billiton.

Exports of bauxite from Surinam totaled 2.17 million long tons in 1977, an increase of about 10% from the previous year. Over 90% of the bauxite exported was shipped to the United States, and most of the remainder was shipped to Canada and Europe. Alumina exports increased 4% to 1.22 million short tons. About 53% of the exports of alumina was shipped to Europe, and 37% was shipped to the United States.

Yugoslavia.—Reports indicated that Yugoslavia planned to double its production of bauxite to about 4 million long tons per year and to increase alumina production to about 1.8 million short tons by 1980. In 1977, alumina plants were under construction at Obrovac, Croatia, and Zvornik, Bosnia-Hercegovina. Production at the 330,000-ton-per-year plant at Obrovac was not expected to begin until 1978, although it had been previously scheduled for an earlier date. The plant at Zvornik, which will have a designed annual capacity of 660,000

Table 18.—Bauxite: World production, by country

(Thousand long tons)

Country	1975	1976	1977[p]
North America:			
Dominican Republic[1 2]	742	508	632
Haiti[3]	514	650	579
Jamaica[4]	11,388	10,149	11,253
United States[1]	1,772	1,958	1,981
South America:			
Brazil	954	983	[e]985
Guyana[e 1]	3,200	2,640	2,690
Surinam	4,850	[e]4,540	4,730
Europe:			
France[5]	2,523	2,293	1,996
Germany, Federal Republic of	1	[r](6)	--
Greece	[r]2,958	2,511	2,936
Hungary	[r]2,844	2,872	2,901
Italy	32	24	34
Romania	767	876	886
Spain	11	13	14
U.S.S.R.[e 7]	4,300	4,400	4,500
Yugoslavia	2,270	2,001	2,012
Africa:			
Ghana	314	263	240
Guinea	[r]8,273	11,137	[e]11,140
Mozambique	[r]5	5	5
Rhodesia, Southern[e]	2	2	2
Sierra Leone	705	650	740
Asia:			
China, People's Republic of[e]	[r]970	[r]970	1,180
India	1,253	1,425	1,487
Indonesia	977	925	1,435
Malaysia	692	650	606
Pakistan	--	(6)	(6)
Turkey	621	454	[e]480
Oceania: Australia	20,672	23,703	25,658
Total	[r]73,610	76,602	81,102

[e]Estimate. [p]Preliminary. [r]Revised.
[1]Dry bauxite equivalent of crude ore.
[2]Shipments.
[3]Dry bauxite equivalent of ore processed by drying plant.
[4]Bauxite processed for conversion to alumina in Jamaica plus exports of kiln-dried ore.
[5]Includes bauxite identified as "usable for fabrication of alumina" as follows in short tons: 1975, 2,311; 1976, 2,214; 1977, not available.
[6]Less than 1/2 unit.
[7]In addition to the bauxite reported in the body of the table, the U.S.S.R. produces nepheline syenite concentrates and alunite ore as sources of aluminum. Estimated concentrate production of nepheline syenite was as follows in thousand long tons: 1975, 3,350; 1976, 3,440; 1977, 3,540; and estimated alunite production was as follows, in thousand long tons: 1975, 590; 1976, 590; 1977, 590. Nepheline syenite grades 25% to 30% alumina and alunite ore grades 16% to 18% alumina. These commodities can be converted to a bauxite equivalent by using factors of 1 ton of nepheline syenite concentrate equals 0.55 ton bauxite and 1 ton of alunite equals 0.34 ton bauxite.

Table 19.—Alumina: World production,[1] by country

(Thousand short tons)

Country[2]	1975	1976	1977[p]
North America:			
Canada	1,250	550	1,200
Jamaica	2,489	1,787	2,244
United States	5,660	[e]6,400	[e]6,650
South America:			
Brazil	[r]295	334	[e]410
Guyana	343	309	299
Surinam	1,265	1,146	1,290
Europe:			
Czechoslovakia[e]	110	100	110
France	1,206	1,124	1,192
German Democratic Republic	53	49	51
Germany, Federal Republic of	1,374	1,470	[e]1,540
Greece	[r]506	495	523
Hungary	[r]834	832	[e]840
Italy[e]	820	[r]830	830
Romania	440	440	[e]440
United Kingdom	91	106	[e]110
U.S.S.R.[e]	2,600	2,800	2,900
Yugoslavia	312	502	[e]530
Africa: Guinea	709	617	[e]660
Asia:			
China, People's Republic of[e]	[r]500	500	600
India	371	487	[e]430
Japan	1,725	1,556	1,967
Taiwan	51	53	[e]55
Turkey	90	154	[e]200
Oceania: Australia	[r]5,654	6,841	7,341
Total	[r]28,748	29,482	32,412

[e]Estimate. [p]Preliminary. [r]Revised.
[1]Figures generally represent calcined alumina equivalent of total alumina production.
[2]In addition to the countries listed, Austria produces alumina (fused aluminum oxide), but output is entirely for abrasives production. Output totaled 31,110 short tons in 1973; production data for 1975-77 are not available.

Table 20.—World annual alumina capacity

(Thousand short tons, yearend)

Country	1975	1976	1977
North America:			
Canada	1,387	1,387	1,387
Jamaica	[r]3,365	[r]3,365	3,365
United States	7,805	7,805	7,870
South America:			
Brazil	365	[r]430	430
Guyana	390	390	390
Surinam	1,490	1,490	1,490
Europe:			
Czechoslovakia	110	110	110
France	1,460	1,440	1,440
German Democratic Republic	70	70	70
Germany, Federal Republic of	1,916	1,906	1,906
Greece	551	551	551
Hungary	[e]800	851	871
Italy	1,014	1,014	1,014
Romania	550	550	550
United Kingdom	110	138	143
U.S.S.R.[e]	3,500	3,500	3,750
Yugoslavia	683	[r]683	683
Africa: Guinea	772	772	772
Asia:			
China, People's Republic of[e]	400	500	600
India	725	749	752
Japan	2,709	2,904	2,904
Taiwan	84	84	154
Turkey	220	220	220
Oceania: Australia	7,385	7,430	7,535
Total	[r]37,861	[r]38,339	38,957

[e]Estimate. [r]Revised.

tons, was also expected to come onstream in 1978.

Venezuela.—Corporación Venezolana de Guayana (CVG), a Government regional development agency, announced the discovery of a major bauxite deposit near Los Pijiguaos, south of the Orinoco River, in the Cedeño district in the Guayana area of Bolivar State. Exploration had confirmed 50 million tons of trihydrate-type bauxite of over 50% Al_2O_3, and the total tonnage in this area was believed to be on the order of 500 million tons. The ore contains 6% to 10% SiO_2 but averages only 2% to 2.5% reactive SiO_2. Mining at a rate of 2 to 3 million tons per year was expected to begin about 1983.

Interamericana de Alúmina, C.A. (INTERALUMINA) was incorporated in October 1977, to produce alumina at a new 1.1-million-short-ton-per-year plant to be constructed at Ciudad Guayana, on the Orinoco River. Interalumina is owned by CVG (85%), Alusuisse (7.5%), and Billiton International Metals B.V. (7.5%). Ground breaking for the plant was scheduled for 1978, and production from the first unit was scheduled for 1981. The plant, which will cost an estimated $680 million, was expected to use imported bauxite initially and Venezuelan bauxite when production at the Los Pijiguaos deposits comes onstream.

TECHNOLOGY

A report prepared for the U.S. Environmental Protection Agency concerning the use of mud wastes generated in the domestic production of alumina concluded that there was no possibility for utilizing the muds that could significantly reduce the need for impoundment in the near future.[11] The report recommended further research on mud dewatering, utilization, and methods of impoundment.

The Federal Bureau of Mines continued its research program on the recovery of alumina from clay, anorthosite, and other raw materials abundant in the United States. The most promising technologies for extracting alumina were being tested and developed in small pilot plants, or miniplants, at the Bureau's Boulder City (Nev.) Metallurgy Engineering Laboratory. Additional research in support of this effort was being conducted at other Bureau research centers. The miniplant program was initiated to evaluate the various processes on a comparative basis and to obtain cost and engineering data for the design and operation of large-scale demonstration plants. Six companies were participating with the Bureau in the miniplant project on a cooperative cost-sharing basis. In 1977, the major emphasis of the miniplant program was on the hydrochloric acid process for recovering alumina from clay, and test runs of several sections of this miniplant were completed.[12]

The first task of a three-part, $1.6 million contract awarded by the Bureau to Kaiser Engineers in 1976 was completed. Six raw material/process technology alternatives were evaluated for their potential commercial success as a source of alumina from a domestic nonbauxitic material. The Bureau selected two processes for a more detailed analysis in the second task of the contract. The third task will be the design of a 25-ton-per-day pilot plant based on the most promising process. Contracts totaling $0.3 million also were awarded to Colorado School of Mines Research Institute and to PEDCO Environmental, Inc., for studies on the environmental factors involved in metallurgical processes utilizing domestic resources in the production of alumina.

The Energy Research and Development Administration (ERDA) announced that it would participate with Alcoa in jointly-funded research to develop a direct reduction process to make aluminum-silicon alloy from low-grade aluminum raw materials.[13] The process, which would also produce ferrosilicon, would use coal rather than electricity as its source of energy. ERDA, together with Iowa State University, was also investigating processes to recover alumina from fly ash generated at coal-burning powerplants.[14]

The possibilities of an integrated aluminum industry based on the kaolinitic clays of Georgia were examined.[15] Processes to recover alumina from alunite were also discussed.[16]

---

[1]Industry economist, Division of Nonferrous Metals.

[2]Hicks, J. C. Refractory Raw Materials: Status of Supply. Am. Ceram. Soc. Bull., v. 56, No. 9, September 1977, pp. 774-780.

[3]Engineering and Mining Journal. The Caribbean: New Faces in a Mixed Mining Scene. V. 178, No. 11, November 1977, pp. 49-198.

[4]Roberts, R. H. Bauxite Mining-Weipa 1967-1977. Soc. Min. Eng., AIME, Fall Meeting, Oct. 19-21, 1977, Preprint 77-H-328, 40 pp.

[5]Dennen, W. H., and H. A. Norton. Geology and Geochemistry of Bauxite Deposits in the Lower Amazon Basin. Econ. Geol., v. 72, January-February 1977, pp. 82-89.

Greig, E. W. Trombetas and Other Amazon Bauxites, Brazil. AIME Ann. Meeting, Mar. 6-10, 1977, Preprint 77-H-92, 34 pp.

[6]Deschamps, J. M. Bauxite Mining at Les Baux de Provence, France. Soc. Min. Eng., AIME, Fall Meeting, Oct. 19-21, 1977, Preprint 77-H-392, 12 pp.

Mining Magazine. Mining Bauxite in France. V. 138, No. 6, June 1978, pp. 546-553

[7]Hoppe, R. W. Sangaredi Pit in Guinea Carves Up a Rich Deposit of Solid Bauxite. Eng. and Min. J., v. 178, No. 6, June 1977, pp. 138-140.

——. Sangaredi—An African Plateau of Bauxite. Eng. and Min. J., v. 178, No. 8, August 1977, pp. 83-90.

[8]Lachmansingh, S. V., and G. A. Nooten. The Occurrence and Production of Specialty Grades of Bauxite in Guyana. AIME Ann. Meeting, Mar. 6-10, 1977, Preprint 77-H-31, 15 pp.

[9]Lyew-Ayee, P. A. Special Paper, Optimal Utilization of Bauxite Lands in Jamaica, Policies and Strategies. I.B.A. Quarterly Review, v. 3, No. 2, Dec. 31, 1977, pp. 27-32.

[10]Smith, C. J. Opinion in Suit No. C. L. 1976/2.004. In the Supreme Court of Jamaica, May 30, 1977, 41 pp.

[11]Parekh, B. K., and W. M. Goldberger. An Assessment of Technology for Possible Utilization of Bayer Process Muds. U.S. Environmental Protection Agency Technol. Series. EPA-600/2-76-301, December 1976, 143 pp.

[12]Poppleton, H. D., and D. L. Sawyer. Hydrochloric Acid Leaching of Calcined Kaolin to Produce Alumina. Proc. 106th AIME Ann. Meeting, Atlanta, Ga., Mar. 6-10, 1977. Light Metals, v. 2, 1977, pp. 103-114.

[13]American Metal Market. ERDA to Join Alcoa in Striving for Coal-Fueled Aluminum Smelting., V. 85, No. 173, Sept. 7, 1977, pp. 12, 17.

[14]Energy Research and Development Admininstration. ERDA Coal Waste Recovery Process Could Help Meet U.S. Aluminum Needs. Information from ERDA, Weekly Announcements, v. 2, No. 39, Oct. 8, 1976, 1 p.

Environmental Science and Technology. V. 11, No. 9, September 1977, p. 846.

[15]Husted, J. E. An Integrated Aluminum Industry for the Southeast—Concerns and Outlook. Min. Cong. J., v. 63, No. 9, September 1977, pp. 28-33.

[16]López, W. X. Three Methods to Produce Alumina From Alunite. Proc. 106th AIME Ann. Meeting, Atlanta, Ga., Mar. 6-10, 1977. Light Metals, v. 2, 1977, pp. 49-58.

Beryllium

By Benjamin Petkof[1]

Bertrandite mined in Utah was the major source of beryllium used in the United States and was a significant part of the world beryllium mineral supply. A minor amount of beryl was produced domestically. Consumption of beryllium ore increased, imports declined, and exports of beryllium materials increased.

Legislation and Government Programs.—Strategic stockpile goals issued October 1, 1976 by the Federal Preparedness Agency of the General Services Administration remained unchanged during 1977. There were no releases of beryllium materials from the strategic stockpile during the year.

Public hearings were held in August and September by the Occupational Safety and Health Administration (OSHA) of the U.S. Department of Labor on proposed beryllium occupational safety and health standards as published in the Federal Register, October 17, 1975. Additional written statements were accepted for the record until December 12, 1977.

Table 1.—Salient beryllium mineral statistics

	1973	1974	1975	1976	1977
United States:					
Beryl, approximately 11% BeO:					
Shipped from mines short tons	W	W	W	W	W
Imports do	1,586	1,368	1,479	1,058	746
Consumption[1] do	8,695	9,279	4,850	3,740	4,165
Price, approximate, per unit BeO, imported cobbed beryl at port of exportation	$30	$30	r$32	r$36	$40
Bertrandite ore: Utah, low-grade, shipped from mines short tons	W	W	W	W	W
World production of beryl do	3,963	3,469	r3,290	r2,675	2,656

rRevised. W Withheld to avoid disclosing individual company confidential data.
[1]Includes bertrandite ore, which was calculated as equivalent to beryl containing 11% BeO.

DOMESTIC PRODUCTION

Brush Wellman, Inc. (Brush) at its Spor Mountain operation in Millard County, Utah, was the only major domestic producer of beryllium concentrates. The company mined bertrandite for processing into beryllium hydroxide. A small quantity of beryl production was reported in South Dakota.

Brush converted its ore to beryllium hydroxide at a facility north of Delta, Utah, and shipped the hydroxide to its facility at Elmore, Ohio for conversion into various beryllium products.

During 1977 Brush closed its Elmore, Ohio beryl-processing plant and completed construction and startup of a facility to process imported beryl ore at its Delta, Utah location. In addition, Brush announcnounced that it expected to recover uranium oxide as a byproduct from its beryllium extraction operations.

Kawecki-Berylco Industries, Inc. (KBI) produced beryllium metal, alloys, and oxide at its plants in Hazelton and Reading, Pa. from imported beryl ore that was converted to beryllium hydroxide.

Domestic production of beryllium metal and beryllium oxide declined significantly from that of the previous year. Beryllium-copper master alloy production declined slightly. Production of beryllia ceramic and beryllium-copper master alloy was expected to increase to meet the future demands of the electrical and electronic industries. Improved production of metal will occur with the inception of new space and nuclear energy programs specifying the use of beryllium metal.

CONSUMPTION AND USES

The domestic beryllium industry consumed beryllium ore equivalent to 4,165 tons of beryl containing a nominal 11% BeO, an increase of 11% from that of 1976.

Beryllium metal, with its high stiffness-to-weight ratio and excellent thermal properties was used in items such as inertial navigation systems, satellite structures, space optics, nuclear devices, and military aircraft brakes.

Products utilizing beryllium-copper alloys accounted for the greatest quantity of beryllium consumption. These alloys were used by the business machine, appliance, transportation, and communications industries. Beryllium-copper alloys were also widely used in electrical and electronic systems for connectors, sockets, switches, and temperature- and pressure-sensing devices to provide reliability and long service life.

Beryllium oxide ceramics were used in lasers, microwave tubes, and semiconductors, primarily for heat dissipation. Beryllia was used as a substrate in various electronic devices and equipment.

STOCKS

Consumer stocks of beryllium minerals containing nominal 11% BeO totaled 3,557 tons at yearend 1977, a 10% decrease from those of 1976. Dealer stocks of beryl were not reported.

PRICES AND SPECIFICATIONS

Metals Week quoted the price of imported beryl at $40 to $42 per short-ton unit of contained BeO throughout the year. At yearend, American Metal Market quoted the following prices for beryllium materials: Vacuum cast ingot, $109 per pound; metal beads (1,000-pound lots), $86.50 per pound; metal powder (5,000-pound lots), $96 per pound; metal rod, $166.90 per pound; beryllium-copper master alloy, $78 per pound of contained beryllium; beryllium-copper casting alloy, $2.75 to $3.15 per pound; beryllium copper in strip, rod, bar and wire, $4.31 per pound; beryllium-aluminum alloy ingot (100,000-pound lots), $78 per pound; and beryllium oxide powder, $26 per pound. All beryllium metal quotations were for 97% purity metal.

FOREIGN TRADE

Exports of wrought and unwrought beryllium alloys and of waste and scrap increased 41% in quantity over those of 1976. Total value of exports increased 9%, but average value declined from $15.38 per pound to $11.91 per pound. On the basis of quantity, 53% of total material exported went to Japan, 28% to Canada, and 8% to France.

Beryl ore imports decreased 29% in quantity and 22% in value from those of 1976. The average value of imported material was $399 per ton compared with $359 per ton in 1976. Major sources of imports were Brazil (63%) and Argentina (24%). In addition, 9,174 pounds of wrought, unwrought, and waste and scrap beryllium metal valued at $35,598 were imported primarily from Mexico and the United Kingdom.

Table 2.—U.S. exports of beryllium alloys, wrought or unwrought, and waste and scrap[1]

Country	1976 Quantity (pounds)	1976 Value (thousands)	1977 Quantity (pounds)	1977 Value (thousands)
Argentina	--	--	967	$21
Australia	--	--	797	3
Austria	32	$1	--	--
Belgium	4	2	549	5
Canada	3,204	63	44,472	28
France	4,718	325	13,414	571
Germany, West	701	92	855	65
Hong Kong	3,000	8	--	--
Italy	2,419	49	56	1
Jamaica	--	--	832	4
Japan	12,591	255	84,410	624
Mexico	73,960	61	4,000	9
Netherlands	1,407	63	1,356	38
Switzerland	2,374	89	30	11
United Kingdom	9,568	742	7,912	521
Other	165	6	855	10
Total	114,143	1,756	160,505	1,911

[1]Consisting of beryllium lumps, single crystals, powder; beryllium-base alloy powder; beryllium rods, sheets, and wire.

Table 3.—U.S. imports for consumption of beryl, by customs district and country

Customs district and country	1976 Quantity (short tons)	1976 Value (thousands)	1977 Quantity (short tons)	1977 Value (thousands)
Philadelphia district:				
Argentina	--	--	66	$22
Australia	103	$38	15	3
Bolivia	11	3	--	--
Brazil	512	201	370	162
France	103	35	--	--
India	120	46	--	--
Rwanda	66	14	--	--
South Africa, Republic of	97	34	32	12
Spain	--	--	9	4
Uganda	44	9	--	--
Total	1,056	380	492	203
Los Angeles district:				
Argentina	--	--	111	38
Brazil	--	--	99	42
Mozambique	--	--	22	6
Rwanda	--	--	22	9
Total	--	--	254	95
New York City district: Mozambique	2	([1])	--	--
Grand total	1,058	380	746	298

[1]Less than 1/2 unit.

WORLD REVIEW

In 1977, world production of beryl continued its downward trend of recent years. Only one major producing nation had any significant increase in production. Production in all other producing nations remained at the same level or declined.

The capability to mine and process low-grade bertrandite ore has maintained the position of the United States as a significant source of commercial beryllium minerals. In addition, the United States and the U.S.S.R. are the major consumers of world beryllium mineral production.

Table 4.—Beryl: World production, by country

(Short tons)

Country[1]	1975	1976	1977[p]
Angola[e]	35	([2])	--
Argentina	303	123	[e]110
Brazil[e]	[r]770	500	470
Madagascar	17	19	[e]15
Mozambique	[r]9	[e]10	[e]10
Portugal	[r]23	--	--
Rhodesia, Southern[e]	70	70	70
Rwanda	20	[e]70	[e]60
South Africa, Republic of	[r]3	3	[e]1
Uganda[e]	60	60	50
U.S.S.R.[e]	1,760	1,820	1,870
United States	W	W	W
Zambia[e]	220	--	--
Total	[r]3,290	2,675	2,656

[e]Estimate. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing individual company confidential data.
[1]In addition to the countries listed, Bolivia and the Territory of South-West Africa (Namibia) may also have produced beryl, but available information is inadequate to formulate reliable estimates of output levels.
[2]Revised to zero.

TECHNOLOGY

Studies relating to the formation of beryllium deposits in western Utah have been reviewed to develop favorable indicators of the presence of epithermal beryllium and associated deposits.[2]

A method was devised for manufacturing a thin-walled beryllium metal structure. The process required beryllium powder that was mixed with a minor quantity of silicon powder. The mix was plasma-sprayed on to a substrate, removed, exposed to a wet atmosphere to pick up moisture, placed in a sizing die with a coefficient of expansion similar to that of beryllium, out-gassed in a vacuum at high temperature, and finally sintered in an inert atmosphere.[3]

A method to measure beryllium concentrations in particulate matter using chelation gas chromatography was developed. This technique was used to observe beryllium levels in suspended particulate matter in ambient air conditions over rural, suburban, and industrial environments. A description of experimental data and techniques was presented.[4]

---

[1]Physical scientist, Division of Nonferrous Metals.
[2]Lindsey, D. A. Epithermal Beryllium Deposits in Water-Laid Tuff, Western Utah. Econ. Geol., v. 72, 1977, pp. 219-232.
[3]Hovis, V. M. Jr., and W. G. Northcutt, Jr. (assigned to the U.S. Energy Research and Development Administration). Method for Fabricating Beryllium Structures. U.S. Pat. 4,011,076, Mar. 8, 1977.
[4]Ross, W. D., J. L. Pyle, and R. E. Sievers. Analysis for Beryllium in Ambient Air Particulates by Gas Chromatography. Environmental Sci. & Technol., v. 11, No. 5, May 1977, pp. 467-471.

Bismuth

By James F. Carlin, Jr.[1]

Exports of bismuth increased during the year; domestic consumption, domestic production, and imports of bismuth all declined in 1977. Consumption was 2.4 million pounds, the same as that of 1976. Exports increased to 95,334 pounds, a gain of 39% over the 1976 level. Imports declined 14% to 2.0 million pounds. The decline was attributed to reduced demand. The domestic producer price for bismuth continued its downward trend of recent years: The price held firm at $7.50 for the first half of the year, but by September had fallen to $4.50 per pound where it remained through December. World bismuth mine production was 8.8 million pounds, an increase of 4% over that of 1976. The general pattern of production was unchanged from that of 1976.

Table 1.—Salient bismuth statistics

(Pounds)

	1973	1974	1975	1976	1977
United States:					
Consumption	2,906,219	2,283,978	1,406,021	2,410,584	2,379,635
Exports[1]	151,053	329,926	128,893	68,488	95,334
Imports, general	2,683,671	1,893,744	1,331,173	2,328,051	2,013,333
Price: New York, average per pound (ton lots)	$4.92	$8.41	$7.72	$7.50	$6.01
Stocks Dec. 31: Consumer	540,756	596,757	451,250	483,810	436,092
World: Production[2]	8,205,000	10,631,000	[r]8,776,000	[r]8,532,000	8,844,000

[r]Revised.
[1]Includes bismuth, bismuth alloys, and waste and scrap.
[2]Excludes the United States.

Legislation and Government Programs.—Government stocks of bismuth remained at 2,081,298 pounds, including 567,186 pounds in the national stockpile and 1,514,112 pounds in the supplemental stockpile. On October 7, 1977, the stockpile goals were reaffirmed by the President, including the goal of 771,000 pounds for bismuth. No action was taken to dispose of the 1,310,298 pounds of excess. Bismuth remained on the list of commodities eligible for exploration assistance under the program administered by the U.S. Geological Survey's Office of Minerals Exploration. However, no funds were available in 1977 for exploration projects, and none has been available since fiscal year 1974.

Federal income tax laws under the Tax Reform Act of 1969 provided a percentage depletion allowance of 22% for domestic production and 14% for U.S. companies producing from foreign sources.

DOMESTIC PRODUCTION

Bismuth was produced almost entirely from the treatment of lead ores and bullion of both foreign and domestic origin. A single primary refinery operated by ASARCO Inc. at Omaha, Nebr., accounted for all primary U.S. production. A small quantity of bismuth was also recovered by recycling secondary material at the United Refining and Smelting Co., Franklin Park, Ill. U.S. refinery production statistics are withheld to avoid disclosing company confidential data.

CONSUMPTION AND USES

Consumption of bismuth in the United States during 1977 was 2.4 million pounds, the same as the quantity consumed in 1976. Consumption in most categories was about the same as that of 1976. Fusible alloys registered an increase of 18%, to 611,219 pounds. Experimental uses declined to 601 pounds from 8,756 pounds in 1976.

Table 2.—Bismuth metal consumed in the United States, by use

(Pounds)

Use	1976	1977
Fusible alloys	518,648	611,219
Metallurgical additives	455,940	461,573
Other alloys	20,263	18,617
Pharmaceuticals[1]	1,391,663	1,274,510
Experimental uses	8,756	601
Other uses	15,314	13,115
Total	2,410,584	2,379,635

[1]Includes industrial and laboratory chemicals and cosmetics.

STOCKS

Consumer stocks at yearend totaled 436,092 pounds, a decline of 47,718 pounds during the year. No data are available on producer or dealer stocks.

PRICES

The domestic producer price for refined bismuth was $7.50 per pound at the beginning of 1977 and declined in several stages, ending the year at $4.50 per pound. Dealer quotations started the year at $4.65 to $4.80 per pound and ended the year at $2.70 to $2.80 per pound. Price weakness was evident throughout the year.

FOREIGN TRADE

Exports of bismuth in all forms rose to 95,334 pounds, an increase of 26,846 pounds over the 1976 figure. During 1977, bismuth was exported to 13 countries, with 5 countries receiving 95% of the total shipments. The principal recipients were the Netherlands (47,479 pounds), Canada (17,648 pounds), the United Kingdom (11,657 pounds), India (9,686 pounds), and Belgium-Luxembourg (4,247 pounds).

Table 3.—U.S. exports of bismuth[1]

Year	Gross weight (pounds)	Value
1974	329,926	$1,520,105
1975[2]	128,893	635,717
1976[2]	68,488	513,660
1977	95,334	636,506

[1]Includes bismuth, bismuth alloys, and waste and scrap.
[2]Adjusted by the Bureau of Mines.

General imports of metallic bismuth in 1977 totaled 2.0 million pounds, down 314,718 pounds compared with those of 1976. The imports were from Peru (31%), the United Kingdom and the Federal Republic of Germany (12% each), Chile (Bolivia) (10%), Japan and Mexico (9% each), the Republic of Korea (8%), Belgium-Luxembourg (7%), and Canada (2%). Chile does not produce bismuth in any form; however, official U.S. statistics report Bolivian bismuth shipped, via a Chilean port, as originating in the intermediate nation.

Table 4.—U.S. general imports[1] of metallic bismuth, by country

Country	1976		1977	
	Quantity (pounds)	Value (thousands)	Quantity (pounds)	Value (thousands)
Belgium-Luxembourg	151,690	$790	137,606	$687
Canada	100,983	612	20,020	124
Chile	107,364	694	208,792	1,296
Germany, Federal Republic of	288,028	2,152	243,465	1,635
India	55,000	299	--	--
Italy	2,203	12	--	--
Japan	278,995	1,634	187,948	946
Korea, Republic of	177,666	970	156,784	499
Mexico	248,120	1,509	182,175	843
Peru	569,078	3,261	632,368	2,766
United Kingdom	307,818	2,037	244,175	1,442
Yugoslavia	41,106	184	--	--
Total	2,328,051	14,154	2,013,333	10,238

[1]General imports and imports for consumption were the same in 1976 and 1977.

WORLD REVIEW

World production of bismuth in 1977 was essentially the same as in 1976. This was attributable primarily to the lack of full economic recovery throughout the world, especially in Europe and Japan. All of the major bismuth-producing countries produced at levels comparable with those in 1976.

Australia.—Mine production of bismuth in Australia rose nominally, from 1.4 million pounds in 1976 to 1.5 million pounds in 1977. Production continued to be less than maximum since copper mining by Peko-Wallsend Ltd. at Tennant Creek in the Northern Territory remained dormant. The main source of bismuth in Australia was a gold-bismuth bullion from the Mount Isa mine in Queensland, which was shipped through northern Europe for gold recovery; the residue was then shipped forward to the United Kingdom for bismuth recovery and refining. Small amounts of bismuth were also shipped from Australia as byproducts in lead ores and concentrates; however, the bismuth assays were too low to be accountable for production purposes.

Bolivia.—Bolivian production of bismuth in 1977 was 1.4 million pounds, virtually the same output as in 1976. Most of the bismuth was either mined directly from high-grade deposits or produced from complex copper-tin ores. The new Corporación Minera de Bolivia (COMIBOL) refinery at Quechisla, Potosi, continued its production of high-purity refined bismuth. Bolivia's output ranks it among the top five countries in world bismuth production.

Canada.—Bismuth metal was produced

by two companies in Canada. The bismuth section of the Belledune plant of Brunswick Mining & Smelting Corp. Ltd. was largely inactive during 1977 due to the declining price of bismuth. Bismuth was also produced by Cominco Ltd. at its lead-zinc plant in Trail, British Columbia. Most bismuth produced in Canada came from Canadian ores, with small amounts derived from imported ores. Under a new agreement with Sullivan Mining Group, Billiton Exploration Canada will conduct an extensive feasibility study of the Sullivan-owned tungsten-bismuth-molybdenum project in the Mount Pleasant area of southern New Brunswick.

Mexico.—Production of bismuth in Mexico was 1.3 million pounds, up slightly from the 1976 output. The two companies that produced bismuth were Industrial Minera Mexico, S.A., at its Chihuahua, Chihuahua plant, and Met Mex Peñoles, S.A., which in 1977 moved its bismuth production from Monterrey to its new lead refinery in Torreon, Coahuila.

Peru.—Bismuth production in Peru continued at a steady level, totaling 1.3 million pounds in 1977. Bismuth was produced at the Oroya works, managed by Centromin-Peru, and marketed worldwide by Minero Peru Comercial.

[1]Physical scientist, Division of Nonferrous Metals.

Table 5.—Bismuth: World mine production, by country

(Thousand pounds)

Country[1]	1975	1976	1977[p]
Argentina (in ore)	[r]1	--	--
Australia (in concentrates)	[r]1,861	1,398	1,455
Bolivia	[2]1,348	1,349	[e]1,350
Canada	345	286	310
China, People's Republic of (in ore)[e]	550	550	550
France (metal)	123	139	[e]145
Germany, Federal Republic of (in ore)[e]	23	23	23
Japan (metal)	[r]1,436	1,501	[e]1,523
Korea, Republic of (metal)	249	384	[e]400
Mexico[3]	[r]1,003	1,228	[e]1,260
Mozambique[e]	9	--	--
Peru[3]	1,354	1,149	1,300
Romania (in ore)[e]	180	180	180
Sweden (in ore)[e]	33	33	33
Uganda (in ore)[e]	9	10	7
U.S.S.R. (metal)[e]	130	130	145
United States	W	W	W
Yugoslavia	122	172	163
Total	[r]8,776	8,532	8,844

[e]Estimate. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing individual company confidential data; not included in total.

[1]In addition to the countries listed, Brazil, Bulgaria, German Democratic Republic, and the Territory of South-West Africa (Namibia) are believed to produce bismuth, but available information is inadequate for formulation of reliable estimates of output levels.

[2]Production by COMIBOL plus exports by medium and small mines.

[3]Bismuth content of refined metal, bullion, and alloys produced indigenously, plus recoverable bismuth content of domestic ores and concentrates exported for processing.

Boron

By Sandra T. Absalom[1]

U.S. production and sales of boron minerals increased dramatically in 1977, attaining an alltime high of 1.5 million tons valued at $236 million. Unprecedented markets for energy-saving materials, spurred by rising fuel prices and the national energy conservation program, were responsible for the strong demand for borates in insulation products and glass-fiber-reinforced plastics. Production of borate minerals and compounds approached capacity levels of the major producers; with respect to boric acid, insufficient domestic capacity to satisfy the demand of the cellulosic insulation industry resulted in a significant quantity of imports for the first time in history.

Fiberglass insulation (glass wool) materials constituted the largest end use for borates, representing more than one-fifth of the total U.S. consumption of 121,090 short tons of boron content. Cellulosic insulation (paper wool) consumed another 15%, and textile-grade glass fibers and borosilicate glasses accounted for 12% each. While the three classifications of glasses have historically accounted for about half of the annual borate consumption, use of borates as flame retardants for cellulosic materials became a major end use in 1977.

California was the domestic source of borate minerals, mostly in the form of sodium borate, but also as calcium borate and sodium-calcium borates. Imports from Turkey of calcium borate (colemanite), primarily for textile-grade fiberglass manufacture, nearly doubled in 1977. Although domestic markets for borates were extremely active, the United States provided most of the domestic supply while maintaining its position as the primary source of sodium borate products and boric acid to foreign markets.

Table 1.—Salient boron minerals and compounds statistics in the United States

(Thousand short tons and thousand dollars)

	1973	1974	1975	1976	1977
Sold or used by producers:					
Quantity:					
Gross weight	1,225	1,185	1,172	1,246	1,469
Boron oxide, content	664	619	603	630	735
Boron, content	207	193	188	196	228
Value	$113,648	$128,306	$158,772	$184,852	$236,163
Imports for consumption:					
Colemanite:					
Quantity	18	21	28	30	51
Value	$568	$852	$1,560	$1,953	$3,695
Boric acid:					
Quantity	(1)	(1)	(1)	(1)	14
Value	$3	$149	$59	$14	$5,596

[1]Less than 1/2 unit.

DOMESTIC PRODUCTION

Production and sales (including exports) of boron-containing minerals and compounds increased 18% in tonnage and 28% in value in 1977. Kern County, Calif., provided about three-quarters of the supply and San Bernardino and Inyo Counties provided the balance. Boric acid sold or used by U.S. producers increased to 158,500 short tons valued at $42.4 million, compared with 130,000 tons valued at $30.5 million in 1976.

At Boron, in Kern County, the open pit tincal-kernite mine and adjacent refining plant of U.S. Borax and Chemical Corp., a member of the RTZ Group of London, England, continued to be the primary world supplier of sodium borates. U.S. Borax mined daily as much as 12,000 tons of ore, from which it processed at the Boron refinery crude and refined hydrated sodium borates and their anhydrous derivatives, and anhydrous boric acid. At a plant located at Wilmington, Calif., U.S. Borax produced boric acid and a variety of specialty chemicals. Toward yearend 1977, the company began production of a boric acid-sodium sulfate chemical in the temporarily idle anhydrous boric acid plant at Boron. This product was produced for the cellulosic insulation industry. Future production will depend upon continued strong demand for flame-retardant chemicals in cellulose.

During the year, the U.S. Borax project to expand productive capacity for sodium borates was redirected to the proposed construction of a new boric acid facility at Boron. Due for completion in 1980, the $74 million facility will have double the capacity of the existing Wilmington plant, which eventually will phase out production of technical-grade boric acid.

Despite the redirection of its expansion program, U.S. Borax increased output and sales of all primary borate products in 1977. Output of refined decahydrate, pentahydrate, and anhydrous borax increased 41% and accounted for over one-half of the company's total sales. Production and sales of crude sodium borates, Rasorite 46 (a pentahydrate) and its anhydrous derivative, for foreign markets increased 2% over the 1976 figure. In the past, the crude products represented almost one-half of U.S. Borax's output and sales; however, the substantial increase in refined sodium borate products in 1977 had the effect of reducing this proportion to slightly more than one-third.

The previously planned 25% expansion of boric acid capacity at Wilmington was achieved in 1977 despite engineering problems in the 50-year-old plant, which is also used for the manufacture of borate soap products, herbicides, and other high-quality specialty chemicals. In addition, the Wilmington facilities served as a warehouse and overseas shipping point for bulk shipments. A large percentage of U.S. Borax's exports were shipped to Europe via the warehouse and distribution facility at Botlek, Rotterdam, Netherlands. RTZ Borax, Ltd., another member of the RTZ Group, maintains this facility.

U.S. Borax operated a plant and warehousing facility at Burlington, Iowa, for compounding, packaging, and distributing household soaps and other consumer products to the Eastern and Midwestern United States. The combined capacity of U.S. Borax operations in 1977 exceeded 600,000 short tons of boric oxide (B_2O_3) equivalent (about 187,000 tons of contained boron).

Kerr-McGee Corp. operated the Trona and Westend plants at Searles Lake, San Bernardino County to produce sodium borates and boric acid from the mineral-rich lake brines. Coproducts included potassium compounds, lithium carbonate, soda ash, and salt cake. Combined capacities of the two plants normally approach 130,000 tons of B_2O_3 equivalent per year; however, in response to the expansive market for boric acid during 1977, Kerr-McGee adjusted its products ratio, effectively increasing output of boric acid by 26% while decreasing output of refined sodium borates by 18%. As a result, total output and sales were 8% below the 1976 level. Kerr-McGee's marketable supply of borax pentahydrate, which is used to produce boric acid, was most affected by the adjustment; output and sales of this compound decreased 65%.

At the Trona plant, Kerr-McGee utilized its differential evaporative process, with annual capacity of 100,000 equivalent tons of B_2O_3, to produce pentahydrate, decahydrate, and anhydrous borax, and boric acid. Solvent-extraction capacity to produce additional boric acid from weak lake brines and recycled plant liquors was expanded during the year. Production of borates by the carbonation process at the Westend plant was formerly limited to 25,000 tons of B_2O_3 capacity in the form of sodium borates, but during the latter part of 1977 equipment for boric acid production was installed. Kerr-McGee predicted that overall capacity for boric acid at both plants would soon double that of 1976, contingent upon continued growth of the market.

American Borate Corp., the third U.S. producer, increased sales of colemanite (calcium borate) and ulexite-probertite (two similar sodium-calcium borates mined and sold as one) by 36% and 31%, respectively. The company's two deposits, each composed of various proportions of the three minerals, are located within the Death Valley National Monument, Inyo County. By yearend, both open pits were nearly depleted of economic-grade ore, and American Borate was attempting to extend the ore supply until development of the Billie underground mine is completed. Methods of extension involved stockpiling of mined ore and reducing the average B_2O_3 content of the final products below that of previous years. Colemanite was processed at the company's washing and calcining plant at Lathrop Wells, Nev. The average B_2O_3 content of shipments, destined primarily for textile-grade fiberglass manufacturers, was 35%, compared with an average of 48% B_2O_3 in 1976. Ulexite-probertite ore was ground, screened, and blended to an average B_2O_3 content of 27% at the storage and shipping facilities at Dunn, Calif., then transported by rail to customers. In 1977, most shipments went to manufacturers of fiberglass insulation and cellulosic insulation.

Two significant developments concerning American Borate were announced in 1977. The parent company, Texas United Corp., entered a joint venture with Owens-Corning Fiberglas Corp. to develop and mine the Billie ore body. This mine, due to become operational in 1979, is unique because the entrance shaft, positioned outside the Death Valley National Monument, will provide subsurface access to the colemanite-ulexite-probertite deposit located within the Monument boundary. In a related development, American Borate announced the signing of a contract to build a 100,000-ton-per-year froth-flotation plant (adjacent to the existing facilities at Lathrop Wells, Nev.) to process colemanite. Experimental studies were conducted at the Colorado School of Mines and construction of the plant was to begin early in 1978. The flotation process shows promise to virtually eliminate the need for the energy-intensive, less efficient calcining operation.

CONSUMPTION AND USES

In terms of boron content, about half of the total U.S. output of boron minerals and compounds was consumed domestically in 1977. This ratio of domestic consumption to production was similar to that of 1976. U.S. consumption, including imports of colemanite and boric acid, amounted to 121,090 short tons of equivalent boron, compared with 93,550 tons in 1976. The increase in domestic consumption of 29% was supplied by a significant rise in imports as well as the record output of the major U.S. producer.

Because 1977 was one of the most dynamic years in the history of the boron minerals industry, the Bureau of Mines initiated a survey to collect data on U.S. consumption of boron minerals and compounds. Canvass forms were sent to producers to obtain comparative data for 1976 and 1977 on domestic shipments by end use. Response was 100%. Tables 2 and 3 present the results of the survey.

The spectacular market for thermal insulation increased demand by 18% for borates (mostly as borax pentahydrate and ulexite-probertite) in the manufacture of fiberglass insulation. Consumption of a variety of borates in cellulosic insulation, the second largest category in 1977, increased 232%. In addition, use of borates as flame retardants in other cellulose products (particle board and cotton batting) and in paints and plastics increased 42%.

The prevailing practice of combining boric acid and borax to impart flame retardance to cellulosic insulation, which is produced mainly from shredded newspapers, created such unusually heavy demand for boric acid that the domestic producers, U.S. Borax, Kerr-McGee, and Stauffer Chemical Co., were unable to supply industry requirements. Despite the U.S. producers' record output and sales of 158,500 tons valued at $42.4 million, imports of boric acid went from 56 tons in 1976 to 14,132 tons in 1977, and import prices tripled those of the U.S. producers.

In the furor over supplies for cellulosic insulation, the fact was sometimes overlooked that boric acid had long-established application in other major industries in the United States and abroad. Using 1975 as an example of the pattern of U.S. consumption of boric acid before cellulosic insulation became dominant, borosilicate glasses accounted for about 19% of total boric acid sales to U.S. consumers; textile-grade glass fibers consumed about 23%; ceramics, 13%; agricultural uses, 8%; metallurgical uses, 3%; soaps and detergents, 1%; and nuclear applications, 1%. About 6% of boric acid was consumed in cellulosic insulation in 1975; whereas in 1976 and 1977, this percentage increased to at least 21% and 33%, respectively.

According to the results of the Bureau of Mines end use survey, 45,310 tons (H_3BO_3 content) of boric acid was used in cellulosic insulation in 1977. The survey also indicated that another 20,750 tons was sold to distributors, and more than likely a large percentage of this boric acid ultimately went to cellulosic insulation manufacturers. Assuming this possibility, use of boric acid in cellulosic insulation may have approached half of the total U.S. consumption of boric acid of 137,310 tons.

Those manufacturers who were unable to obtain enough boric acid or were unwilling to pay the open-market price dealt with the situation in various ways. Some companies extended their boric acid by adding other boron compounds to their products. Examples of these extenders (collectively totaling 10,350 tons of boron content) were the minerals ulexite-probertite, and the refined compounds borax pentahydrate, borax decahydrate, anhydrous borax, and a boric acid-sodium sulfate combination chemical. Consumption of borax pentahydrate, the most common constituent of insulation in addition to boric acid, amounted to 52,900 tons ($Na_2B_4O_7 \cdot 5H_2O$ content). Other nonboron chemicals were reportedly used either as extenders or as substitutes, but the apparent inadequacy of substitute chemicals to retard flammability of cellulose brought the entire industry under the scrutiny of Federal and State regulatory agencies, the U.S. Congress, and consumer advocate groups. Furthermore, some of these chemicals appeared to exacerbate problems of potential corrosiveness, moisture accumulation, and fungal growth.

A third major growth market for borates, textile-grade glass fibers, represented an increase of 37% (in equivalent boron) in consumption of colemanite, boric acid, and anhydrous boric acid. These high-tensile-strength fibers are used to reinforce lightweight plastic materials in a variety of products. In its effort to facilitate fuel economy through manufacture of lighter weight vehicles, the automobile industry, one of the most promising markets for reinforced plastics, was turning to these composite materials as substitutes for the metal structural parts used in the past.

Although borosilicate glasses have always been a substantial end use category, consumption of borates (colemanite, anhydrous borax, borax decahydrate and pentahydrate, boric acid, and anhydrous boric acid) in their manufacture did not increase at a rate comparable to that of the other major borate markets. Consumption in 1977 was 2% greater than consumption in 1976; however, a related application of borates, in porcelain enamels, frits, and ceramic glazes, increased 17%.

Boron compounds in cleaning and bleaching increased 4% over the 1976 tonnage of equivalent boron. More than one quarter of these compounds were used to produce sodium perborate detergents. Consumption of boron compounds increased 49% in the manufacture of biological growth control chemicals for use in algicides and water treatment, fertilizers, herbicides, and insecticides. Boron compounds were consumed in metallurgical processes as fluxes, as shielding slag in the nonferrous metallurgical industry, and as components in plating baths in the electroplating industry. Small amounts of boron and ferroboron were constituents of certain nonferrous alloys and of specialty steels, respectively. Compared to the 1976 consumption in metallurgical applications, equivalent boron tonnage decreased 18%. Consumption of borates in nuclear applications decreased 25%.

Many important but small-percentage end uses for borates and boron-containing chemical derivatives comprised a diverse miscellaneous category that increased by 12% in 1977. According to the Bureau of Mines end use survey of the boron minerals producers, another group of borate compounds that were sold to chemical distributors was enlarged by 33%. Their ultimate end use was unknown.

Having rebounded in 1977 from the preceding years of reduced activity, markets for boron are projected to show continued strength in the near term. Growth in demand will be most significant with respect to insulation products and textile-grade glass fibers.

Table 2.—U.S. consumption of boron minerals and compounds, 1976 and 1977

(Short tons of equivalent boron and short tons of equivalent boron oxide)[1]

End use	1976		1977	
	B	B_2O_3	B	B_2O_3
Fiberglass insulation	21,595	69,440	25,400	81,670
Fire retardants:				
Cellulosic insulation[2]	5,510	17,730	18,280	58,775
Other	1,350	4,340	1,920	6,180
Textile-grade glass fibers[2]	10,970	35,275	14,990	48,190
Borosilicate glasses	14,460	46,505	14,720	47,340
Soaps and detergents	13,150	42,270	13,700	44,035
Enamels, frits, and glazes	4,435	14,260	5,170	16,630
Agriculture	3,480	11,185	5,190	16,680
Metallurgy	1,810	5,810	1,300	4,190
Nuclear applications	240	785	180	590
Miscellaneous uses	8,180	26,290	9,140	29,380
Sold to distributors, end use unknown	8,370	26,910	11,100	35,700
Total consumption	93,550	300,800	121,090	389,360

[1]Data were collected on the basis of B_2O_3 equivalent; boron equivalents were calculated.
[2]Includes imports.

Table 3.—U.S. consumption of boric acid, 1976 and 1977

(Short tons H_3BO_3 content)

End use	1976	1977
Fire retardants:		
Cellulosic insulation	20,640	[1]45,310
Other	3,940	6,570
Textile-grade glass fibers	19,680	23,980
Borosilicate glasses	12,950	12,250
Metallurgy	2,580	2,030
Soaps and detergents	790	1,355
Enamels, frits, and glazes	1,210	980
Nuclear applications	1,010	730
Agriculture	100	100
Fiberglass insulation	--	--
Miscellaneous uses	18,340	23,255
Sold to distributors, end use unknown	16,400	20,750
Total consumption	97,640	137,310

[1]Includes imports.

PRICES

U.S. borate mineral and chemical shipments had an average value of $322 per short ton of B_2O_3 in 1977, compared with $293 in 1976. Prices of borate compounds were increased at least 7% (depending upon the product) at the beginning of the year. U.S. producers raised boric acid prices about 7% in February, 8% to 9% in July, and, in one instance, another 6% in October. Open-market prices for boric acid skyrocketed as the year progressed, first doubling then tripling the producers' prices.

Figures quoted in table 4 are per short ton of product in carlots, f.o.b. U.S. plant or port. Other conditions of final preparation, transportation, quantities, and qualities are subject to negotiation and/or somewhat different price quotations.

General inflationary pressure plus the continued accelerating cost of energy for industrial purposes in California prompted the domestic producers to announce an increase in the price of refined borate compounds (including boric acid) of about 15%, to take effect in January 1978.

Table 4.—Borate prices per short ton, 1977

Product	Dec. 31, 1977
Borax, technical, anhydrous, 99%, bulk, carlots, works	[1]$266
Borax, technical, granular, pentahydrate, 99-1/2%, bulk, carlots, works	[1]117.50
Borax, technical, granular, decahydrate, 99-1/2%, bulk, carlots, works	[1]97.50
Boric acid, technical, granular, 99.9%, bulk, carlots, works	[2]$265-281
Boric acid, technical, granular, 99.9%, bags, carlots, works	[2]301-317
Boric acid, anhydrous, 96.0% B_2O_3, bulk, carlots, works	[3]559
Colemanite, American Borate Corp., calcined and screened, minus 70 mesh, 35% B_2O_3, f.o.b. railcars, Dunn, Calif	[4]140
Colemanite, Turkish, 44%-46% B_2O_3, crude, lump, f.o.b. railcars, U.S. east coast port	[5]140
Ulexite-probertite, American Borate Corp., screened, minus 7 mesh, 29% B_2O_3, f.o.b. railcars, Dunn, Calif	[4]55

[1]Chemical Marketing Reporter. V. 213, No. 27, Jan. 2, 1978, p. 51.
[2]Chemical Marketing Reporter. V. 213, No. 27, Jan. 2, 1978, p. 19.
[3]U.S. Borax & Chemical Corp.
[4]American Borate Corp.
[5]Philipp Brothers.

FOREIGN TRADE

U.S. exports of boric acid decreased to 35,992 short tons valued at $12.9 million in 1977, compared with 36,492 tons valued at $12.4 million in 1976. Exports of refined sodium borates increased 26% in tonnage and 31% in value to 265,470 tons valued at $64.6 million. Exports of crude sodium borates (mostly Rasorite 46 of 48% B_2O_3 content) increased slightly over 1976 exports. Because there is only one producer of crude sodium borates, the Bureau of the Census does not publish export data on these products.

Table 5 presents a detailed breakdown of the reported exports in 1977. Although data for countries outside of Western Europe are considered accurate, the large quantity of refined sodium borate exports to the Netherlands tends to distort the data for other European countries. The Netherlands is actually a major transshipment point for Europe rather than the final destination. A more meaningful tabulation, including U.S. exports of crude sodium borates, would indicate (in decreasing order) that France, the Federal Republic of Germany, the United Kingdom, Belgium, Spain, and Italy consumed greater tonnages of borates than did the Netherlands.

The United States imported from Turkey 51,087 short tons of commercial-grade colemanite (calcium borate) valued at $3.7 million. It was used principally for textile-grade fiberglass manufacture. This was an increase of 69% in quantity and 90% in value over the 1976 imports of 30,247 tons valued at $1.95 million.

U.S. imports of boric acid were significant for the first time in 1977; 14,132 short tons valued at $5.6 million was imported from 14 countries. Virtually all of these imports went to the cellulosic insulation industry. Four countries provided 87% of the supply: Turkey, Italy, France, and the U.S.S.R. Table 6 presents comparative figures on boric acid imports for 1976 and 1977.

Table 5.—U.S. exports of boric acid and sodium borates, in 1977

Destination	Boric acid (H_3BO_3 content) Quantity (short tons)	Boric acid (H_3BO_3 content) Value (thousands)	Sodium borates (refined) Quantity (short tons)	Sodium borates (refined) Value (thousands)
Australia	2,563	$982	6,927	$1,548
Belgium-Luxembourg	48	15	11	5
Brazil	3,016	1,375	15,589	3,753
Canada	4,137	1,052	49,241	8,205
Chile	7	4	420	143
China, Republic of	--	--	1,102	168
Colombia	538	196	1,348	302
Costa Rica	13	6	136	41
Ecuador	12	3	231	113
El Salvador	4	3	809	356
Finland	5	2	296	67
France	18	8	476	221
Germany, Federal Republic of	1,581	602	60	29
Greece	--	--	83	11
Guatemala	6	3	72	25
Hong Kong	212	89	3,190	881
Indonesia	38	15	1,546	263
Iran	--	--	772	249
Israel	106	46	198	37
Italy	601	189	11	5
Japan	12,130	4,584	47,196	11,749
Korea, Republic of	1,569	599	12,312	1,937
Madagascar	--	--	33	16
Malaysia	8	4	235	39
Mexico	3,660	1,104	23,006	4,263
Netherlands	2,087	723	49,530	15,566
New Guinea	105	42	150	48
New Zealand	412	158	3,150	1,105
Nicaragua	--	--	229	104
Norway	158	48	--	--
Pakistan	130	62	274	46
Peru	23	13	44	8
Philippines	588	167	1,407	381
Singapore	286	104	343	63
South Africa, Republic of	364	136	2,448	787
Spain	36	15	--	--
Sweden	50	16	322	29
Switzerland	--	--	98	15
Taiwan	583	211	4,612	1,055
Thailand	278	129	964	200
United Kingdom	73	22	34,343	10,246
Uruguay	198	73	225	71
Venezuela	308	113	1,872	436
Other	41	18	159	48
Total	35,992	12,931	265,470	64,634

Table 6.—U.S. imports for consumption of boric acid, by country

(Short tons H_3BO_3 content and thousand dollars[1])

Exporting sources	1976 Quantity	1976 Value	1977 Quantity	1977 Value
Argentina	--	--	785	342
Belgium	--	--	232	102
Canada	56	14	48	24
China, People's Republic of	--	--	55	24
France	--	--	2,677	974
Germany, Federal Republic of	--	--	162	88
Italy	--	--	3,000	1,471
Japan	--	--	107	60
Netherlands	--	--	60	26
Romania	--	--	110	52
Spain	--	--	194	99
Turkey	--	--	5,135	1,744
United Kingdom	--	--	118	61
U.S.S.R	--	--	1,449	529
Total	56	14	14,132	5,596

[1]U.S. Customs declared values.

WORLD REVIEW

Argentina.—Argentina, the foremost producer of boron minerals in South America, revised reported output and exports in 1976 to 88,900 short tons and 10,400 tons, respectively.[2] Boroquimica Samicaf, an RTZ Borax Ltd. subsidiary, provided most of the output in recent years from its Tincalayu mine in the Salar del Hombre Muerto basin in the Salta region of northwest Argentina. Additional production came from the Compañia Productora de Boratos. In 1977, a third company, Minera Simon Grandinetti Asociados S.A., was planning mining and processing facilities to extract ulexite from Laguna Guayatayoc, located 13,000 feet above sea level and about 160 miles from the Boroquimica Samicaf operation.[3] Probable and possible reserves in this subsurface deposit were estimated at 620,000 tons of ulexite with 30% to 35% B_2O_3 content. The proposed plant may employ flotation techniques. Facilities for producing boric acid also may be constructed at the mine site. Current boric acid capacity in Argentina is estimated at 2,000 to 3,000 short tons per year.

Chile.—Productos Quimicos Pareschi Limitada (Proquipal) produced borates and boric acid from the Minera Ascotan ulexite deposit. In 1977, Proquipal was planning to build a new boric acid plant near Antofagasta as part of a joint venture with Trans Boron Ltd.[4] In exchange for technology, plant financing, and access to the U.S. market, Proquipal will sell 33,000 tons of boric acid to Trans Boron Ltd. All of this boric acid is destined for the United States, with shipments to begin early in 1978.

China, People's Republic of.—Although little is known about the industry, it is believed that China produced a sufficient amount of borate minerals for domestic consumption with some available for export. Japan reported 374 tons of boric acid imports from China in 1977.[5] China also exported 55 tons of boric acid to the United States.

Europe.—Several European countries imported colemanite from Turkey and sodium borates from the United States to produce boric acid and other borate chemicals. Annual boric acid capacities were estimated as follows: France (Borax Français S.A.), 42,000 tons; Italy (Sta. Chimica Lardarello S.p.A.), 30,000 tons; Spain (La Productora de Borax y Articulos Quimicos S.A.), 11,000 tons; the United Kingdom (Borax Consolidated Ltd.), 11,000 tons.

Peru.—Ulexite was mined by two companies in Arequipa (southern Peru) for local use in glass manufacture. Annual capacity of Boratos del Peru S.A. was 33,000 tons, and capacity of Boroquimica S.A. is projected to reach 33,000 tons in 1978.[6]

Turkey.—The Turkish boron minerals industry, dominated by the mines, washing concentrators, and refineries of Etibank (the Turkish Government mining corporation responsible for all State mining activities) was second only to the U.S. boron minerals industry. In 1977, output was estimated to have increased about 20% to 1.2 million tons.[7] Etibank's annual productive capacity for colemanite concentrates of 40% to 47% B_2O_3 content was 496,000 tons; capacity for tincal concentrate of 34% B_2O_3 was 440,000 tons. Facilities at Bandirma-Edincik to process concentrated ore into refined borates had capacities of 61,000 tons of borax decahydrate; 11,000 tons of borax pentahydrate; 27,500 tons of boric acid; and 22,000 tons of sodium perborate. An expansion to 38,600 tons of boric acid capacity was scheduled for early 1978.

Completion of the new 110,000-ton-per-year boric acid plant, planned for 1979, was reported to be a year behind schedule.[8] The delay was attributed to a shortage of financing to purchase plant equipment. Cost of the project was estimated around $20 million.

Construction of facilities to produce sodium borates at Kirka has also been delayed. Plans for the modern refinery include annual capacities of 200,000 tons of crude borax pentahydrate; 55,000 tons of crude anhydrous borax; 10,000 tons of refined anhydrous borax; and 19,000 tons of refined borax decahydrate.

It was reported that project studies are underway for annual production of 150,000 tons of washed colemanite ore of low arsenic content from the Bigadic area.[9] In addition, modern handling facilities for boron exports are scheduled to be completed at the port of Bandirma by 1979. A total of 5,000 tons of crude and refined products will be stored in covered silos and 50,000 tons of ore will be stored as open stockpile.

U.S.S.R.—The U.S.S.R. announced plans to commission a new facility for the production of 23,000 tons per year of sodium perborate and 10,000 tons per year of anhydrous borax by 1980.[10] In 1977, for the first time, the United States imported boric acid from the U.S.S.R. Japan reported imports of 578 short tons of Soviet borax and 1,786 short tons of boric acid.[11]

TECHNOLOGY

During 1977, boron minerals producers were engaged in technological research to improve the efficiency of their operations. U.S. Borax continued research to utilize offgrade and difficult-to-process ores in its refining system. American Borate's research into froth flotation of colemanite had advanced to an announcement of plans to construct a 100,000-ton-per-year flotation plant in 1978. Kerr-McGee was investigating techniques of brine enrichment to enhance borate extraction.

With the switch by industry and utilities to firing boilers with coal instead of oil, several chemical producers have developed proprietary formulations to combat slag accumulation in boiler bottoms and scale buildup in boiler tubes.[12] One type of additive, Coaltrol R, is described as a proprietary combination of inorganic and organic boron-containing chemicals. It was developed by Apollo Chemical Co. to lower the fusion point of coal. Unlike oil, coals contain alkali metals and iron, silica, and alumina, which along with the ash resulting from combustion are left behind to foul the boiler system and reduce its efficiency, usually to the point of eventual shut down. Addition of chemicals to either lower the fusion point or raise it (depending upon the type of coal and boiler system) appears to be an effective means for improving boiler efficiency.

Although still in its infancy, research on use of the tunable laser is expected to have considerable impact on the chemical industry.[13] Promising applications include the production of rare isotopes, synthesis of specialty chemicals, and use in ultrasensitive analytical instruments. Among the thousands of materials potentially amenable to laser chemistry, the most promising initial targets will be substances that are presently very expensive to produce. Foremost among these is the isotope boron-10, which costs about $3,000 per pound.[14] With respect to the synthesis of specialty chemicals, U.S. Government scientists at the Los Alamos Scientific Laboratory (New Mexico) have produced essentially pure dichloroborane. In the past, synthesis of this chemical (once considered to have potential as a rocket fuel) by heating boron trichloride and hydrogen produced many useless byproducts. The University of Alabama is also studying the laser synthesis of boranes and related compounds, which have numerous potential applications, but are currently prohibited from widespread use by their high cost.

The trend to greater use of fiberglass-reinforced plastics has promoted research into effective ways to strengthen these composite materials beyond their former limitations. The result has been a better understanding of the strengthening mechanism, which has led to increased strengthening ability of glass fibers embedded in a polymer.[15] Through improved techniques to increase fiber length, control fiber orientation, and raise fiber content, the same fibers that doubled or tripled plastic strength in the past now have potential to increase plastic strength by at least a factor of 10. Until recently, glass content of 20% to 30% by weight was typical of most fiberglass-reinforced plastics; however, newly developed techniques allow for glass content of 70% or more. Considered a significant engineering achievement among plastics formulators, the capability to add high concentrations of glass reinforcement has one disadvantage in that raw materials costs, including costs of boron compounds, may increase as much as 35%.

U.S. military aviation researchers have experienced considerable success in developing lightweight advanced composite materials for structural components of airplanes and helicopters.[16] Composites are a mixture of two or more materials that exist in continuous and discontinuous phases and that provide a material with properties different from the sum of the continuous properties. The most recent filamentary reinforcements are boron fibers and graphite fibers. When used as reinforcements in epoxy, other plastic matrices, or in some metals such as aluminum, these fibers offer remarkable advances in both strength and stiffness, compared on a weight basis to metals or glass-fiber-reinforced plastics. Another advantage is the simultaneous fabrication of the composite material and the structural part, which eliminates several steps in the traditional manufacturing process. In a related development, Avco Corp.'s Specialty Materials Division, a major manufacturer of boron filaments for use in aerospace vehicles and sporting goods, announced plans to reduce manufacturing costs of boron filament and boron tape preimpregnated with epoxy by substituting a carbon substrate for tungsten.[17]

---

[1]Physical scientist, Division of Nonmetallic Minerals.
[2]U.S. Embassy, Buenos Aires, Argentina. State Department Airgram A-18. Mar. 18, 1978, p. 1 of enclosure 1, and p. 1 of enclosure 5.
[3]Industrial Minerals. Argentina-High Hopes for Borate Production. No. 126, March 1978, p. 9.
[4]U.S. Embassy, Santiago, Chile. U.S. Department of Commerce Airgram 507. January 12, 1978, 1 p.
[5]Japan Chemical Week. Borax, Boric Acid Imports Recover. Mar. 23, 1978, p. 8.
[6]U.S. Embassy, Lima, Peru. U.S. Department of Commerce Airgram 325. February 24, 1978, 1 p.
[7]Mining Journal (London). Turkish Dilemma. V. 290, No. 7448, May 19, 1978, pp. 370-371.
[8]Chemical Age. Financial Problems Delay Turkish Boric Acid Venture. V. 115, No. 304, Nov. 4, 1977, p. 8.
[9]Industrial Minerals. Etibank as a Boron Producer. No. 123, December 1977, pp. 51-52.
[10]European Chemical News. Soviet Phosphate Industry Steps Up Investment Program. V. 30, No. 785, May 6, 1977, p. 41.
[11]Work cited in footnote 5.
[12]Chemical Week. Chemicals Lance Coal Boiler Slag. V. 122, No. 1, Jan. 4, 1978, pp. 44-45.
[13]Chemical Week. Lasers Loom Bright on Chemical Horizon. V. 121, No. 22, Nov. 30, 1977, pp. 43-45.
[14]Fortune. Laser Alchemy is Just Around the Corner. V. 96, No. 3, September 1977, pp. 186-189.
[15]Materials Engineering. Pumping More Strength Into Reinforced Plastics. V. 87, No. 5, May 1978, pp. 27-30.
[16]Bersch, C. F. and L. B. Lockhart, Jr. Navy Composite Materials Research. Nat. Defense, November-December 1977, pp. 220-223, 250, 259.
Immen, F. H. Army Helicopter Composites. Nat. Defense, November-December 1977, pp. 224-225, 230-231, 251.
[17]American Metal Market. No Machining Necessary With New Composite. V. 86, No. 20, Jan. 30, 1978, pp. 12-13.

Bromine

By Russell J. Foster[1]

Domestic producers sold or used nearly 434 million pounds of elemental bromine in 1977, a decrease of 6% from that of 1976. Demand for the industry's primary product, ethylene dibromide, as a leaded-gasoline additive was down, but sales of the compound for agricultural use improved. Consumption of other bromine-containing compounds declined. The total value of bromine and bromine compounds sold by producers was $203 million.

Bromine capacity in Arkansas continued to grow as a producer completed an expansion of its bromine production facilities. Several Federal agencies were evaluating some bromine compounds that could possibly be hazardous to consumers and workers.

DOMESTIC PRODUCTION

The amount of elemental bromine sold or used by domestic producers in 1977 declined 6% to 434 million pounds. Sales of bromine compounds by producers were down 7%. Producers' sales of methyl bromide rose 6%, but the quantities of ethylene dibromide and other bromine compounds sold decreased 6% and 10%, respectively. The total value of elemental bromine and bromine compounds sold dropped $13 million. The unit value of elemental bromine declined, but the average price of manufactured compounds was essentially unchanged.

Six companies operated nine bromine-producing plants in two States, Arkansas and Michigan. Three of these companies combined sold or used 88% of the U.S. total.

The Governor's Brine Study Commission in Arkansas proposed legislation covering unitization and royalty payments. The bill was referred to a joint interim committee of the Arkansas legislature.

Great Lakes Chemical Corp. brought additional brine production and bromine extraction facilities onstream at Marysville, Ark., and acquired Drug Research, Inc., a Michigan-based firm which produces brominated chemicals primarily for swimming pool sanitation. Great Lakes' new research and development laboratories were completed at West Lafayette, Ind.[2]

Emery Industries, Inc., signed an agreement with Dead Sea Bromine Co., Ltd., of Israel to market certain nonagricultural bromine compounds in the United States. A jointly owned U.S. plant for the manufacture of bromine derivatives is being considered. Dead Sea Bromine will continue to market some bromine products in the United States through its subsidiary, Ameribrom.[3]

Table 1.—Elemental bromine sold as such or used in the preparation of bromine compounds by primary producers in the United States

(Thousand pounds and thousand dollars)

	1976		1977	
	Quantity[r]	Value[r]	Quantity	Value
Sold	57,405	12,859	59,036	12,763
Used	402,655	99,488	374,782	86,915
Total[1]	460,061	112,348	433,818	99,678

[r]Revised.
[1]Data may not add to totals shown because of independent rounding.

Table 2.—Bromine compounds sold by primary producers in the United States

(Thousand pounds and thousand dollars)

	1976[r]			1977		
	Quantity		Value	Quantity		Value
	Gross weight	Bromine content		Gross weight	Bromine content	
Ethylene dibromide	298,752	254,149	77,286	279,581	237,840	75,061
Methyl bromide	31,032	26,120	13,773	32,930	27,717	15,701
Other compounds[1]	138,417	97,191	112,007	125,066	86,650	99,200
Total[2]	468,201	377,459	203,067	437,576	352,206	189,962

[r]Revised.
[1]Includes hydrobromic acid, tetrabromobisphenol-A, ethyl, ammonium, sodium, potassium, and other bromides.
[2]Data may not add to totals shown because of independent rounding.

Table 3.—Bromine-producing plants in the United States

State and company	County	Plant	Production source
Arkansas:			
Arkansas Chemicals, Inc	Union	El Dorado	Well brines.
The Dow Chemical Co	Columbia	Magnolia	Do.
Ethyl Corp	do	do	Do.
Great Lakes Chemical Corp	Union	El Dorado	Do.
Do	do	Marysville	Do.
Velsicol Chemical Corp	do	El Dorado	Do.
Michigan:			
The Dow Chemical Co	Mason	Ludington	Do.
Do	Midland	Midland	Do.
Morton Chemical Co	Manistee	Manistee	Do.

CONSUMPTION AND USES

Total demand for ethylene dibromide declined in 1977, primarily because reduced requirements for lead in gasoline necessitated a corresponding reduction in lead-scavenging additives. The decline was tempered by increased consumption of the compound as an agricultural fumigant brought about by the removal of 1,2-dibromo-3-chloropropane from the marketplace. Ethylene dibromide accounted for 55% of bromine sold or used by domestic producers. Results of National Cancer Institute (NCI) carcinogenicity studies have prompted the Environmental Protection Agency (EPA) to examine ethylene dibromide under the rebuttable presumption against registration process. However, preliminary EPA studies have recognized its importance, since elimination could result in losses to grain and other crops, increased pest control costs to farmers for substitute pesticides, and restricted movement of certain fruits and vegetables in interstate and overseas commerce.[4] The Occupational Safety and Health Administration (OSHA) issued guidelines recommending that worker exposure in air be limited to the lowest possible concentration.[5] EPA was also considering adding ethylene dibromide and 37 other compounds to a proposed list of 23 hazardous pesticides that can only be applied by trained applicators.[6]

Among the 23 substances on the original list was methyl bromide. Consumption of this fumigant was up in 1977. Methyl bromide's share of bromine sold or used by producers was 6%. Total demand for other bromine compounds, which represented 20% of the total sold or used by producers, declined, although consumption of certain flame retardants, calcium bromide, and other compounds increased.

Preliminary NCI data released in February showed that tris(2,3-dibromopropyl)phosphate, a flame retardant used in textiles including children's sleepwear, was a carcinogen.[7] The Consumer Products Safety Commission (CPSC), after placing an initial ban on the sale and manufacture of "tris"-treated garments, banned tris and all treated fabric, yarn, and fiber in May.[8] However, a U.S. District Court in South Carolina prohibited CPSC from enforcing the ban.[9] CPSC has since voted to propose rules to eliminate the portion of the children's sleepwear standards that necessitated the use of flame retardants.[10]

In August EPA announced that it would regulate the flame retardant polybrominated biphenyl under the Toxic Substances Control Act, by prohibiting its use as a fire retardant, requiring new uses to come under review, and applying quality-control limitations to manufacture for export.[11] Results of a continuing study by a New York medical team on the health effects of polybrominated biphenyl on Michigan residents indicated that the duration of exposure to the compound was as important as the intensity. However, tentative findings of the Michigan Public Health Department showed no significant pattern of immunological problems related to exposure levels.[12]

The agricultural fumigant 1,2-dibromo-3-chloropropane was suspected of causing sterility in male chemical workers at Occidental Chemical Co.'s pesticides plant in Lathrop, Calif., and at the facilities of the two major producers of the compound, The Dow Chemical Co. and Shell Chemical Co.[13] The State of California prohibited the use or manufacture of pesticides containing the compound.[14] Emergency temporary worker exposure limits were announced by OSHA in September, and stringent permanent exposure limits were proposed in November. In addition, the Food and Drug Administration began monitoring foods for residues.[15] EPA ordered a halt to all sales and use of the compound in late October, but may allow limited utilization if producers agree to the application of the compound only by trained personnel.[16] Tests conducted by Dow at yearend indicated that the sterility may be reversible.[17]

Monsanto Co. announced that results of the first year of a 2-year study on vinyl bromide showed that no danger to its plant workers existed at present exposure levels. Although a statistical increase in cancer was observed among rats inhaling 1,250 and 250 parts per million (ppm) vinyl bromide, no adverse effects occurred at levels of 100 and 50 ppm. Monsanto's plant exposure standard is 1 ppm, with actual exposure levels far less. Other firms sponsoring the study are The Dow Chemical Co., Dow-Badische Co., and Ethyl Corp.[18]

PRICES

The average price of bulk elemental bromine, f.o.b. plant, as reported by producers in 1977 was 21.62 cents per pound, down 3% from the 1976 average price of 22.40 cents per pound. Quoted prices for bromine and selected compounds at yearend follow:

Product	Value per pound (cents)
Bromine, purified:	
Carlots, truckloads, delivered	75
Drums, carlots, truckloads, delivered east of the Rocky Mountains[1]	55-62
Bulk tank car, tank trucks (45,000-pound minimum), delivered east of the Rocky Mountains[1]	25-30
Ammonium bromide, national formulary (N.F.), granular, drums, carlots, truckloads, freight equalized	74
Bromochloromethane, drums, carlots, f.o.b. Midland	98
Bromoform, pharmaceutical grade, 5-gallon drums, f.o.b. works	270
Ethyl bromide, technical, 98%, drums, carlots, freight allowed, East	61.5
Ethylene dibromide, drums, carlots, freight equalized	37
Hydrobromic acid, 48%, drums, carlots, truckloads, f.o.b. works	39-41
Hydrogen bromide, anhydrous, cylinders, 30,000 pounds, f.o.b. works	65
Methyl bromide, distilled, tanks, 140,000-pound minimum, freight allowed	41
Potassium bromate, granular, powdered, 200-pound drums, carlots, f.o.b. works	106
Potassium bromide, N.F., granular, drums, carlots, f.o.b. works	67
Sodium bromide, 99% granular, 400-pound drums, freight, f.o.b. works	65

[1]Delivered prices for drums and bulk shipped west of the Rockies, 1 cent per pound higher. Bulk truck prices 1 cent per pound higher for 30,000-pound minimum and 2 cents per pound higher for 15,000-pound minimum. Price f.o.b. Midland and Ludington, Mich., freight equalized, 1 cent per pound lower.

Source: Chemical Marketing Reporter. Current Prices of Chemicals and Related Materials. V. 213, No. 26, Dec. 26, 1977, pp. 26-37.

FOREIGN TRADE

The quantity of elemental bromine and bromine contained in compounds that was exported by domestic bromine producers declined 11% in 1977 to 59 million pounds, and represented 14% of total bromine sold or used. The amount of exported elemental bromine rose 21%, but exports of bromine compounds were down 13%. The value of all bromine exports decreased 6%.

Bromine imports amounted to less than 0.2% of domestic consumption. About 95% of U.S. bromine imports were shipped from Israel.

The U.S. Treasury Department initiated a countervailing duty investigation into imports of bromine from Israel. A petition filed in July by Velsicol Chemical Corp. alleged that the Government of Israel made benefits available to Israeli manufacturers and exporters of bromine and bromine compounds which may constitute bounties or grants under U.S. law.[19]

Table 4.—U.S. exports of bromine and bromine compounds

(Thousand pounds and thousand dollars)

Year	Elemental bromine		Bromine compounds		
	Quantity	Value	Gross weight	Contained bromine	Value
1975	3,635	1,037	72,395	61,598	25,791
1976	4,435	944	74,063	62,589	29,244
1977	5,379	1,096	64,381	54,061	27,278

WORLD REVIEW

The United States continued as the world leader in bromine production with about two-thirds of the total. Other principal bromine-producing nations included Israel, the United Kingdom, France, the U.S.S.R., and Japan.

Canada.—The Department of Fisheries and the Environment has banned the import, manufacture, and use of polybrominated biphenyl fire retardants.[20]

Israel.—Dead Sea Bromine Co., Ltd., commissioned a 110-ton-per-day chlorine plant at Sodom which will provide an assured supply of chlorine for existing and future bromine production. Present bromine capacity of 44,000 tons per year at the Sodom plant should reach 66,000 tons per year by yearend 1978, with further additions expected. A new bromine-compounds plant, due onstream at Ramat Hovev in 1978, will consist of three single-product units—methyl bromide, tetrabromobisphenol-A, and inorganic bromides—plus several smaller multipurpose plants. Production of compounds will increase export value and reduce the transportation and distribution problems associated with the corrosive nature of elemental bromine.[21]

Japan.—Daikin Kogyo Co. brought a trifluorobromomethane plant onstream based on Produits Chimiques Ugine Kuhlmann technology. The compound is used as a fire-extinguishing fluid for high-value applications.[22]

Netherlands.—A bromine-derivatives plant constructed by Dead Sea Bromine Co., Ltd., of Israel came onstream at Terneuzen in October.[23]

United Kingdom.—ISC Chemicals, Ltd., brought a new plant onstream for the production of brominated diphenyl oxides, which are used as flame retardants in plastics.[24] Steetley Chemicals, Ltd., acquired a sodium and potassium bromides and bromates plant located at Gillingham from Akzo Chemie (UK) Ltd.[25]

Table 5.—Bromine: World production, by country

(Thousand pounds)

Country[1]	1975	1976	1977[p]
France	36,971	33,466	[e]35,000
Germany, Federal Republic of	9,414	9,158	[e]9,000
India[e]	600	600	620
Israel	39,700	46,100	69,445
Italy[2]	[r]1,477	[e]1,500	[e]1,500
Japan[e]	24,900	25,400	26,500
Spain	838	[e]880	900
U.S.S.R	28,000	30,000	33,000
United Kingdom	62,391	65,918	66,000
United States[3]	407,163	460,061	433,818
Total	[r]611,454	673,083	675,783

[e]Estimate. [p]Preliminary. [r]Revised.
[1]In addition to the countries listed, several other nations produce bromine, but output data are not reported and available general information is inadequate for formulation of reliable estimates of output levels.
[2]Figure for 1975 is from official Italian sources; figures for 1976 and 1977 are U.S. Bureau of Mines estimates. Officially reported figures for years prior to 1975 are as follows, in thousand pounds: 1971—11,515; 1972—9,965; 1973—3,073; 1974—1,512.
[3]Sold or used by producers.

TECHNOLOGY

Bromine chloride could be an alternative to chlorine for disinfecting secondary waste water treatment plant effluent because of its greater effectiveness and lower toxicity. The rate of hydrolysis is faster than for either bromine or chlorine alone. Bromine chloride reacts with ammonia in waste water to form bromamines which are superior to corresponding chloramines in terms of bactericidal and viricidal activity.[26] Environmental officials of the State of Virginia and Ethyl Corp. were conducting tests with bromine chloride and chlorine at a Newport News sewage treatment plant to compare their effectiveness as well as the toxicity of treated effluent on fish.[27]

The Dow Chemical Co. introduced 2,2-dibromo-nitrilopropionamide as a fast-acting, broad-spectrum, industrial antimicrobial for water-cooling towers, paper mills, and aqueous metalworking fluids. The liquid rapidly decomposes in water to produce ammonia, carbon dioxide, and bromide ions.[28]

Researchers at the University of Illinois have found that perfluorooctyl bromide can effectively coat the gastrointestinal tract, temporarily blocking food absorption. In conjunction with a program of diet and exercise, the chemical may provide treatment for obesity. Apparently none of the perfluorooctyl bromide is absorbed into the bloodstream, but further tests are needed to determine the safety of the compound and whether it accumulates in any of the body tissues.[29]

[1]Physical scientist, Division of Nonmetallic Minerals.
[2]Chemical Marketing Reporter. Bromine Chemical Firm Bought by Great Lakes. V. 211, No. 25, June 20, 1977, pp. 7, 20.
Kampen, E. Progress Report From Great Lakes Chemical Corp. Oct. 28, 1977, 2 pp.

[3]Chemical Marketing Reporter. Emery, Dead Sea Group Sign a Marketing Pact. V. 211, No. 11, Mar. 14, 1977, pp. 3, 53.

[4]Chemical Marketing Reporter. EDB Review Ordered by Environmental Unit; Risks, Benefits Assessed. V. 212, No. 25, Dec. 19, 1977, pp. 5, 53.

Chemical Week. EPA Says: "Prove It!" V. 121, No. 25, Dec. 21, 1977, p. 17.

[5]Chemical & Engineering News. OSHA Issues Guidelines on EDB Exposure. V. 55, No. 51, Dec. 19, 1977, p. 13.

[6]Chemical & Engineering News. EPA Proposes List of Hazardous Pesticides. V. 55, No. 37, Sept. 12, 1977, p. 8.

[7]Chemical Marketing Reporter. Tris Ban Demanded by EDF. V. 211, No. 7, Feb. 14, 1977, pp. 3, 53.

[8]Chemical & Engineering News. Concentrates. Government. V. 55, No. 19, May 9, 1977, p. 7.

[9]Chemical Week. Tris Ban Nullified. V. 121, No. 1, July 6, 1977, p. 14.

[10]Chemical Marketing Reporter. CPSC Votes Rule for Child Sleepwear. V. 212, No. 12, Sept. 19, 1977, p. 68.

[11]Chemical Week. PBB Effects Cited. V. 121, No. 6, Aug. 10, 1977, p. 20.

[12]Chemical Week. Two Views on PBB. V. 121, No. 22, Nov. 30, 1977, p. 22

[13]Chemical & Engineering News. More Tests Link DBCP to Worker Sterility. V. 55, No. 36, Sept. 5, 1977, pp. 5-6.

Chemical Week. Workers Found Sterile. V. 121, No. 6, Aug. 10, 1977, p. 21.

[14]Chemical Week. More DBCP Problems. V. 121, No. 8, Aug. 24, 1977, p. 20.

[15]Chemical Marketing Reporter. OSHA Sets Workplace Rules for DBCP Worker Exposure. V. 212, No. 19, Nov. 7, 1977, pp. 7, 37.

Chemical Week. Crackdown on DBCP. V. 121, No. 11, Sept. 14, 1977, p. 19.

[16]Chemical & Engineering News. EPA Puts the Lid on DBCP. V. 55, No. 45, Nov. 7, 1977, p. 24.

[17]Chemical Marketing Reporter. DBCP Comparison Run by Dow Chemical Turns Up Reassuring Statistics on Workers. V. 212, No. 21, Nov. 21, 1977, p. 15.

[18]Chemical Marketing Reporter. Monsanto Reports Result of Vinyl Bromide Studies. V. 212, No. 20, Nov. 14, 1977, pp. 4, 42.

[19]Chemical Marketing Reporter. Bromine Probe Launched. V. 212, No. 15, Oct. 10, 1977, p. 7.

[20]European Chemical News. Technology. In Brief. V. 31, No. 813, Nov. 25, 1977, p. 26.

[21]European Chemical News. Israel Set To Expand Stake in World Bromines Market. V. 31, No. 800, Aug. 19/26, 1977, p. 21.

European Chemical News. Section II. Israel Chemical Industry Ready for New Export Drive. V. 31, No. 815, Dec. 9, 1977, p. 28.

[22]Chemical Age. New Daikin Plant. V. 115, No. 3047, Dec. 9, 1977, p. 3.

[23]Work cited in footnote 21.

[24]European Chemical News. New Flame Retardant Plant. V. 30, No. 772, Feb. 4, 1977, p. 16.

[25]European Chemical News. Akzo Sells to Steetley. V. 30, No. 786, May 13, 1977, p. 6.

[26]Chemical & Engineering News. Bromine Chloride Looks Good As Disinfectant. V. 55, No. 41, Oct. 10, 1977, p. 8.

[27]Chemical Week. Testing Disinfectant. V. 121, No. 1, July 6, 1977, p. 13.

[28]European Chemical News. Technology. In Brief. V. 30, No. 787, May 20, 1977, p. 36.

[29] Chemical Week. Chemical May Gain As Weight-Loss Aid. V. 121, No. 5, Aug. 3, 1977, pp. 33-34.

Cadmium

By John M. Lucas[1]

Domestic cadmium metal production posted a minor decline from that of 1976. Although apparent consumption in 1977 exceeded the quantity consumed during the recession year of 1975, it was less than that consumed in 1976. Shipments of metal reported by producers were below those of 1976, but, far above those of 1975.

Six companies operating seven plants produced all of the domestic cadmium. Canada continued as the major source of zinc concentrates from which cadmium was extracted as a byproduct. The producer price of cadmium remained at $3.00 per pound until December, at which time it was reduced to $2.25 to $2.50.

Legislation and Government Programs.—The Environmental Protection Agency (EPA) issued interim final pretreatment standard (effective July 12, 1977) covering effluent discharges into publicly owned treatment works operating within the electroplating point source category. Shortly after issuing the new regulations, which did not specifically address cadmium, the EPA began considering the inclusion of six other metals, including cadmium.

In October, the EPA issued a notice of rebuttable presumption against the registration of pesticide products containing cadmium. Cadmium is one of 20 substances that the EPA is investigating to determine whether the evidence of health risk is sufficient to revoke registration of pesticides containing these substances. Pesticides containing cadmium have been used for several years to control moles and plant diseases affecting residential lawns and golf courses. Producers of registered cadmium pesticides were notified to submit evidence in rebuttal of the presumption prior to December 12, 1977.

On October 22, pursuant to provisions of the Federal Clean Air Act Amendments of 1977, the EPA initiated inquiries into the health effects of cadmium, arsenic, and polycyclic organic compounds in the ambient air.

The national stockpile goal of 12,351 tons of cadmium established in 1976 by the Federal Preparedness Agency (FPA) was reaffirmed by the President on October 7. The inventory of stockpile metal was 3,163 tons on December 31, 1977.

Table 1.—Salient cadmium statistics

	1973	1974	1975	1976	1977
United States:					
Production[1] short tons	3,751	3,333	2,193	2,256	2,204
Shipments by producers[2] do	4,304	3,250	818	r2,984	2,025
Value thousands	$23,891	$21,405	$4,166	$10,498	$7,072
Exports short tons	153	31	198	252	118
Imports for consumption, metal do	1,948	1,985	2,618	3,411	2,570
Apparent consumption do	6,267	6,050	3,368	5,932	4,480
Price: Average per pound[3]	$3.64	$4.09	$3.36	$2.66	$2.96
World: Production short tons	18,925	19,041	r16,793	r18,180	18,898

rRevised.
[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 balls in lots of 1 to 5 tons.

DOMESTIC PRODUCTION

Total domestic production of cadmium metal during 1977 was 2,204 tons, slightly below the 2,256 tons produced in 1976. Metal production was 631 tons in the first quarter, then declined to 428 tons in the third quarter. Production of cadmium during the fourth quarter rebounded to 583 tons following the September settlement of the nearly 5-month labor strike at The Bunker Hill Co. smelter.

For every ton of slab zinc produced during the year, an average of 9.8 pounds of cadmium metal was recovered. In 1976, the recovery rate averaged about 7 pounds of metal per ton of zinc compared with 10 pounds in 1975 and 12 pounds in 1974. Prior to 1973, an average of 10 to 12 pounds of cadmium was produced for every ton of slab zinc. This decline in cadmium metal recovery may reflect a growing tendency by producers to make more cadmium compounds at the expense of metal production as well as a combination of possible factors such as a greater percentage recovery of zinc as compared with cadmium and an overall decrease in the cadmium content of the ores and concentrates.

Cadmium sulfide production (including cadmium sulfoselenide and lithopone) was 12% below the production level of 1976.

Production of other cadmium compounds (cadmium content), which includes both electroplating salts and cadmium oxide, declined about 14% from production levels of the previous year. However compared with 1974, production of other compounds has increased nearly ninefold. Cadmium oxide was produced at two primary-metal-producing plants. Data on cadmium oxide production are not published to avoid disclosing individual company confidential data.

Table 2.—Primary cadmium producers in the United States in 1977

Company	Plant location
AMAX Zinc Co. Inc	Sauget, Ill.
ASARCO Inc	Corpus Christi, Tex.
Do	Denver, Colo.
The Bunker Hill Co	Kellogg, Idaho
National Zinc Co	Bartlesville, Okla.
New Jersey Zinc Co	Palmerton, Pa.
St. Joe Zinc Co	Monaca, Pa.

Table 3.—Cadmium sulfide[1] produced in the United States

(Short tons)

Year	Quantity (cadmium content)
1973	1,412
1974	1,085
1975	987
1976	804
1977	704

[1]Includes cadmium lithopone and cadmium sulfoselenide.

CONSUMPTION AND USES

The apparent consumption of cadmium was 4,480 tons, 24% less than that of 1976. Over 95% of the consumption of cadmium was accounted for under five principal use categories: Plating, pigments, alloys, batteries, and plastic stabilizers. Electrically or mechanically plated hardware used in transportation vehicles and fixed electrical and mechanical equipment was estimated to have consumed between 40% and 45% of the apparent consumption. Red, orange, yellow, and maroon pigments formulated from cadmium compounds consumed an estimated 15% of the supply. The balance was consumed in nickel-cadmium batteries, special-purpose alloys, and compounds employed to impart heat and light stability to some plastics, particularly polyvinylchloride.

Table 4.—Supply and apparent consumption of cadmium

(Short tons)

	1976	1977
Stocks—beginning	2,841	2,387
Production	2,256	2,204
Imports, metal	3,411	2,570
Shipments from Government stockpile excesses	63	--
Total supply	8,571	7,161
Exports	252	118
Stocks—end	2,387	2,563
Apparent consumption[1]	5,932	4,480

[1]Total supply minus exports and yearend stocks.

STOCKS

Inventories of metal held by producers at the end of 1977 were 1,553 tons, 13% over those held at the close of 1976. Compound manufacturers' stocks of cadmium compounds rose 15% above those held at yearend 1976. Inventories of metal held by distributors were essentially unchanged from those reported at the end of 1976.

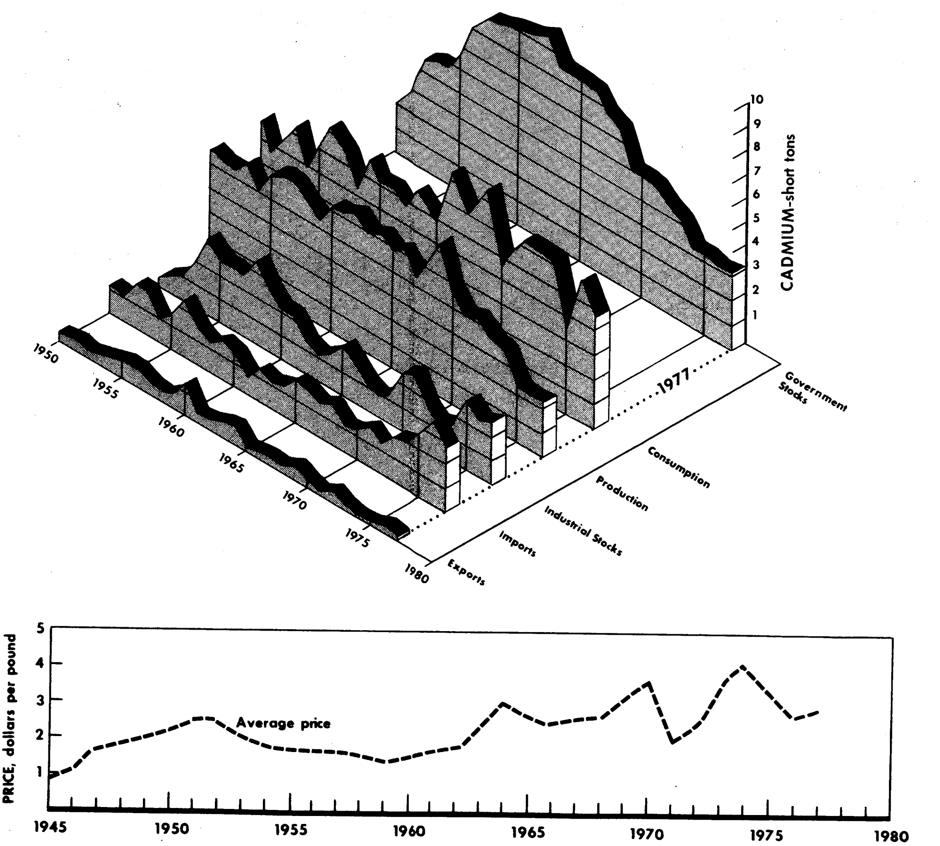


Figure 1.—Trends in production, consumption, yearend stocks, exports, imports, and average price of cadmium metal in the United States.

Table 5.—Industry stocks, December 31

(Short tons)

	1976		1977	
	Cadmium metal	Cadmium in compounds	Cadmium metal	Cadmium in compounds
Metal producers	1,369	W	1,553	W
Compound manufacturers	163	547	79	630
Distributors	279	29	281	20
Total	1,811	576	1,913	650

W Withheld to avoid disclosing individual company confidential data; included with "Compound manufacturers."

PRICES

Despite continued weakening demand and expanding inventories, the producer price of cadmium remained unchanged at $3 per pound throughout most of the year. On December 1, National Zinc Co. reduced its quoted price for cadmium by $0.50, to $2.50 per pound. On December 7, Bunker Hill lowered its price to $2.25 per pound. On the following day, ASARCO Inc., aligned its quote at the $2.50 per pound level established earlier by National Zinc. For the remainder of the year, all domestic cadmium producers were quoting prices in a range of $2.25 to $2.50 per pound. Dealer prices for cadmium remained firm throughout most of the first quarter at $2.90 to $2.95 per pound. In late March, the price began to weaken, and by yearend it had declined to $1.85-$1.95 per pound.

FOREIGN TRADE

Exports of cadmium metal and scrap decreased sharply to 118 tons compared with 252 tons exported during 1976. The principal recipients during 1977 were the Federal Republic of Germany (37%), Belgium-Luxembourg (33%), and Canada (13%).

Cadmium metal imports for consumption were received from 16 countries. Canada continued to be the principal source of imports with 18%; followed by Australia and Mexico (17% each), Yugoslavia (14%), Belgium-Luxembourg (10%), Finland and the Netherlands (5% each), and the Republic of Korea (4%). Fourteen tons of cadmium-bearing flue dust was imported from Canada. No imports of flue dust were received from Mexico, which shipped 246 tons to the United States in 1976.

Table 6.—U.S. exports of cadmium metal and cadmium in alloys, dross, flue dust, residues, and scrap

Year	Quantity (short tons)	Value (thousands)
1975	198	$589
1976	252	713
1977	118	316

Table 7.—U.S. imports for consumption[1] of cadmium metal and cadmium flue dust, by country

Country	1976		1977	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Cadmium metal:				
Australia	421	$2,003	448	$2,353
Belgium-Luxembourg	279	1,330	246	1,322
Canada[2]	1,052	5,361	472	2,519
Finland	43	237	131	580
France	130	533	13	74
Germany, Federal Republic of	133	576	44	217
India	40	187	6	20
Italy	32	146	--	--
Korea, Republic of	110	478	105	462
Mexico	393	1,696	436	2,202
Netherlands	52	220	121	581
Peru	95	419	89	399
Spain	39	173	63	271
Sweden	--	--	22	98

See footnotes at end of table.

Table 7.—U.S. imports for consumption[1] of cadmium metal and cadmium flue dust, by country —Continued

Country	1976 Quantity (short tons)	1976 Value (thousands)	1977 Quantity (short tons)	1977 Value (thousands)
Cadmium metal —Continued				
U.S.S.R	[2]193	[2]$133	--	--
United Kingdom	11	65	6	$25
Yugoslavia	322	611	351	483
Zaire	66	343	[2]17	[2]74
Total	3,411	14,511	2,570	11,680
Flue dust (cadmium content):				
Canada	--	--	14	4
Mexico	246	536	--	--
Total	246	536	14	4
Grand total	3,657	15,047	2,584	11,684

[1]General imports and imports for consumption were the same in 1976 and 1977.
[2]Includes waste and scrap (gross weight).

WORLD REVIEW

Total world smelter production of refined cadmium was 18,898 short tons. This represented an increase of 4% above production levels achieved during 1976. The four largest cadmium producers were the U.S.S.R. and Japan (16% each), the United States (12%), and the Federal Republic of Germany (8%). Apparent U.S. consumption of cadmium amounted to nearly 24% of the total world production.

Table 8.—Cadmium: World smelter production, by country[1]

(Short tons)

Country	1975	1976	1977[p]
North America:			
Canada (refined)	1,314	1,448	1,321
United States[2]	2,193	2,256	2,204
Latin America:			
Mexico (refined)	646	783	[e]800
Peru	176	192	[e]200
Europe:			
Austria	33	32	[e]26
Belgium	[r]1,047	1,296	1,574
Bulgaria[e]	220	250	250
Finland	239	470	579
France	502	586	[e]605
German Democratic Republic[e]	22	22	22
Germany, Federal Republic of	1,122	1,405	[e]1,470
Italy	451	480	466
Netherlands[e]	[r]300	[r]439	340
Norway	52	89	106
Poland[e]	390	[r]390	440
Romania	97	110	110
Spain	[r]226	271	332
U.S.S.R.[e]	2,900	3,000	3,050
United Kingdom	[r]303	209	326
Yugoslavia[e]	300	300	330
Africa:			
South-West Africa, Territory of[3]	130	91	96
Zaire	291	293	176
Zambia	[r]7	8	4
Asia:			
China, People's Republic of[e]	120	120	120
India	[r]58	37	40
Japan	2,929	2,756	3,048
Korea, North[e]	120	130	130
Oceania: Australia (refined)	[r]605	717	733
Total	[r]16,793	18,180	18,898

[e]Estimate. [p]Preliminary. [r]Revised.
[1]This table gives unwrought metal production from ores, concentrates, flue dusts, and other materials of both domestic and imported origin. Sources generally do not indicate if secondary metal (recovered from scrap) is included or not; where known, this has been indicated by footnote. Data derived in part from World Metal Statistics (published by World Bureau of Metal Statistics, London) and from Metal Statistics (published by Metallgesellschaft Aktiengesellschaft, Frankfurt am Main). Cadmium is produced in ores, concentrates, and/or flue dusts in several other countries, but these materials are exported for treatment elsewhere to recover cadmium metal; therefore, such output is not recorded in this table to avoid double counting.
[2]Includes secondary.
[3]Output of Tsumeb Corp. for calendar years.

TECHNOLOGY

In February, the First International Cadmium Conference was convened in San Francisco, Calif., to review technological, occupational health, and marketing aspects of cadmium; over 50 papers on cadmium were presented.[2] During the first week of October, the Government-Industry Workshop on Alternatives for Cadmium Electroplating and Metal Finishing was held at the National Bureau of Standards, Gaithersburg, Md. Representatives from both Government and industry appraised various anticorrosive coatings and processes such as zinc and aluminum coatings, mechanical-plating techniques, and several relatively new electroless organic coatings.

Research focusing on cadmium in the environment and its possible effects upon human health continued to be an important area of investigation. The accumulation and distribution of heavy metals, including lead, zinc, and cadmium, were studied in the soil profile at two sites, which had been irrigated for an extended period of time with treated wastewater and sludge-injected wastewater. No serious contamination of the soils by heavy metals was found in either area.[3] Another study noted that although biological accumulations of cadmium are found in many living organisms, most of the dissipated cadmium eventually becomes fixed in soil, sediment, and ocean sinks.[4]

The results of a sampling program conducted around and below several copper and zinc mills and smelters in high runoff regions detected up to0.1% cadmium in the suspended sediments of some streams used for irrigation and drinking water. The report recommended techniques for control and treatment of contaminated wastewater destined for discharge into these streams.[5] Samples of polished and unpolished rice were analyzed for zinc and cadmium, and the results indicated that polishing brings about a loss of zinc, an essential dietary trace element, but no loss of cadmium. In countries where rice is a major food staple, uncontrolled cadmium may be taken up by the rice and result in excessive absorption of the metal.[6]

The degree of toxicity of metal oxide fumes generated by various materials during different welding and brazing processes was evaluated. The threshold limit value (TLV) for cadmium was found to be 0.05 milligram per cubic meter of air. The control of airborne pollutants and the use of special breathing and ventilating apparatus were also discussed.[7] A systematic study of factors such as acid strength and temperature that may influence the leaching of cadmium from solid acrylonitrile-butadiene-polystyrene (ABS) plastic toys containing cadmium selenide or sulfide pigments has been undertaken in the Netherlands.[8]

Photovoltaic solar cells using cadmium compounds received much attention during the year. The use of cadmium sulfide may lead to lower cost solar cells that could be a competitive energy source within a few years.[9] Pressure-sintered electrodes of cadmium selenide, subsequently, doped with cadmium vapor have demonstrated solar energy conversion efficiencies approaching three-fourths of those of single crystal specimens in sunlight experiments. Expanded use of these polycrystalline electrodes may result in a substantial cost advantage over single crystal electrodes.[10]

A new process developed in the United Kingdom for producing a grid alloy for maintenance-free batteries employs a lead matrix in which a cadmium-tin eutectic phase has been dispersed. The recommended levels of cadmium and tin are 0.6% to 0.8% by weight.[11] Electric automobiles powered by nickel-cadmium batteries are being developed as a semipublic rent-a-car network to serve the downtown area of Amsterdam, Netherlands. The batteries in the small two seat, three-wheeled vehicles can be quickly recharged at strategically located stations.[12]

Cadmium telluride probes are being employed clinically to diagnose venous thrombosis of the leg and to detect concealed dental infections in patients scheduled for cardiovascular and orthopedic surgery.[13]

A new liquid barium-cadmium-zinc heat stabilizer is expected to find application in flexible automotive plastics such as polyvinylchloride. The stabilizer is reported to provide protection to rolled and extruded plastic sheet against color change for up to 2 weeks of testing at 175°F (79°C).[14]

Developments in cadmium technology are abstracted in Cadmium Abstracts, a bimonthly publication available from the Zinc Institute Inc., 292 Madison Ave., New York 10017.

---

[1]Physical scientist, Division of Nonferrous Metals.

[2]Metal Bulletin Limited (London, England). Proceedings, First International Cadmium Conference. San Francisco, Jan. 31 - Feb. 2, 1977. January 1978, 265 pp.

[3]Sidle, R. C., J. E. Hook, and L. T. Kardos. Accumulation of Heavy Metals in Soils From Extended Wastewater Irrigation. J. Water Pollution Control, v. 49, No. 2, February 1977, pp. 311-318.

[4]Environmental Protection Agency. Multimedia Levels Cadmium. EPA 600 6-77 032, September 1977, 156 pp.

[5]Environmental Protection Agency. Heavy Metal Pollution From Spillage at Ore Smelters and Mills. EPA 600 2-77 171, 1977, 125 pp.

[6]Masironi R., S. R. Koirtyohann, and J. O. Pierce. Zinc, Copper, Cadmium, and Chromium In Polished and Unpolished Rice. Sci. Total Environment (Holland), v. 7, No. 1, January 1977, pp. 27-43.

[7]Moreton, J. Fume Hazards in Welding, Brazing & Soldering. Metal Construction. Brit. Welding J. (United Kingdom), v. 9, No. 1, January 1977, pp. 33-34.

[8]Fowles, G. W. A. The Leaching of Cadmium From Plastic Toys. Sci. Total Environment (Holland), v. 7, No. 3, May 1977, pp. 207-216.

[9]Hammond, A. L. The Semiconductor Revolution Comes to Solar. Science, v. 197, No. 4302, July 29, 1977, pp. 445-447.

[10]Miller, B., A. Heller, M. Robbins, S. Menzies, K. D. Chang, and J. Thomson, Jr. Solar Conversion Efficiency of Pressure Sintered Cadmium Selenide Liquid Junction Cells. J. Electrochem. Soc., v. 124, No. 7, July 1977, pp. 1019-1021.

[11]Tin International. V. 50, No. 10, October 1977, p. 374.

[12]Bell, L. Electric Automatic. Ind. Design. V. 24, No. 2, March-April 1977, pp. 50-51.

[13]Entine, G., D. A. Garcia, and D. E. Tow. (Review of Cadmium Telluride Medical Applications). Revue De Physique Applique (France), v. 12, No. 2, 1977, pp. 354-359.

[14]Modern Plastics. V. 54, No. 9, September 1977, p. 61.

Calcium and Calcium Compounds

By J. W. Pressler[1]

Calcium metal was manufactured by one company in Connecticut. Calcium chloride was produced by two companies in California and three companies in Michigan. Synthetic calcium chloride was manufactured by one company in New York and two companies in Washington.

DOMESTIC PRODUCTION

Pfizer Inc. produced calcium metal at Canaan, Conn., by an aluminothermic process, in which high-purity quicklime and aluminum powder are briquetted and heated in vacuum retorts; at a temperature of 1,170° C, calcium vaporizes and is collected at the other end of the retort, which has a water-cooled condenser section.

National Chloride Co. of America and Leslie Salt Co. produced calcium chloride from wells in San Bernardino County, Calif.; average output increased 6%. The Dow Chemical Co., Velsicol Chemical Corp., and Wilkinson Chemical Corp. recovered calcium chloride from brine in Gratiot, Lapeer, Mason, and Midland Counties, Mich.; average output increased 10%. Total production of natural calcium chloride was 710,000 tons, an increase of 9% compared with 1976 production.

The Dow Chemical Co. announced that it intended to build a new plant at Ludington, Mich., which will be completed late in 1978. It will include the production of calcium chloride pellets.[2]

Allied Chemical Corp. recovered synthetic calcium chloride as a byproduct of soda ash at Syracuse, N.Y.; Reichold Chemicals, Inc., recovered synthetic calcium chloride as a byproduct of pentachlorophenol manufacture at Tacoma, Wash.; and Hooker Chemicals & Plastics Corp. manufactured calcium chloride at Tacoma using limestone and hydrochloric acid. Total output of synthetic calcium chloride was 257,000 tons, an increase of 4% compared with that of 1976.

CONSUMPTION AND USES

Calcium metal was used as a reducing agent to separate refractory metals such as tantalum, uranium, and zirconium from their oxides; to form alloys with metals such as aluminum, lead, and silicon; as a desulfurizer and deoxidizer in steel refining; in the manufacture of calcium hydride used in the production of chromium, titanium, and zirconium in the Hydromet process; and as an aid in removing bismuth from lead in refining. Some minor, but interesting, uses were in the preparation of vitamin B, and as a cathode coating in some types of photo tubes.

A high growth rate was forecast for the use of calcium in the battery sector, particularly in the maintenance-free lead-calcium

(0.1% Ca) automotive storage battery. As with nickel-cadmium batteries, the lead batteries were completely sealed, and replacement of the electrolyte is not necessary. They were sold particularly on their merit of being of long life. Demand in the United States continued strong throughout the year.

In addition to the use of calcium in the refining of steel, beneficial effects were reported in steel manufacture, in which calcium was used largely as an additive to high-tensile steels, such as those used in oil pipelines, although research has pointed to possibilities of using calcium additives in other high-quality steels.

The principal use of calcium chloride was to melt snow and ice from roads, streets, bridges, and pavements. Calcium chloride is more effective at lower temperatures than rock salt and is mainly used in the northern and eastern States. Because of its considerably higher price, it is used in conjunction with rock salt for maximum effectiveness and economy. It was also used to stabilize the surface of roads and driveways for dust control and as a set-accelerator for concrete. Demand continued strong throughout the year for liquid, pellet, and flake forms of calcium chloride.

PRICES AND SPECIFICATIONS

The price of calcium metal crowns increased from $1.33 per pound to $1.49 per pound on January 17, 1977, and maintained that level throughout the year. The price of calcium-silicon alloy remained at 51 cents per pound in 1977. Published prices and specifications at yearend were as follows:

	Value per pound
Calcium metal, 1-ton lots, 50-pound full crowns, 10 by 18 inches, Ca+Mg 99.5%, Mg 0.7%	$1.49
Calcium-silicon alloy, 32% calcium, carload lots, f.o.b. shipping point	.51

Source: Metals Week. V. 49, No. 1, Jan. 2, 1978, p. 4.

Calcium metal is usually sold in the form of crowns, broken pieces, or billets, shipped in 55-gallon metal containers with a maximum of 300 pounds, and gasketed to provide an airtight condition, with argon atmosphere provided if desired. The value for imported calcium metal in 1977 ranged from $0.63 to $1.61 per pound, and averaged $1.54 per pound for the year. This did not include the assessed tariff, which was either 7.5% ad valorem for preferential status, or 25% ad valorem for statutory status.

Calcium chloride is usually sold either as solid flake or pellet averaging about 75% $CaCl_2$, or as a concentrated liquid averaging about 40% $CaCl_2$. The price of calcium chloride increased 10% during the year, although published prices did not indicate this. Published prices and specifications at yearend were as follows:

	Value per ton[1]
Calcium chloride, regular grade, 77% to 80%, flake, bulk, carload, works	$55-$65
Calcium chloride, liquid, 40% to 45%, tankcar or tanktruck, works	22- 24

[1]Differences between high and low price are accounted for by differences in quantity, quality, and location.

Source: Chemical Marketing Reporter. V. 213, No. 27, Jan. 2, 1978, p. 51.

As reported by producers on an f.o.b. warehouse basis, with conversions of all products to a 75% $CaCl_2$ basis, the average value in 1977 for natural calcium chloride was $63.41 per ton; the average value for synthetic calcium chloride was $68.74 per ton. Combining natural and synthetic products, the average value of solid 75% $CaCl_2$ for the year was $72.62 per ton, and the average value of liquid 40% $CaCl_2$ was $26.88 per ton.

FOREIGN TRADE

Exports of dicalcium phosphate were 53,309 tons valued at $9,550,000, compared with 32,302 tons valued at $6,460,000 in 1976; leading destinations were Canada, Mexico, Taiwan, and Thailand. Exports of calcium chloride, mainly to Canada and Mexico, were 39,552 tons valued at $3,383,000, compared with 33,533 tons valued at $2,578,000 in 1976. Exports of precipitated calcium carbonate, mainly to Canada and Mexico, totaled 14,887 tons valued at $4,053,000, compared with 3,411 tons valued at $735,000 in 1976.

Total imports of calcium and calcium

compounds were 207,000 tons valued at $19.4 million. Imports of calcium metal from Canada, the U.S.S.R., and France were 229 tons valued at $705,600. Imports of calcium chloride, mainly from Canada were 19,708 tons valued at $1.0 million. Imports of other calcium compounds, mainly from Norway, Turkey, Canada, the United Kingdom, and France totaled 187,000 tons, valued at $17.7 million.

Imports of other calcium compounds included 80,619 tons of calcium nitrate, mainly from Norway; 51,087 tons of calcium borate from Turkey; 32,473 tons of chalk whiting, mainly from France; 8,127 tons of precipitated calcium carbonate, mainly from the United Kingdom and Japan; 5,994 tons of calcium carbide from Canada; 1,708 tons of calcium cyanamide, mainly from Canada; 1,146 tons of calcium cyanide, mainly from Canada; and 5,820 tons of other compounds, mainly from the United Kingdom, West Germany, and Canada.

Table 1.—U.S. imports for consumption of calcium and calcium chloride, by year

Year	Calcium		Calcium chloride	
	Quantity (pounds)	Value[1]	Quantity (short tons)	Value[1]
1973	110,407	$77,864	7,357	$317,007
1974	109,252	120,883	3,599	155,727
1975	70,128	77,684	12,021	597,758
1976	461,965	475,119	16,046	480,259
1977	458,319	705,634	19,708	1,002,386

[1]U.S. Customs import value, generally representing value in foreign country, and, therefore, excluding U.S. import duties, freight, insurance, and other charges incurred in shipping merchandise to the United States.

Table 2.—U.S. imports for consumption of calcium chloride in 1977, by country

Country	Quantity (short tons)	Value[1]
Belgium-Luxembourg	17	$3,401
Canada	19,671	979,381
France	(2)	262
Germany, West	18	19,087
Japan	1	255
Total	[3]19,708	1,002,386

[1]U.S. Customs import value. See detailed explanation in footnote 1 of table 1.
[2]Less than 1/2 unit.
[3]Data do not add to total shown because of independent rounding.

WORLD REVIEW

Canada.—Chromasco Corp. Ltd. produced calcium metal at its Haley smelter near Renfrew, Ontario. Canada continued to lead all other countries in the production of calcium metal, producing about 1.1 million pounds per year, with most of it exported to the United States, Mexico, and European countries. About 216 tons valued at $691,000 was exported to the United States.

Allied Chemical Canada, Ltd., completed a 42% expansion of flake calcium chloride conversion capacity at its Solvay soda ash plant at Amherstburg, Ontario. Canada was the leading source of U.S. imports of calcium chloride.

France.—Planet Wattohm S.A., a subsidiary of Compagnie de Mokta, produced calcium metal by the Pidgeon process. About 2 tons valued at $14,000 was exported to the United States.

Japan.—Production of calcium silicide in Japan was 5,635 tons in 1975 and 4,297 tons in 1976.[3]

U.S.S.R.—Some calcium metal was produced in the U.S.S.R. Only 11 tons of Soviet calcium metal valued at $16,070 was exported to the United States. This was a major decrease compared with the 65 tons exported in 1976.

TECHNOLOGY

Demand is accelerating rapidly for calcium bromide. It is usually mixed 50-50 with calcium chloride and water to form a high-density brine solution (specific gravity 12 to 15 pounds per gallon), and used as a packer and completion fluid for completing oil and gas wells and filling the annulus between casing and tubing. This solids-free fluid is especially applicable in high-pressure oil and gas wells, and where formation sensitivity to mud damage is common. It is reported that this fluid is relatively noncorrosive and of low ecological impact.[4]

The use of calcium carbide and calcium alloys in steel refining had an increased growth demand. The injection of calcium carbide directly into the torpedo ladle was practiced by at least two companies in the United States during the year. Several different calcium-bearing alloys were manufactured by U.S. ferroalloy producers for deoxidizing, desulfurizing, and refining of specialty steels in the ladle. Calcium-barium-silicon, calcium silicide, and other metallic alloy formulations were used in the form of wire or pellets. The choice of which to use was often made on the basis of price and technical ease of using the material.

---

[1]Physical scientist, Division of Nonmetallic Minerals.

[2]State Journal (Lansing, Mich.). Sept. 13, 1977, p. 3.

[3]Roskill Information Service Ltd. (London). Roskill's Letter From Japan. RLJ No. 18, October 1977, p. 6.

Pfizer, Inc. Private communication, May 18, 1978.

[4]Great Lakes Chemical Corp. Progress Report for Nine Months Ending Sept. 30, 1977. Oct. 28, 1977, 2 pp.

Dow Chemical Co., Dowell Div. (Tulsa, Okla.). Heviwater Completion Fluid. Brochure No. DWL 1734, August 1973, 10 pp.

Cement

By Earl G. Hoover[1]

Shipments of portland cement including cement imported and distributed by domestic producers from plants in the United States and Puerto Rico in 1977 were 77,850,000 tons, 8% greater than in 1976, and the highest since 1974. However, shipments were 11% below the record of 86.6 million tons in 1973. When compared with the 5 year average, 1972-76, shipments in 1977 were 0.5% above the average. Total mill value was $2.8 billion and reflected a unit value increase of $2.50 per ton over that of 1976.

In 1977, the cement industry contended with severe winter weather conditions in the first quarter along with high energy and labor costs throughout the year. But with rebounding construction, cement demand rose sufficiently to allow a moderate increase of 7% in the average price of cement. In contrast, the increase in average price between 1975 and 1976 was 9%, with a corresponding increase in shipments of 6%. Price increases in the Eastern United States have not offset escalating costs sufficiently to provide the return on investment required to justify the enormous capital demands necessary for major new plant construction. However, in the Western United States, record sales and earnings were reported for several companies. Demand for cement outstripped production capability by midyear resulting in cement shortages, principally in California and Nevada. Shifting population from Eastern and North Central States to Western, Southwest, and Southeast States augurs well for continued strong profit potential in the high growth Sunbelt areas and very likely increased new plant construction in these regions.

According to the U.S. Department of Commerce, new private housing units started in 1977 totaled 1.99 million — an increase of 28% over 1976. Southern and Western geographic regions combined had a total of 1.32 million new units started, reflecting the increasing migration toward the Sunbelt. Private construction of nonresidential buildings, and public utilities were up; however, public construction of buildings and highways was down.

Energy, taxation, and environmental matters were major concerns, since profits, although up in 1977, were inadequate to attract capital for construction of new plants. New construction costs per annual ton of capacity now exceeds $100. Compounding the problem is that since the early 1960's cement's return of investment has failed to reach double digit levels, and 15% is required as viable. The net result was that only 565,000 tons of net capacity additions were completed in 1977.[2]

Some companies were hard-pressed to finance programs of continued upgrading, added pollution controls, and conversion to alternate fuel.

For several years the U.S. cement industry has been in a state of upheaval, as witnessed by plant closings, modernizations, bankruptcies, acquisitions by foreign interests and domestic conglomerates, and retreats from diversification, and 1977 was characteristic of this trend.

As in every year since 1973, energy continued to be a major concern. In 1977, the Federal Energy Administration (FEA) announced that the cement industry must reduce by 15.7% its energy consumption per ton of production by January 1, 1980. As a result of this action, renovation and modernization projects planned for the future will be aimed at increasing energy efficiency. The Portland Cement Association (PCA), using FEA's own projections of 1980 product demand and the final energy-efficiency target promulgated June 9, estimated that 65 new preheater kilns would be required, of which only 13 are now planned or under construction.[3]

Cement technologists gave major emphasis in 1977 to energy saving measures. Among these measures was the increased use of insulating firebrick as an aid to better heat conditioning of the cement load, thus permitting kiln production to increase with no increase in fuel consumption. Many companies also were accurately controlling the chemical, physical, and mineralogical properties and obtaining higher energy efficiencies as a result. Energy savings in wet process kilns focused on reducing the moisture content by using slurry thinners.[4]

Conversions of plants to burn coal as a primary or backup fuel, conversion from wet- to dry-process operations, and the installation of preheaters were major items of planned or actual capital expenditure. More companies announced plans to develop their own coal reserves and mining facilities.

Regulations and costs of compliance with pollution control were significant areas of concern for cement producers in 1977. During the year, clean air act amendments were signed that will prohibit new stationary sources from emitting sulfur dioxide and particulates beyond specific increments above baseline concentrations. Complex permit procedures will be applied to any source emitting more than 100 tons per year of sulfur dioxide and particulates or 250 tons per year of any other pollutant. States must meet primary ambient standards by the end of 1982; where these are impossible to meet, revised plans must then be submitted for compliance by 1987.[5]

Several cement companies announced plans or awarded contracts to install dust collection systems. Collection efficiences were designed to remove 99.9% of particulates from exhaust gases, alkali bypass systems, and raw material processing operations.

Pollution control equipment consisted of both glass bag collectors and electrostatic precipitators. Of the 222 kilns in wet-process plants, 44 were equipped with baghouse collectors and 198 with precipitators. The remaining 184 dry-process kilns were equipped with 95 baghouse collectors and 74 precipitators. An advantage of using baghouse collectors is the elimination of a tall and widely visible stack from which steam plumes emanate.

Vigorous enforcement of particulate emissions by regional pollution control districts caused problems for a number of cement producers. Most notable was the announcement that the Bay Area Air Pollution Control district was seeking a conditional abatement order requiring shutdown of Kaiser Cement & Gypsum Corp.'s largest cement plant, located at Permanente, Calif.[6]

Technology to find new ways to give cement plants more capacity and efficiency for less money was the theme at several seminars held during the year. The 13th International Cement Seminar presented the latest in concepts, methods, and practical plant experience geared towards achieving production efficiencies. Process technology made a major step forward when the PCA formed a manufacturing process committee to work with manufacturers of cement plant original equipment and with consulting engineers to improve cement manufacturing technology and to reduce production costs. During the Institute of Electrical and Electronics Engineers, Inc., 1977 Cement Industry Conference (19th) emphasis was on drive motors, general practices and process equipment, automation, and power distribution.

The PCA presented safety trophy awards to 20 cement plants that operated injury-free in 1977. Medusa Cement Co., Manitowoc, Wis., received its 30th award for 31 years without a disabling injury.

Statistical data in some tables are arranged by State or groups of States to form cement districts. A cement district may represent a group of States, a portion of a State, or in some cases, will correspond to a State. The States of California, New York, and Pennsylvania have been divided to provide additional marketing information. Divisions for these States are as follows:

California, Northern.—Points north and west of San Luis Obispo and Kern Counties and the western borders of Inyo and Mono Counties.

California, Southern.—All other counties in California.

New York, Western.—All counties west of a dividing line following the eastern boundaries of St. Lawrence, Lewis, Oneida, Madison, Chenango, and Broome Counties.

New York, Eastern.—All counties east of the above dividing line.

New York, Metroplitan.—The five counties of New York City (Bronx, Kings, New York, Queens, and Richmond) plus Westchester, Rockland, Suffolk, and Nassau Counties.

Pennsylvania, Eastern.—All counties east of the eastern boundaries of Potter, Clinton, Centre, Huntingdon, and Franklin Counties.

Pennsylvania, Western.—All other counties in Pennsylvania.

The Department of the Treasury began an investigation for the purpose of determining whether or not imports of portland hydraulic cement from Canada are being sold at less than fair value within the meaning of the Antidumping Act of 1921. Sales at less than fair value generally occur when the prices of the portland cement sold for exportation are less than the prices in the home market.[7]

A citizens group filed in the U.S. district court a suit to halt air pollution from the Missouri Portland Co.'s St. Louis, Mo. plant. Among the pollutants cited in the suit are smoke, ashes, grime, fumes, vapors, odors, gases, dirt, dust, noise, and chemical elements.

Legislation and Government Programs.—The Mining Enforcement and Safety Administration (MESA) announced plans to step up enforcement procedures at metal and nonmetal mines and plants. As a consequence inspections increased significantly in the last part of 1977. It also announced that all self-propelled equipment be fitted or retrofitted with rollover protective structures and seatbelts. Signed into law during 1977 was the Federal Mine and Safety Act of 1977. The Act among other provisions officially transfered MESA from the U.S. Department of the Interior to the U.S. Department of Labor, provides for strong penalties for safety violations, increased worker participation in the enforcement process and requires formal training prior to actual employment in mines or quarries. The accident frequency rates at cement operations in 1977 were as follows:

MESA accident frequency rates for cement operations, 1977

Activity	Number	Total employed
Mills	153	18,383
Quarries	119	2,293
Underground mines	2	69
Total	274	20,745
Fatal accidents	**Number**	**Frequency rate**
Mills	3	0.08
Quarries	1	.22
Total	4	.10
Nonfatal injuries		
Mills	532	14.85
Quarries	204	44.06
Underground	1	6.29
Total	737	18.15
Nondisabling injuries		
Mills	397	11.08
Quarries	145	31.32
Underground	31	194.84
Total	573	14.11

The National Institute of Occupational Safety and Health (NIOSH) presented preliminary details for a morbidity study of cement plant workers. The study is to be a cooperative effort with member companies of the PCA.

Table 1.—Salient cement statistics

(Thousand short tons and thousand dollars)

	1973	1974	1975	1976	1977
United States:[1]					
Production[2]	85,513	80,917	68,139	72,950	78,647
Shipments from mills[2 3]	88,665	81,033	69,102	73,668	80,247
Value[2 3 4]	$1,975,409	$2,150,659	$2,159,160	$2,510,100	$2,932,403
Average value per ton[2 3 4]	$22.28	$26.54	$31.25	$34.07	$36.54
Stocks, Dec. 31 at mills[2]	5,512	7,467	6,930	7,154	6,041
Exports	268	199	417	343	236
Imports for consumption	6,647	5,702	3,637	3,074	3,989
Consumption, apparent[5 6]	90,679	82,862	70,062	74,136	81,537
World: Production	773,769	775,183	[r]773,989	[r]810,656	[p]856,939

[p]Preliminary. [r]Revised.
[1]Excludes Puerto Rico.
[2]Portland and masonry cement only.
[3]Includes imported cement shipped by domestic producers.
[4]Value received, f.o.b. mill, excluding cost of containers.
[5]Quantity shipped, plus imports, minus exports.
[6]Adjusted to eliminate duplication of imported clinker and cement shipped by domestic cement manufacturers.

DOMESTIC PRODUCTION

During 1977, 1 State agency and 57 companies operated 163 plants in 40 States and Puerto Rico to manufacture one or more kinds of hydraulic cement.

PORTLAND CEMENT

Manufacturers in the United States and Puerto Rico produced 71,987,000 tons of clinker and imported 1,613,000 tons of foreign clinker to grind 76,340,000 tons of portland cement. Domestic producers shipped 77,850,000 tons of portland cement which included 969,000 tons of imported cement. Stocks at mills decreased by 1,081,000 tons. An additional 880,000 tons of portland cement was imported and shipped or used by others not producing cement in the United States and Puerto Rico.

Clinker Production Capacity.—Twenty-eight companies had multiplant operations ranging from 2 to 14 plants. No single company accounted for more than 6.0% of the Nation's total clinker production capacity. Five companies provided 26% of the total clinker production capacity, while 10 accounted for 46%, and the 20 had 72% of the total capacity. The 10 largest companies in terms of clinker production capacity were: Ideal Basic Industries, Inc.; Lone Star Industries, Inc.; General Portland, Inc.; Martin Marietta Cement Corp.; Amcord, Inc.; Marquette Cement Manufacturing Co.; Medusa Cement Co.; Kaiser Cement & Gypsum Corp.; National Gypsum Co.; and Universal Atlas Cement Div. of the United States Steel Corp.

At yearend, 403 kilns located at 157 plants were being operated by 52 companies and 1 State agency in 40 States in the United States and Puerto Rico. Estimated 24-hour daily clinker production capacity was 285,000 tons. An average of 56 days downtime was reported for kiln maintenance and replacing refractory brick. Based on 309 days of operation, the annual clinker production capability of the industry was 88.2 million tons. The industry operated at 81.6% of its apparent capacity, 1.7% better than in 1976. Average annual clinker capacity of each kiln in the United States was 219,000 tons, that of each plant was 562,000 tons, and for each producing company, 1,604,000 tons. Average kiln capacity ranged between the smallest 100 tons per day to the largest 4,000 per day.

Clinker was produced by wet-process kilns at 91 plants and by dry-process kilns at 60 plants; 6 plants had both processes in operation. Dry-process kilns with preheaters, are the dominant systems replacing many older wet-process facilities. Dry process kilns, preheaters, and flash calciners have attracted wide appeal in new plant design because of their higher operating efficiency and lower fuel consumption. By yearend, 35 suspension and 17 grate preheaters were in operation in 30 plants. A total of 13.6 million tons of clinker were produced by using preheater-equipped kilns.

Clinker Grinding Capacity.—Clinker grinding mills were associated with 163 clinker producing plants, 6 of which produced white cement. Additionally, 12 plants operated grinding mills only on imported, purchased, or interplant transfers of clinker; 4 of these produced only masonry cement, 1 plant ground both portland and masonry cement, and 1 ground only calcium aluminate cement. Based on the fineness necessary to grind types I and II cements, and making allowances for downtime required for maintenance, the cement industry in the United States and Puerto Rico had an estimated grinding capacity of 103.9 million tons of cement annually.

New and Planned Plant Installations.—One new plant started up in 1977. In May, Citadel Cement Corp. started up its new 750,000-ton-per-year cement plant in Demopolis, Ala. The plant is a dry-process system with preheater and kiln gas bypass capability. Design, construction, and startup was handled by Lafarge Consultants, Ltd., Montreal, Canada.

Two plants were under construction. They included the new Nazareth, Pa., plant of Coplay Cement Manufacturing Co., (subsidiary of Eurochem Inc. of Société des Ciments Français). Construction costs are expected to be about $55 million for the 1.1-million-ton-per-year cement plant. It will be coal-fired, and reportedly will be the largest size single, four-stage preheater kiln in the United States. The Polysius kiln has a diameter of 17 feet, is 276 feet long, and is equipped with a planetary cooler. Kiln feed will be ground in a roller mill. This facility will replace 11 older, smaller kilns.

The other plant being constructed was by Oregon Portland Cement Co. near Durkee, Oreg. A $37 million contract was awarded in late 1977 to Hoffman Construction Co. to build a 500,000-ton-per-year cement plant designed by F. L. Smidth & Co. This plant will be coal-fired and incorporates a four-stage cyclone preheater. Startup was scheduled for early 1979. It will replace a 200,000-ton-per-year plant at Lime, Oreg.

Five companies announced plans to construct new plants. General Portland Inc., will build in New Braunfels, Tex., an $80 million, 800,000-ton-per-year, coal-fired, dry-process with preheater system. The new plant is expected to be completed in 1980, and will replace the Houston, Tex. plant shutdown in April 1977. Ideal Basic Industries, Inc., announced the construction of a 1.5-million-ton-per-year plant at Theodore, Ala. Total cost is projected at $175 million and will be designed and built by Brown & Root. Included in the cost is $20 million worth of pollution control construction. The plant will also have the largest dry-process, suspension preheater system constructed in a single-stage in the United States. Also included as a cost item is the development of a new limestone quarry in Monroe County, Ala., approximately 110 miles from the new plant. Raw materials, including coal from Indiana, will be transported to the plant by barge on the Alabama River. When the plant is completed in 1981, it will replace the closed Baton Rouge, La. plant and ultimately the Mobile, Ala. operation. Lehigh Portland Cement Co. (Heidelberg Cement, Inc., a subsidiary of Portland Zementwerke Heidelberg A.G.) announced that a new plant costing $25 million with an annual capacity of 500,000 tons, is planned for Mason City, Iowa. It will be coal-fired and will replace six old kilns currently in operation at their Mason City, Iowa plant. Marquette Cement Manufacturing Co., (subsidiary of Gulf & Western Industries, Inc.) is planning to construct at Cape Girardeau, Mo., a new plant costing about $85 million with a design capacity of 1 million tons per year. Kaiser Engineers Inc. will manage the construction of the planned coal-fired operation scheduled for completion in 1980. Once the new plant is operational it will replace older capacities at Cowan, Tenn., and Rockmart, Ga. Site selection was determined to utilize low-cost river barge transportation. Martin Marietta Cement Corp. retained Kaiser Engineers Inc., and Lafarge Consultants, Ltd., of Montreal, Canada, to submit separate designs for an $80 million plant for Davenport, Iowa. The design companies are to focus on dry-process plant size within the expenditures announced.

Plant Closures.—One plant closure and one shutdown involving three kilns was announced in 1977. General Portland Inc., premanently closed its Houston, Tex. plant in April partly because of a court order requiring a reduction of capacity to be in compliance with environmental regulations and partly because of production inefficiency.

Louisville Cement Co., abandoned the operation of three old kilns at its Bessemer, Pa. plant. The kilns, installed in 1919, were cost intensive and the capital investment required to improve efficiency and bring them into compliance with air pollution control regulations were prohibitive. There was no production from the kilns in 1977.

Plant Modernizations, Expansions, and Terminals.—During 1977, seven plants underwent modernization. Ash Grove Cement Co. at its Louisville, Neb. plant rebuilt the 700-ton-per-hour raw materials portal scraper reclaimer. IFE Systems Inc., Ridgewood, N.J., was the contractor for the project that was completed in late 1977.

Ideal Basic Industries, Inc. began a $24 million modernization program at its Boettcher Co. plant involving a grate preheater kiln designed to use kerogen in the limestone as part of its energy requirement. Kerogen; a solid, bituminous mineraloid substance that yields oil when the rock undergoes calcination, is estimated to be in sufficient quantity and quality to provide 25% of the fuel needed for burning clinker. Other energy improvements include a reduction of 80% in electric power over the present usage. Projected overall energy savings will make Boettcher one of the most energy-efficient plants in the world. Startup is expected in early 1979.

Kaiser Cement & Gypsum Corp. announced plans to modernize its Permanente, Calif. plant. The plans call for a one-step replacement of all six wet-processing kilns with a single 1.6-million-ton-per-year dry-process, preheater, precalciner kiln that will be coal-fired.

Lone Star Industries, Inc., at its Santa Cruz, Calif. plant will spend $30 million modernizing and rebuilding. The work consists of the installation of a single preheater rotary kiln and cooler, a new self-contained roller mill, and electrostatic precipitators. Completion date is set for 1979.

Martin Marietta Cement Corp. plans to install a new raw mill, dust collectors, and kiln ends at its Roberta, Ala. plant.

Medusa Cement Co. will spend $50 million modernizing its Charlevoix, Mich., plant. Plans include conversion from wet- to dry-process with a resultant 33% fuel reduction, installation of a flash calciner-preheater, and new dust collection equipment. Completion is scheduled for spring 1980.

National Cement Co., Inc., (subsidiary of S.A. des Ciments Vicat) during 1977 carried out an extensive rehabilitation, modernization, and expansion program at its Ragland, Ala. plant. Cement production continued with minimal interruption during the construction phase. Capacity will be increased from 1,500 to 2,000 tons per day.

Construction projects designed to expand plant cement capacity were either planned or started at four plants in 1977.

California Portland Cement Co. plans to spend $40 to $50 million expanding its Mojave, Calif. plant. Expected completion of the project is 1980-81.

Northwestern States Portland Cement Co. will spend $24 million on a new 500-foot-kiln, finish mill and rod mill. The new kiln will add 850 tons per day to its Mason City, Iowa plant, and result in a 37% increase in capacity.

Southwestern Portland Cement Co. (subsidiary of Southdown, Inc.), announced that it will expand its Odessa, Tex. plant with construction to start in the second quarter of 1978.

New or improved cement distribution terminals were included in capital expenditures at four locations in 1977.

Arkansas Cement Corp. built a 750 ton bulk cement terminal in Shreveport, La.

California Portland Cement Co. put into operation its new French Camp, Calif., distribution terminal in the second half of 1977.

Dundee Cement Co. (subsidiary of Holderbank Management & Consulting Ltd. (Canada), completed a new distribution terminal and transfer station at Waverly, Ohio. At its Minneapolis, Minn. terminal, Dundee installed a cyclonaire pneumatic barge unloading system with a rated unloading capability of 350 tons per hour.

Plant Energy Conversions and Efficiency Improvements.—In 1977, six plants were either converted or construction started to burn coal; they include the Alpha Portland Industries Inc. plant at Orange, Tex.; the Arkansas Cement Corp.'s Foreman, Ark. plant, The Flintkote Co.'s plants at Redding, Calif. and San Andreas, Calif., and Gifford-Hill Portland Cement Co. plants at Midlothian, Tex. and Harleyville, S. C.

With the increased trend toward coal-fired kilns, many companies have either taken options, entered long-term leases, or acquired coal properties. At least two cement companies followed that trend in 1977. California Portland Cement Co. indicated it may exercise an option to buy a 960-acre coal lease. In 1977, Keystone Portland Cement Co., acquired coal reserves in western Pennsylvania to meet all of its fuel requirements for 10 years. Mining began in late 1977.

Fuel efficiency improvement along with conversions to coal will continue as high priority profit improvement projects. In 1977, Ideal Basic Industries, Inc., began a fuel efficiency improvement project at its Knoxville, Tenn. plant. Under a contract awarded to Fuller Co., a SF-130 suspension preheater and flash calciner, a 12- by 165-foot-kiln, and a 610S - 821S-breaker-1027H clinker cooler. The SF process increases calcination from the usual 40% to about 90% by the addition of a stationary flash furnace between the suspension preheater and kiln. The new system will replace four wet-process kilns.

Corporate Changes.—Aetna Cement Corp. (subsidiary of Lake Ontario Cement, Ltd.) acquired Martin Marietta Cement's Essexville, Mich. plant at a cost of $7 million. The plant will operate as a grinding and storage facility for clinker from Lake Ontario Cement's Picton, Ontario, Canada plant. Clinker is shipped across Lake Huron in self-unloading bulk carriers. Prior to the purchase of the plant, Lake Ontario Cement had been supplying Martin Marietta with clinker under a 4-year contract scheduled to expire in 1979.

In May, Lone Star Industries, Inc., and Canada Cement Lafarge, Ltd., agreed to equally divide the jointly owned Citadel Cement Corp. Under the division, Lone Star owns and operates the Roanoke, Va. plant and Canada Cement Lafarge, Ltd. takes over the Birmingham and Demopolis, Ala. plants.

Lone Star Industries, Inc., announced that a newly formed affiliate, Lone Star Florida, Inc., made an offer to purchase the operating assets of Maule Industries—including its cement plant at Pennsuco, Fla.

Table 2.—Portland cement shipped by producers in the United States, by district[1] [2]

(Thousand short tons and thousand dollars)

District	1976 Quantity	1976 Value	1976 Average per ton	1977 Quantity	1977 Value	1977 Average per ton
New York and Maine	3,723	102,686	$27.58	3,745	108,094	$28.86
Pennsylvania, eastern	4,045	125,671	31.07	4,111	132,013	32.12
Pennsylvania, western	1,945	59,498	30.59	2,051	64,429	31.41
Maryland and West Virginia	1,818	54,642	30.06	1,939	65,972	34.02
Ohio	2,130	65,656	30.82	1,970	65,899	33.45
Michigan	4,931	145,381	29.48	5,582	166,803	29.88
Indiana, Kentucky, Wisconsin	3,328	98,773	29.68	3,153	98,087	31.11
Illinois	1,632	53,524	32.80	1,823	61,849	33.93
Tennessee	1,256	43,495	34.63	1,522	52,894	34.75
Virginia, North Carolina, South Carolina	2,546	83,381	32.75	2,790	89,903	32.22
Georgia	930	30,085	32.35	1,192	37,711	31.64
Florida	1,949	67,832	34.80	2,540	87,561	34.47
Alabama	2,134	70,365	32.97	2,351	79,302	33.73
Louisiana and Mississippi	1,508	52,388	34.74	1,610	58,224	36.16
South Dakota and Nebraska	1,473	52,506	35.65	1,399	54,944	39.27
Iowa	2,438	86,107	35.32	2,645	99,383	37.57
Missouri	4,353	142,976	32.85	4,654	155,945	33.51
Kansas	2,005	66,478	33.16	2,020	72,815	36.05
Oklahoma and Arkansas	2,551	86,695	33.98	2,863	102,367	35.76
Texas	7,388	271,066	36.69	8,482	331,758	39.11
Wyoming, Montana, Idaho	1,086	39,188	36.08	1,131	46,918	41.48
Colorado, Arizona, Utah, New Mexico	3,612	134,279	37.18	4,021	167,841	41.74
Washington	1,238	48,669	39.31	1,462	65,281	44.65
Oregon and Nevada	920	37,667	40.94	867	39,071	45.06
California, northern	2,357	92,016	39.04	2,774	121,659	43.86
California, southern	5,539	201,630	36.40	6,496	284,526	43.80
Hawaii	328	17,747	54.11	320	16,315	50.98
Puerto Rico	1,558	66,150	42.46	1,367	67,775	49.58
U.S. total or average[3] [4]	70,721	2,396,552	33.89	76,881	2,795,338	36.36
Foreign imports[5]	1,201	38,843	32.34	969	35,348	36.48
Total or average	71,922	2,435,395	33.86	77,850	2,830,687	36.36

[1]Includes data for white cement facilities (seven in 1976 and six in 1977): Texas (three in 1976, two in 1977); Pennsylvania (two); one each in California and Wisconsin. Includes data for grinding plants (six) as follows: Wisconsin (two); Michigan (two); and one each in Florida and New York.

[2]Includes Puerto Rico.

[3]Data may not add to totals shown because of independent rounding.

[4]Includes cement produced from imported clinker.

[5]Cement imported and distributed by domestic producers only.

Table 3.—Portland cement production, capacity, and stocks in the United States, by district[1 2]

(Thousand short tons)

District	1976					1977				
	Plants active during year	Production[3]	Capacity[4]		Stocks[5] at mills Dec. 31	Plants active during year	Production[3]	Capacity[4]		Stocks[5] at mills Dec. 31
			Finish grinding	Percent utilized				Finish grinding	Percent utilized	
New York and Maine	9	3,303	5,536	59.6	422	9	3,617	5,634	64.2	486
Pennsylvania, eastern	11	4,272	6,637	64.3	618	11	4,252	6,680	63.6	593
Pennsylvania, western	5	2,012	2,885	69.7	317	5	1,920	2,970	64.6	188
Maryland and West Virginia	4	1,897	2,821	67.2	245	4	2,021	2,821	71.6	253
Ohio	7	2,190	3,074	71.2	212	5	1,956	2,360	82.8	187
Michigan	8	5,118	7,543	67.8	689	7	5,568	7,684	72.4	514
Indiana, Kentucky, Wisconsin	9	3,338	5,058	65.9	323	9	3,399	4,994	68.0	328
Illinois	4	1,849	2,136	86.5	287	4	1,915	2.341	81.8	187
Tennessee	6	1,289	2,568	50.1	152	6	1,476	2,626	56.2	153
Virginia, North Carolina, South Carolina	6	2,486	4,804	51.7	257	5	2,722	4,774	57.0	220
Georgia	3	982	1,477	66.4	77	3	1,235	1,702	72.5	75
Florida	6	1,931	4,119	46.8	189	6	2,569	4,273	60.1	129
Alabama	7	2,098	3,115	67.3	223	7	2,340	3,804	61.5	191
Louisiana and Mississippi	5	1,551	2,193	70.7	130	4	1,538	1,993	77.1	105
South Dakota and Nebraska	3	1,484	1,915	77.4	158	3	1,368	1,879	72.8	136
Iowa	5	2,454	3,094	79.3	273	5	2,513	3,167	79.3	220
Missouri	7	4,334	5,171	83.8	376	7	4,551	5,211	87.3	346
Kansas	5	1,950	2,326	83.8	189	5	2,072	2,340	88.5	130
Oklahoma and Arkansas	5	2,620	3,462	75.6	253	5	2,771	3,422	80.9	143
Texas	18	7,438	9,711	76.5	543	18	8,233	9,761	84.3	343
Wyoming, Montana, Idaho	4	1,044	1,219	85.6	56	4	1,118	1,199	93.2	78
Colorado, Arizona, Utah, New Mexico	8	3,524	5,675	62.1	220	8	3,858	5,375	71.7	149
Washington	4	1,391	2,068	67.2	98	4	1,636	2,095	78.0	81
Oregon and Nevada	3	912	1,385	65.8	43	3	904	1,385	65.2	50
California, northern	4	2,377	3,026	78.5	152	4	2,541	3,276	77.5	107
California, southern	8	5,515	7,810	70.6	224	8	6,499	7,758	83.7	238
Hawaii	2	323	550	58.7	33	2	333	560	59.3	46
Puerto Rico	3	1,545	2,768	55.8	31	2	1,413	1,796	78.6	33
Total or average	169	71,227	104,146	68.4	6,790	163	[6]76,340	103,880	73.5	5,709

[1]Includes Puerto Rico.
[2]Includes data for white cement facilities (seven in 1976 and six in 1977): Texas (three in 1976, two in 1977); Pennsylvania (two); one each in California and Wisconsin. Includes data for grinding plants (six) as follows: Wisconsin (two); Michigan (two); and one each in Florida and New York.
[3]Includes cement produced from imported clinker (1976—1,024; 1977—1,483).
[4]Grinding capacity based on fineness necessary to grind Types I and II cement, making allowance for downtime required for maintenance.
[5]Includes imported cement. Source of imports withheld to avoid disclosing individual company confidential data.
[6]Data do not add to total shown because of independent rounding.

Table 4.—Clinker capacity and production in the United States, by district, as of December 31, 1977[1] [2]

District	Active plants: Process used: Wet	Dry	Both	Total	Number of kilns	Daily capacity (thousand short tons)	Average number of days for maintenance	Apparent annual capacity[3] (thousand short tons)	Production[4] (thousand short tons)	Percent utilized
New York and Maine	6	2	--	8	13	15.9	65	4,767	3,587	75.2
Pennsylvania, eastern	3	8	--	11	49	19.5	50	6,147	4,181	68.0
Pennsylvania, western	3	2	--	5	10	7.5	43	2,416	1,820	75.3
Maryland and West Virginia	2	2	--	4	10	8.1	42	2,618	2,086	79.7
Ohio	2	2	1	5	10	7.5	48	2,381	1,860	78.1
Michigan	5	1	--	6	17	18.1	46	5,779	5,046	87.3
Indiana, Kentucky, Wisconsin	3	4	--	7	16	14.6	55	4,533	3,080	66.8
Illinois	--	4	--	4	10	9.3	35	3,070	1,906	62.1
Tennessee	6	--	--	6	12	5.2	49	1,644	1,437	87.4
Virginia, North Carolina, South Carolina	3	2	--	5	14	12.2	74	3,554	2,785	78.4
Georgia	--	2	1	3	5	4.8	39	1,565	1,196	76.4
Florida	4	1	--	5	11	11.2	50	3,532	2,258	63.9
Alabama	3	4	--	7	15	11.4	86	3,183	2,393	75.2
Louisiana and Mississippi	4	--	--	4	8	5.7	73	1,664	1,455	87.4
South Dakota and Nebraska	2	--	1	3	9	4.6	74	1,340	1,260	94.0
Iowa	3	2	--	5	18	9.1	50	2,871	2,449	85.3
Missouri	5	2	--	7	12	15.4	52	4,814	4,346	90.3
Kansas	3	2	--	5	15	7.1	60	2,166	1,917	88.5
Oklahoma and Arkansas	3	2	--	5	11	8.6	43	2,768	2,653	95.8
Texas	12	3	2	17	44	25.7	57	7,911	7,434	94.0
Wyoming, Montana, Idaho	4	--	--	4	5	3.1	26	1,052	1,061	100.8
Colorado, Arizona, Utah, New Mexico	3	5	--	8	21	13.1	66	3,918	3,616	92.3
Washington	3	1	--	4	7	3.6	34	1,190	1,139	95.7
Oregon and Nevada	2	1	--	3	7	3.3	58	1,013	874	86.3
California, northern	2	2	--	4	13	9.4	55	2,916	2,397	82.2
California, southern	2	5	1	8	29	21.8	49	6,891	6,126	88.9
Hawaii	1	1	--	2	3	2.3	88	638	338	53.0
Puerto Rico	2	--	--	2	9	7.3	105	1,896	1,337	70.5
Total or average	91	60	6	157	403	285.4	56	88,237	71,987	81.6

[1]Includes Puerto Rico.
[2]Includes white-cement-producing facilities.
[3]Calculated on individual company data: 365 days, minus average days for maintenance, times the reported 24-hour capacity.
[4]Includes production reported for plants which added or shut down kilns during the year.

Table 5.—Daily clinker capacity, December 31[1 2]

Short tons per 24-hour period	Number: Plants	Number: Kilns[3]	Total capacity (short tons)	Percent of total capacity
1976:				
Less than 600	7	8	2,891	1.0
600 to 1,150	37	70	32,067	11.4
1,150 to 1,700	47	116	68,375	24.4
1,700 to 2,300	29	81	57,117	20.3
2,300 to 2,800	14	44	34,831	12.4
2,800 and over	23	86	85,755	30.5
Total	157	405	281,036	100.0
1977:				
Less than 600	6	8	2,841	1.0
600 to 1,150	37	67	30,089	10.5
1,150 to 1,700	45	113	66,981	23.5
1,700 to 2,300	32	92	65,389	22.9
2,300 to 2,800	14	34	32,168	11.3
2,800 and over	23	89	87,919	30.8
Total	157	403	285,387	100.0

[1]Includes Puerto Rico.
[2]Includes white-cement-producing facilities.
[3]Total number in operation at plants.

Table 6.—Raw materials used in producing portland cement in the United States[1]

(Thousand short tons)

Raw materials	1976	1977
Calcareous:		
Limestone (includes aragonite and marble)	81,342	81,470
Cement rock (includes marl)	20,159	25,124
Oystershell	2,390	2,076
Argillaceous:		
Clay	7,009	6,859
Shale	3,655	3,950
Other (includes staurolite, bauxite, aluminum dross, pumice, and volcanic material)	187	200
Siliceous:		
Sand	1,985	2,107
Sandstone and quartz	707	603
Ferrous: Iron ore, pyrites, millscale, and other iron-bearing material	825	870
Other:		
Gypsum and anhydrite	3,658	3,930
Blast furnace slag	435	464
Fly ash	264	353
Other, n.e.c	8	39
Total	122,624	128,045

[1]Includes Puerto Rico.

MASONRY CEMENT

Shipments of masonry cement were 3,764,000 tons in 1977, an increase of 14% over the previous year, but still 9% less than the record shipments of 1973. The unit price averaged over the Nation was $45.03 per ton, 6% higher than in 1976. Total value of masonry cement shipments increased to $169 million, nearly 20% above the value of 1976 shipments. By yearend, 107 plants manufactured masonry cement in the United States. Four plants producing masonry cement exclusively were, Cheney Lime & Cement Co., Allgood, Ala.; G. W. Corson, Inc., Plymouth Meeting, Pa.; Campbell-Grove Div. of The Flintkote Co., Frederick, Md.; and Riverton Corp., Riverton, Va. Masonry cement was not produced in some parts of the country because many of the masons preferred to use portland cement and add clay or lime on the job as needed for the necessary plasticity.

Table 7.—Masonry cement shipped by producers in the United States, by district[1] [2]

(Thousand short tons and thousand dollars)

District	1976 Quantity	1976 Value	1976 Average per ton	1977 Quantity	1977 Value	1977 Average per ton
New York and Maine	86	2,828	$32.88	85	2,973	$34.98
Pennsylvania, eastern	240	11,581	48.25	256	13,286	51.90
Pennsylvania, western	139	5,322	38.29	155	6,640	42.84
Maryland and West Virginia	124	4,317	34.81	141	5,221	37.03
Ohio	155	7,288	47.02	186	8,875	47.72
Michigan	218	8,370	38.39	246	9,761	39.68
Indiana, Illinois, Kentucky, Wisconsin	560	22,377	39.96	620	26,287	42.40
Tennessee	175	6,476	37.01	195	7,878	40.40
Virginia, North Carolina, South Carolina	300	13,863	46.21	359	17,873	49.79
Georgia and Florida	176	8,177	46.46	257	12,338	48.01
Alabama	314	13,671	43.54	345	14,255	41.32
Louisiana, Mississippi, South Dakota, Nebraska	84	3,536	42.10	92	3,883	42.21
Iowa	76	4,143	54.51	86	5,052	58.74
Missouri	76	2,718	35.76	82	3,286	40.07
Kansas	72	3,281	45.57	79	3,742	47.37
Oklahoma and Arkansas	124	5,015	40.44	143	6,139	42.93
Texas	213	10,596	49.75	254	13,095	51.56
Wyoming, Montana, Idaho	9	406	45.11	10	533	53.30
Colorado, Arizona, Utah, New Mexico	106	4,507	42.52	141	6,769	48.01
Washington, Oregon, Nevada; California, northern; California, southern	8	430	53.75	9	605	67.22
Hawaii	11	663	60.27	10	607	60.70
Puerto Rico	--	--	--	--	--	--
U.S. total or average[3]	3,266	139,564	42.73	3,753	169,101	45.07
Foreign imports[4]	38	1,291	33.97	11	390	35.45
Total or average	3,304	140,855	42.63	3,764	169,491	45.03

[1]Does not include quantities produced on the job by masons.
[2]Includes Puerto Rico.
[3]Data may not add to totals shown because of independent rounding.
[4]Cement imported and distributed by domestic producers only. Source of imports withheld to avoid disclosing company proprietary data.

Table 8.—Masonry cement production and stocks in the United States, by district[1]

(Thousand short tons)

District	1976 Plants active during year	1976 Production	1976 Stocks[2] at mills Dec. 31	1977 Plants active during year	1977 Production	1977 Stocks[2] at mills Dec. 31
New York and Maine	5	82	7	3	86	11
Pennsylvania, eastern	9	246	36	9	250	30
Pennsylvania, western	5	140	20	5	150	16
Maryland and West Virginia	3	135	7	3	149	7
Ohio	4	157	15	4	184	14
Michigan	5	214	72	5	248	71
Indiana, Illinois, Kentucky, Wisconsin	7	563	53	7	623	59
Tennessee	5	195	22	5	211	21
Virginia, North Carolina, South Carolina	5	301	20	5	351	15
Georgia and Florida	5	167	27	5	239	24
Alabama	7	312	27	6	339	23
Louisiana, Mississippi, South Dakota, Nebraska	6	66	8	5	80	7
Iowa	3	74	13	3	82	9
Missouri	4	70	8	4	88	12
Kansas	5	70	18	5	70	8
Oklahoma and Arkansas	5	126	7	5	143	8
Texas	12	220	19	12	259	16
Wyoming, Montana, Idaho	3	11	5	4	8	3
Colorado, Arizona, Utah, New Mexico	6	103	8	6	141	8
Washington, Oregon, Nevada; California, northern; California, southern	5	6	1	4	9	1
Hawaii	2	10	2	2	10	2
Puerto Rico	--	--	--	--	--	--
Total	111	[3]3,268	395	107	[3]3,720	365

[1]Includes Puerto Rico.
[2]Includes imported cement.
[3]Includes 2,597 tons produced from clinker, and 671 tons produced from cement (1976); 2,947 tons produced from clinker, and 773 tons produced from cement (1977).

ALUMINOUS CEMENT

Aluminous cement, also known as calcium aluminate cement, high-alumina cement, and "Ciment Fondu," is a nonportland hydraulic cement produced at three plants in the United States: United States Steel Corp., Universal Atlas Cement Div., Buffington, Ind.; Lone Star Lafarge Inc., Chesapeake, Va.; and Aluminum Co. of America at Bauxite, Ark.

ENERGY

The largest single cost in cement manufacture is the cost of energy which accounts for about a third of the industries total production costs. Cement manufacture according to the U.S. Department of Commerce is one of the six most energy-intensive industries as rated by the energy necessary to produce a ton of product.

In the Federal Regulations of June 9, 1977, the FEA published its final industrial energy-efficiency targets for the 10 most energy-intensive industries. The target established for the portland cement industry (SIC 32) is a 15.7% reduction in energy by January 1, 1980. The industry commented that there is not sufficient time to complete the massive new construction and process conversion programs required in the final target. In addition, the capital requirement is far beyond the industry's financial resources.

According to a report submitted to the U.S. Department of Energy by the PCA, the United States portland cement industry used 7.9% less energy per ton of cement manufactured in 1977 than in 1972.

The report showed that coal or coke was used as the primary fuel for 65% of total 1977 output, compared with 38% in 1972, the base year for the Federal Government's voluntary industrial energy conservation program. Natural gas consumption was 56% under 1972 levels and petroleum usage fell 31% in the same period.

The all-industry average energy consumption in 1977 was 6.27 million British thermal units (BTU) per ton of production, ranging from 12.90 to 3.38 million Btu's per ton. Electric power consumption rose 2% from the base period, reflecting increased power requirements for operating pollution-control and coal-handling equipment.

In 1977, the industry used 11.5 million tons of coal, 8.1 million barrels of oil, 97.2 billion cubic feet of natural gas, and 10.0 billion kilowatt-hours of electricity in the production of 72.0 million tons of clinker and 76.3 million tons of finished portland cement. In comparison, during the base year of 1972, the industry used 7.3 million tons of coal, 12.2 million barrels of oil, 223.0 billion cubic feet of natural gas, and 10.6 billion kilowatt-hours of electricity to produce 77.4 million tons of clinker and 80.7 million tons of finished portland cement.

Increased usage of energy-saving preheater systems has become a standard feature in both new plant installations and modernization projects. There were 34 suspension preheaters and 13 traveling grate preheaters. Kilns utilizing suspension preheaters used an average of 4.77 million Btu's per ton, those with traveling grate preheaters used an average of 5.86 million Btu's, and kilns without preheaters used an average of 6.95 million Btu's.

Conversions from the more energy-intensive wet-process plant to dry-process is another approach being used by the industry to cut energy costs. Of the 157 plants active in 1977, 91 were wet-process, 60 dry-process, and 6 utilized both wet- and dry-process. In contrast with 1972, out of 170 plants, 107 were wet-process and 63 were dry-process. Average energy consumption for wet-process plants in 1977 was 6.49 million Btu's per ton, while for dry-process it was 5.11 million Btu's per ton.

Pozzolanic additives are another means of conserving energy but use of these additives is not widespread, representing less than 0.5% of the total portland cement shipments. Of the 367,000 tons of pozzolanic cement shipped in 1977, almost 74% was manufactured west of the Mississippi River.

Energy conservation will continue as a major focus for cutting production costs.

Table 9.—Clinker produced in the United States, by kind of fuel[1]

Year and fuel	Clinker produced: Plants active during year	Clinker produced: Quantity (thousand short tons)	Clinker produced: Percent of total	Fuel consumed: Coal[2] (thousand short tons)	Fuel consumed: Oil (thousand 42-gallon barrels)	Fuel consumed: Natural gas (thousand cubic feet)
1976:						
Coal	38	[3]16,447	24.0	3,773	--	--
Oil	7	[3]2,497	3.6	--	2,322	--
Natural gas	12	[3]4,304	6.3	--	--	26,617,431
Coal and oil	21	9,487	13.8	1,920	1,026	--
Coal and natural gas	42	16,708	24.4	2,492	--	45,568,090
Oil and natural gas	27	13,069	19.1	--	3,928	53,376,632
Coal, oil, natural gas	14	6,067	8.8	1,103	330	6,657,355
Total	161	68,579	100.0	9,288	7,606	132,219,508
1977:						
Coal	35	[3]17,523	24.3	3,912	--	--
Oil	7	[3]2,743	3.8	--	2,468	--
Natural gas	10	[3]2,727	3.8	--	--	16,553,865
Coal and oil	22	9,617	13.4	2,112	602	--
Coal and natural gas	42	17,239	23.9	3,126	--	38,529,813
Oil and natural gas	15	8,494	11.8	--	3,625	28,136,572
Coal, oil, natural gas	26	13,643	19.0	2,340	1,414	13,983,078
Total	157	[4]71,987	100.0	11,490	8,109	97,203,328

[1]Includes Puerto Rico.
[2]Includes 96.5% bituminous, and 3.5% petroleum coke in 1976; and 97.9% bituminous, and 2.1% petroleum coke in 1977.
[3]Average consumption of fuel per ton of clinker produced as follows: 1976-coal, 0.22940 ton; oil, 0.930 barrel; and natural gas, 6,184 cubic feet; 1977-coal, 0.22325 ton; oil, 0.900 barrel; and natural gas, 6,070 cubic feet.
[4]Data do not add to total shown because of independent rounding.

Table 10.—Clinker produced and fuel consumed by the portland cement industry in the United States, by process[1]

Year and process	Clinker produced: Plants active during year	Clinker produced: Quantity (thousand short tons)	Clinker produced: Percent of total	Fuel consumed: Coal[2] (thousand short tons)	Fuel consumed: Oil (thousand 42-gallon barrels)	Fuel consumed: Natural gas (thousand cubic feet)
1976:						
Wet	93	37,980	55.4	5,050	5,508	88,107,261
Dry	61	26,720	39.0	3,947	1,347	35,245,967
Both	7	3,879	5.6	291	751	8,866,280
Total	161	68,579	100.0	9,288	7,606	132,219,508
1977:						
Wet	91	39,308	54.6	6,494	5,860	62,705,475
Dry	60	28,987	40.3	4,698	1,592	25,656,621
Both	6	3,692	5.1	298	657	8,841,232
Total	157	71,987	100.0	11,490	8,109	97,203,328

[1]Includes Puerto Rico.
[2]Includes 96.5% bituminous, and 3.5% petroleum coke in 1976; and 97.9% bituminous, and 2.1% petroleum coke in 1977.

Table 11.—Electric energy used at portland cement plants in the United States, by process[1] [2]

Year and process	Electric energy used: Generated at portland cement plants: Active plants	Generated at portland cement plants: Quantity (million kilowatt-hours)	Purchased: Active plants	Purchased: Quantity (million kilowatt-hours)	Total: Quantity (million kilowatt-hours)	Total: Percent	Finished cement produced (thousand short tons)	Average electric energy used per ton of cement produced (kilowatt-hours)
1976:								
Wet	3	77	92	5,158	5,235	51.9	39,757	131.7
Dry[3]	6	493	66	3,784	4,277	42.4	27,807	153.8
Both	--	--	7	569	569	5.7	3,663	155.3
Total	9	570	165	9,511	10,081	100.0	71,227	141.5
Percent of total electric energy used	--	5.6	--	94.4	--	--	--	--
1977:								
Wet	2	66	91	5,392	5,458	51.3	42,465	128.5
Dry[3]	5	521	65	4,134	4,655	43.7	30,299	153.6
Both	--	--	6	531	531	5.0	3,576	148.5
Total	7	587	162	10,057	10,644	100.0	76,340	139.3
Percent of total electric energy used	--	5.5	--	94.5	--	--	--	--

[1]Includes grinding plants and white cement facilities.
[2]Includes Puerto Rico.
[3]Includes data for six grinding plants.

TRANSPORTATION

Bulk and bagged portland cement in the United States was transported by highways, railways, and waterways. Trucks were the dominant carrier, hauling 87.5% of the total 77,850,000 tons, followed by rail with 10.6%, and barge at 1.6%. Since 1972, truck deliveries have increased from 82.6%, rail shipments have declined from 15.8%, and waterway shipments have remained about the same.

In May, the National Association of Cement Shippers met primarily for the purpose of analyzing the present and future role of railroads in the transportation of cement. Several railroad executives participated and were optimistic for the future. Areas of interest included intermodal service, rail costing, communications, rail car availability, and rail car innovations. Forming the basis for these discussions was a report prepared by Reebie Associates titled Bulk Cement Transportation. This study was undertaken by the association for the purpose of determining whether to participate in formal proceedings involving transportation rates and services. A second objective was to determine whether action could be taken to reduce overall bulk cement distribution costs. Another goal was to improve transportation efficiency of the inbound fuel and raw materials used by the cement industry.

Table 12.—Shipments of portland cement from mills in the United States, in bulk and in containers, by type of carrier[1]

(Thousand short tons)

Year and type of carrier	Shipments from plant to terminal		Shipments to ultimate consumer				Total shipments
			From terminal to consumer		From plant to consumer		
	In bulk	In containers	In bulk	In containers	In bulk	In containers	
1976:							
Railroad	8,054	204	746	22	7,259	254	8,281
Truck	1,282	151	16,389	977	40,077	4,808	62,251
Barge and boat	7,333	15	464	--	609	--	1,073
Unspecified[2]	260	--	204	--	102	10	316
Total	16,929	370	17,803	999	48,047	5,072	[3] [4]71,922
1977:							
Railroad	8,080	360	1,324	37	6,665	250	8,276
Truck	1,430	94	17,336	1,041	45,081	4,698	68,156
Barge and boat	8,421	12	107	--	820	330	1,257
Unspecified[2]	59	1	--	--	150	9	159
Total	17,990	467	18,767	1,078	52,716	5,287	[3] [4]77,850

[1]Includes Puerto Rico.
[2]Includes cement used at plant.
[3]Bulk shipments were 92.0% (65,850 tons), and container (bag) shipments were 8.0% (6,071 tons) for 1976. Bulk shipments were 91.8% (71,483 tons), and container (bag) shipments were 8.2% (6,365 tons) for 1977.
[4]Data may not add to totals shown because of independent rounding.

Table 13.—Cement shipments, by destination and origin[1]

(Thousand short tons)

	Portland cement[2]		Masonry cement	
	1976	1977	1976	1977
Destination:				
Alabama	1,376	1,400	117	137
Alaska[3]	134	120	W	W
Arizona	1,111	1,477	W	W
Arkansas	885	929	69	77
California, northern	2,734	3,246	--	(4)
California, southern	4,569	5,289	--	2
Colorado	1,197	1,407	30	38
Connecticut[3]	568	648	14	13
Delaware[3]	142	149	7	8
District of Columbia[3]	196	155	8	8
Florida	3,347	3,831	222	283
Georgia	1,614	2,074	166	187
Hawaii	328	308	10	10
Idaho	511	509	2	3
Illinois	3,760	3,622	117	133
Indiana	1,700	1,684	116	122
Iowa	1,800	1,758	32	33
Kansas	1,229	1,230	34	33
Kentucky	1,046	1,157	118	127
Louisiana	2,486	2,524	79	93
Maine	308	259	11	10
Maryland	1,188	1,254	101	114
Massachusetts[3]	811	859	35	36
Michigan	2,596	2,681	139	158
Minnesota	1,551	1,654	50	60
Mississippi	830	946	66	74
Missouri	1,723	1,781	50	54
Montana	335	350	4	4
Nebraska	1,029	1,002	18	20
Nevada	359	511	(4)	(4)
New Hampshire[3]	236	264	13	12
New Jersey[3]	1,366	1,335	54	56
New Mexico	543	619	16	17
New York, eastern	745	483	26	28
New York, western	872	887	43	47
New York, metropolitan[3]	866	876	32	24
North Carolina	1,459	1,537	220	250
North Dakota[3]	412	429	10	10
Ohio	2,804	3,199	188	223
Oklahoma	1,262	1,594	61	71
Oregon	794	841	1	1
Pennsylvania, eastern	1,756	1,861	75	77
Pennsylvania, western	1,102	1,085	91	103
Puerto Rico	1,433	1,368	(4)	--
Rhode Island[3]	142	139	5	5
South Carolina	782	853	119	135
South Dakota	373	369	10	11
Tennessee	1,309	1,467	172	187
Texas	6,469	7,877	194	240
Utah	920	900	2	2
Vermont[3]	109	131	5	6
Virginia	1,599	1,624	182	205
Washington	1,168	1,355	9	10
West Virginia	579	573	51	59
Wisconsin	1,602	1,739	67	78
Wyoming	418	389	5	5
Total United States	72,583	78,608	3,266	3,699
Foreign countries[5]	250	122	63	91
Total shipments	72,833	78,730	3,329	3,790
Origin:				
United States[6]	69,171	75,514	3,266	3,753
Puerto Rico	1,550	1,367	--	--
Foreign:[7]				
Domestic producers	1,201	969	38	11
Others	911	880	25	26
Total shipments	72,833	78,730	3,329	3,790

W Withheld to avoid disclosing company proprietary data; included with "Foreign countries."

[1]Includes cement produced from imported clinker and imported cement shipped by domestic producers, Canadian cement manufacturers, and other importers. Includes Puerto Rico.

[2]Excludes cement (1976—397; 1977—458) used in the manufacture of prepared masonry cement.

[3]Has no cement-producing plants.

[4]Less than 500 short tons.

[5]Direct shipments by producers to foreign countries and U.S. possessions and territories; includes States indicated by symbol W.

[6]Includes cement produced from imported clinker by domestic producers (1976—1,024; 1977—1,483).

[7]Imported cement distributed by domestic producers, Canadian cement manufacturers, and other importers. Origin of imports withheld to avoid disclosing company proprietary data.

Table 14.—Portland cement shipments in 1977, by type of customer[1]

(Thousand short tons)

District origin	Building material dealers		Concrete product manufacturers		Ready-mixed concrete		Highway contractors		Other contractors		Federal, State, and other government agencies		Miscellaneous including own use		Total[2]
	Quantity	Percent	Quantity	Percent	Quantity	Percent	Quantity	Percent	Quantity	Percent	Quantity	Percent	Quantity	Percent	
New York and Maine	219	5.9	673	18.0	2,743	73.2	43	1.1	62	1.7	1	(3)	5	0.1	3,745
Pennsylvania, eastern	515	12.5	1,030	25.1	2,284	55.6	170	4.1	71	1.7	2	0.1	38	.9	4,111
Pennsylvania, western	202	9.8	328	16.0	1,298	63.3	188	9.2	31	1.5	2	.1	2	.1	2,051
Maryland and West Virginia	115	5.9	437	22.5	1,289	66.5	14	.7	65	3.4	19	1.0	1	(3)	1,939
Ohio	163	8.3	338	17.2	1,316	66.8	106	5.4	8	.4	2	.1	37	1.8	1,970
Michigan	353	6.3	850	15.2	3,673	65.8	605	10.9	85	1.5	15	.3	--	--	5,582
Indiana, Kentucky, Wisconsin	222	7.0	521	16.5	2,138	67.8	178	5.7	69	2.2	5	.2	20	.6	3,153
Illinois	110	6.0	138	7.6	1,286	70.5	270	14.8	19	1.0	--	--	1	.1	1,823
Tennessee	143	9.4	331	21.7	936	61.5	36	2.4	27	1.8	33	2.2	16	1.0	1,522
Virginia, North Carolina, South Carolina	162	5.8	424	15.2	1,951	69.9	212	7.6	33	1.2	1	.1	6	.2	2,790
Georgia	145	12.2	171	14.4	610	51.2	179	15.0	50	4.2	4	.3	32	2.7	1,192
Florida	296	11.6	409	16.1	1,384	54.5	206	8.1	112	4.4	114	4.5	20	.8	2,540
Alabama	162	6.9	478	20.3	1,340	57.0	179	7.6	163	6.9	6	.3	24	1.0	2,351
Louisiana and Mississippi	156	9.7	134	8.3	846	52.6	100	6.2	255	15.8	72	4.5	47	2.9	1,610
South Dakota and Nebraska	76	5.4	147	10.5	942	67.4	209	15.0	18	1.3	--	--	6	.4	1,399
Iowa	125	4.7	532	20.1	1,767	66.8	200	7.6	9	.3	--	--	12	.5	2,645
Missouri	99	2.1	441	9.5	3,587	77.1	455	9.8	66	1.4	--	--	6	.1	4,654
Kansas	126	6.2	139	6.9	1,373	68.0	172	8.5	96	4.8	--	--	113	5.6	2,020
Oklahoma and Arkansas	220	7.7	256	8.9	1,835	64.1	335	11.7	159	5.6	10	.4	47	1.6	2,863
Texas	592	7.0	732	8.7	5,328	62.8	282	3.3	1,129	13.3	111	1.3	307	3.6	8,482
Wyoming, Montana, Idaho	35	3.1	80	7.1	860	76.0	33	2.9	81	7.2	3	.2	40	3.5	1,131
Colorado, Arizona, Utah, New Mexico	205	5.1	447	11.1	2,819	70.1	134	3.3	222	5.5	2	.1	191	4.8	4,021
Washington	39	2.7	197	13.5	1,019	69.7	74	5.1	88	6.0	3	.2	41	2.8	1,462
Oregon and Nevada	40	4.6	82	9.5	673	77.6	11	1.3	56	6.5	--	--	4	.5	867
California, northern	257	9.3	389	14.0	1,891	68.2	85	3.1	89	3.2	2	(3)	61	2.2	2,774
California, southern	590	9.1	851	13.1	4,681	72.0	138	2.1	194	3.0	4	.1	38	.6	6,496
Hawaii	12	3.8	5	1.5	278	86.9	--	--	15	4.7	1	.3	9	2.8	320
Puerto Rico	629	46.0	124	9.1	598	43.7	--	--	12	.9	3	.2	1	.1	1,367
Imports[4]	25	2.6	83	8.6	835	86.2	11	1.1	9	.9	--	--	6	.6	969
Total or average[2]	6,033	7.8	10,767	13.8	51,580	66.3	4,625	5.9	3,293	4.2	415	.5	1,131	1.5	77,850

[1]Includes Puerto Rico.
[2]Data may not add to totals shown because of independent rounding.
[3]Less than 0.1%.
[4]Cement imported and distributed by domestic producers only. Source of imports withheld to avoid disclosing company proprietary data.

Table 15.—Portland cement shipped from plants in the United States, by type[1]

(Thousand short tons and thousand dollars)

Type	1976 Quantity	1976 Value[2]	1976 Average per ton	1977 Quantity	1977 Value[2]	1977 Average per ton
General use and moderate heat (Types I and II)	66,598	2,222,426	$33.37	71,648	2,569,836	$35.87
High-early-strength (Type III)	2,217	77,013	34.74	2,699	97,263	36.04
Sulfate-resisting (Type V)	279	10,567	37.87	339	14,716	43.41
Oil well	1,275	46,765	36.68	1,575	61,852	39.27
White	362	31,359	86.63	368	35,176	95.59
Portland slag and portland pozzolan	344	10,760	31.28	367	12,188	33.21
Expansive	97	4,243	43.74	95	4,115	43.32
Miscellaneous[3]	750	32,262	43.02	759	35,541	46.89
Total or average	71,922	2,435,395	33.86	77,850	2,830,687	36.36

[1]Includes Puerto Rico.
[2]Mill value is the actual value of sales to customers, f.o.b. plant, less all discounts and allowances, less all freight charges to customer, less all freight charges from producing plant to distribution terminal if any, less total cost of operating terminal if any, less cost of paper bags and pallets.
[3]Includes waterproof cement and low-heat (Type IV).

CONSUMPTION AND USES

Shipments of cement into various States are considered to be an index of consumption. Portland cement consumption increased 8% over that of 1976. Domestic producers shipped 77.9 million tons of portland cement, which included 1.4 million tons of imported cement. In addition to the imported cement shipped by domestic manufacturers, 880,000 tons of portland cement was imported and shipped or used by others not producing cement in the United States or Puerto Rico.

Consumption increased in all but 15 States, the District of Columbia, and Puerto Rico. The greatest regional reduction in usage was in the eastern New York area, down 35%. Maine was the State showing the largest drop where shipments were down 16%. Other large decreases in consumption were the District of Columbia, down 21%; Alaska, down 10%; Wyoming, down 7%; and Hawaii, down 6%. The largest increase in consumption was in Nevada, where shipments were up by 152,000 tons, a 42% increase over 1976. The second largest increase was in Arizona, where 366,000 tons more was used than in 1976, a 33% increase. Next in order of increasing consumption were Georgia, up 460,000 tons or 29%; Oklahoma up 332,000 tons, a 26% increase; and Texas up 1,408,000 tons, a 22% increase over 1976.

Ready-mix concrete producers were the primary consumers of portland cement, accounting for 66% of the total shipped by domestic producers. Manufacturers of concrete products used 14% to make concrete blocks and pipe, precast, prestressed, and other concrete products. Building material dealers received 8% of the total consumed. Highway contractors used 6% of cement shipped to customers in 1977, while other contractors used 4% of the total. The remaining 2% was consumed by various government agencies and other miscellaneous users.

PRICES

The average mill value[8] of all types of portland cement was $36.36 per ton in 1977, $2.50 per ton higher than in 1976. The mill values ranged from a low of $28.86 in New York and Maine, to highs of $49.58 in Puerto Rico, and $50.98 in Hawaii.

According to Engineering News—Record at yearend bulk mill prices ranged from $28.80 per ton in Louisville, Ky., to $60.20 in Waianae, Hawaii. The highest price in the continental United States was $58.40 at Redding, Calif. Bagged cement prices ranged from $1.68 at Louisville, Ky., to $3.25 per 94-pound bag at Waianae, Hawaii. The area price for bulk cement reached a high of $82.80 per ton in Anchorage, Alaska. Base prices for portland cement in carload lots f.o.b. were reported monthly in Engineering

News-Record for 20 cities in the United States. The yearend average for bulk cement was $44.79 per ton. This compares with $41.06 per ton at yearend 1976. Bulk prices in the 20 cities ranged from $33.98 in Philadelphia, Pa., to $62.40 in San Francisco, Calif.

The Federal Trade Commission began an investigation of the portland cement industry for possible antitrust violations. A major focus of the investigation is the delivered price system, a method which requires the customer to take shipments by transportation provided by the cement company. In a similar investigation of the delivered price systems used by plywood companies, the commission ruled in February that the systems violated the antitrust laws.

Table 16.—Average mill value in bulk, of cement in the United States[1]

(Per short ton)

Year	Portland cement	Prepared masonry cement[2]	All classes of cement
1973	$21.88	$29.43	$22.23
1974	26.52	32.93	26.79
1975	31.09	38.90	31.41
1976	33.86	42.63	34.25
1977	36.36	45.03	36.76

[1]Includes Puerto Rico.
[2]Masonry cement made at cement plants only.

FOREIGN TRADE

Hydraulic cement exported from the United States decreased 48.7% in quantity but only 10.8% in value from those of 1976. Exported cement was equivalent to 0.3% of domestic shipments by quantity and 0.8% of their value. Six countries - Canada, Leeward and Windward Islands, Bahamas, Mexico, Saudi Arabia, and Guyana - received nearly 89% of the 239,000 tons of cement valued at $23.7 million, which was exported to 95 countries.

Hydraulic cement and clinker imported into the United States increased 30% in quantity and 40% in value over those of 1976. Imported cement amounted to 5.2% of domestic shipments by weight and 3.3% of the value.

Canada continued to supply the largest amount of imported cement and clinker, providing 55% of the total, followed by Mexico, 16%, Japan, 10%, and Norway, France, and the United Kingdom, each 5%.

Clinker comprised 40% of the total imports in 1977, compared with 31% in 1976, 33% in 1975, 32% in 1974, and 41% in 1973.

Table 17.—U.S. exports of hydraulic cement, by country

Country	1975 Quantity (short tons)	1975 Value (thousands)	1976 Quantity (short tons)	1976 Value (thousands)	1977 Quantity (short tons)	1977 Value (thousands)
Austria	4,671	$147	205	$57	143	$44
Australia	212	87	581	151	161	50
Bahamas	1,666	135	1,455	121	12,514	641
Belgium-Luxembourg	391	71	1,167	168	105	31
Belize	269	14	110	14	255	16
Bermuda	49	12	72	25	201	36
Brazil	2,117	185	702	112	72	49
Canada	274,236	16,105	218,932	15,995	156,047	13,156
Colombia	10	10	1,111	66	234	43
Chile	22	14	242	54	84	26
Dominican Republic	34,862	788	8,508	361	1,503	286
Ecuador	428	73	5,534	300	124	53
France	165	43	161	52	158	46
French West Indies	728	19	290	17	986	25
Germany, Federal Republic of	105	44	404	116	347	115
Guatemala	578	55	849	89	2,748	221
Guyana	--	--	1	3	3,091	159
Haiti	37	10	1,973	105	1,445	94
Indonesia	3,061	2,407	336	57	183	69
Italy	949	140	640	159	435	141
Jamaica	1,221	184	418	128	188	113
Japan	1,075	313	844	276	848	493
Korea, Republic of	143	63	53	13	323	147
Kuwait	12	11	83	35	69	16
Leeward and Windward Islands	23,498	651	24,148	655	24,715	933
Libya	11	17	313	214	1,167	237
Mexico	108,503	3,910	127,803	3,625	10,407	2,011
Netherlands Antilles	6,791	212	4,057	123	833	87
Nicaragua	413	36	50	22	984	79
Nigeria	14	5	3	1	1,522	98
Other Pacific Islands, n.e.s.[1]	360	22	72	5	565	46
Panama	49	15	1,746	138	17	9
Peru	3,119	368	2,165	183	1,888	221
Philippines	67	18	313	95	230	68
Saudi Arabia	1,540	243	732	306	5,826	1,792
Singapore	126	35	180	86	94	36
South Africa, Republic of	168	59	476	72	395	62
Spain	114	63	135	55	140	69
Switzerland	170	51	151	57	278	104
Taiwan	359	113	214	38	68	21
Trinidad and Tobago	62	94	49	16	3,083	306
Turkey	20	24	58	29	234	94
Turks and Caicos Islands	--	--	644	34	556	34
United Kingdom	338	120	426	121	186	77
Venezuela	16,120	589	56,178	1,527	705	281
Yugoslavia	552	142	101	24	296	204
Other	r4,731	r692	r1,370	r701	2,453	797
Total	494,132	28,409	466,055	26,601	238,906	[2]23,740

r Revised.
[1] Includes U.S. Trust Territory of the Pacific, previously listed separately.
[2] Data do not add to total shown because of independent rounding.

Table 18.—U.S. imports for consumption of hydraulic and clinker cement, by country

(Thousand short tons and thousand dollars)

Country	1976		1977	
	Quantity	Value	Quantity	Value
Bahamas	242	6,195	90	2,562
Belgium-Luxembourg	14	750	21	1,143
Canada	1,801	38,833	2,203	52,197
Colombia	--	--	5	170
France	178	5,279	196	5,452
Germany, Federal Republic of	([1])	48	([1])	35
Japan	6	139	384	5,332
Mexico	175	3,678	635	16,449
Norway	265	4,410	210	4,462
Spain	314	5,630	104	1,974
Sweden	20	361	--	--
United Kingdom	90	1,590	186	3,968
Yugoslavia	2	170	3	243
Other	([1])	2	([1])	17
Total[2]	3,107	67,085	4,038	94,005

[1]Less than 1/2 unit.
[2]Data may not add to totals shown because of independent rounding.

Table 19.—U.S. imports for consumption of cement

(Thousand short tons and thousand dollars)

Year	Roman, portland and other hydraulic cement		Hydraulic cement clinker		White nonstaining portland cement		Total	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1975	2,474	49,286	1,207	20,218	21	1,116	3,702	70,620
1976	2,122	46,635	962	19,136	23	1,314	3,107	67,085
1977	2,394	62,920	1,613	29,224	31	1,861	4,038	94,005

Table 20.—U.S. imports for consumption of hydraulic and clinker cement, by customs district and country

(Thousand short tons and thousand dollars)

Customs district and country	1976 Quantity	1976 Value	1977 Quantity	1977 Value
Anchorage:				
Canada	33	1,105	51	2,014
Japan	(1)	3	6	157
Total	33	1,108	57	2,171
Boston: Canada	--	--	(1)	5
Buffalo:				
Canada	515	11,260	579	13,112
Germany, Federal Republic of	(1)	3	--	--
Mexico	--	--	1	14
Total	515	11,263	580	13,126
Chicago:				
Belgium-Luxembourg	--	--	(1)	1
Canada	--	--	6	160
Netherlands	--	--	(1)	3
United Kingdom	--	--	(1)	1
Total	--	--	6	165
Cleveland: Canada	30	621	8	177
Detroit:				
Canada	525	10,336	655	13,158
United Kingdom	(1)	(1)	--	--
Total	525	10,336	655	13,158
El Paso:				
Canada	(1)	1	--	--
Mexico	14	605	92	2,569
Total	14	606	92	2,569
Galveston:				
Mexico	--	--	5	129
Spain	--	--	30	551
United Kingdom	--	--	28	525
Total	--	--	63	1,205
Great Falls: Canada	6	234	6	305
Honolulu: Japan	6	136	--	--
Houston:				
Germany, Federal Republic of	--	--	(1)	10
Mexico	--	--	33	755
United Kingdom	(1)	1	63	1,365
Total	(1)	1	99	2,130
Laredo: Mexico	1	57	100	3,384
Los Angeles:				
Germany, Federal Republic of	(1)	10	(1)	10
Spain	1	42	1	85
Yugoslavia	--	--	(1)	55
Total	1	52	1	150
Miami:				
Bahamas	46	1,271	63	1,753
Belgium-Luxembourg	4	205	6	335
Mexico	36	874	130	2,644
Norway	50	827	--	--
Spain	112	1,470	23	284
Total	248	4,647	222	5,016
Milwaukee: Canada	31	766	(1)	2
New Orleans:				
Bahamas	2	53	--	--
Canada	(1)	(1)	(1)	6
Germany, Federal Republic of	(1)	17	--	--
Mexico	--	--	73	1,680
United Kingdom	90	1,588	21	495
Total	92	1,658	94	2,181

See footnotes at end of table.

Table 20.—U.S. imports for consumption of hydraulic and clinker cement, by customs district and country —Continued

(Thousand short tons and thousand dollars)

Customs district and country	1976 Quantity	1976 Value	1977 Quantity	1977 Value
New York City: Norway	215	3,583	208	3,925
Nogales: Mexico	--	--	1	40
Norfolk:				
Bahamas	103	2,339	--	--
Canada	(1)	3	--	--
France	178	5,264	36	2,231
Mexico	--	--	30	572
Spain	16	187	--	--
Total	297	7,793	66	2,803
Ogdensburg:				
Canada	108	2,618	151	3,770
Yemen (Aden)	--	--	(1)	4
Total	108	2,618	151	3,774
Pembina:				
Canada	102	2,621	116	4,132
Mexico	(1)	2	--	--
Total	102	2,623	116	4,132
Philadelphia:				
Germany, Federal Republic of	(1)	18	(1)	5
Yugoslavia	2	170	3	188
Total	2	188	3	193
Port Arthur: Mexico	--	--	21	299
Portland, Maine: Canada	41	1,256	34	1,041
Providence: Canada	--	--	1	38
St. Albans:				
Canada	181	3,820	289	7,730
Germany, Federal Republic of	--	--	(1)	(1)
Italy	(1)	1	--	--
Japan	(1)	(1)	--	--
Norway	(1)	(1)	--	--
Total	181	3,821	289	7,730
San Diego: Mexico	(1)	1	19	1,008
San Juan:				
Belgium-Luxembourg	10	532	15	800
Colombia	--	--	5	170
Denmark	--	--	(1)	4
Dominican Republic	--	--	(1)	5
France	(1)	15	(1)	11
Spain	23	751	7	500
Total	33	1,298	27	1,490
Savannah:				
Denmark	(1)	1	--	--
Spain	4	43	--	--
United Kingdom	(1)	1	--	--
Total	4	45	--	--
Seattle:				
Canada	229	4,192	305	6,547
Japan	--	--	377	5,175
Mexico	--	--	(1)	6
Total	229	4,192	682	11,728
Tampa:				
Bahamas	91	2,532	27	809
Belgium-Luxembourg	(1)	13	(1)	7
France	--	--	160	3,210
Germany, Federal Republic of	--	--	(1)	9
Mexico	124	2,139	130	3,348

See footnotes at end of table.

Table 20.—U.S. imports for consumption of hydraulic and clinker cement, by customs district and country —Continued

(Thousand short tons and thousand dollars)

Customs district and country	1976		1977	
	Quantity	Value	Quantity	Value
Tampa —Continued				
Norway	--	--	2	538
Spain	158	3,137	43	554
Sweden	20	361	--	--
United Kingdom	--	--	71	1,583
Total	393	8,182	433	10,058
Grand total[2]	3,107	67,085	4,038	94,005

[1]Less than 1/2 unit.
[2]Data may not add to totals shown because of independent rounding.

WORLD REVIEW

Building industries in many countries were affected by a recession caused by political instability, soaring inflation, unemployment, and economic uncertainty.

Three trends on the cement international scene during 1977 were the growing number of nations achieving their own cement self-sufficiency; the domination of dry-process, preheater manufacturing technology; and further moves toward clinker as a major material of export production.[9]

Western Europe was the leader among the main cement producers in the world according to the European Cement Association (CEMBUREAU). Total production for Western Europe was 227.9 million short tons, followed by Eastern Europe and the U.S.S.R. with 222.6 million short tons. There were 237 companies producing cement in Western Europe. Italy, the Federal Republic of Germany, and Spain were the only countries with more than 20 companies in operation in 1977. Seven countries have effective monopolies, Norway, Denmark, Sweden, Ireland, Iceland, Luxembourg, and the Netherlands.[10]

Fuel systems were a major cost item and concern, and a few countries were heavily committed to the production of pozzolanic cement as a means of cutting fuel cost, most notable were Finland and Luxembourg where better than 96% of the production consisted of pozzolanic cement. The most popular forms of pozzolan used in cement in Europe are pulverized fuel ash and slag from blast furnaces.

World cement production rose to 857 million tons, 6% more than the 1976 total. The largest increase in production was in the People's Republic of China where overall production averaged 33% above 1976.

Afghanistan.—Fuller Co. heads an American consortium undertaking a $50.5 million turnkey cement plant project in the Kandahar region. The 1,760-short-ton-per-day plant and associated facilities will be the nation's largest industrial complex. Completion is scheduled for mid-1979.[11]

Total production of 150,000 short tons in 1977 was from two plants, the largest one at Ghori was built in 1964 is rated at 440 short tons per day. The second plant at Jhabulsaraj has a capacity of about 110 short tons per day.

Production was hampered by the lack of spare parts to operate one of the two finish mills which did not function for about 10 months. Czechoslovakia had refused to ship the parts unless the Ghori Cement management agreed to reemploy two Czech experts.[12]

Algeria.—An estimated 1.9 million short tons were produced in 1977. Algeria's Société Nationale des Materiaux de Construction (SNMC), the nation's public construction corporation, had several ongoing programs for expanding cement capacity. Self-sufficiency in cement is projected to be 10 million short tons by 1980.

Prospective Engineering Gestion (PEG), Geneva, is acting as consulting engineer for two major projects—a 1.1-million-short-ton-per-year dry-process plant at Zhana and a 1.1-million-short-ton-per-year dry-process plant at Beni-SAF.

Kawasaki Heavy Industries Ltd., Japan, is involved with two programs, one is a 550,000-short-ton-per-year plant at Saida scheduled for startup in 1978; and the other at El Asnam, a 1.1-million-short-ton-per-year plant with suspension preheater set for completion early in 1979.[13]

Other projects include a 1.1-million-short-ton-per-year plant at Constantine and a 1.1-million-short-ton-per-year operation at Ain el Kebira.

Argentina.—The Argentinian cement industry is entirely in private ownership. Production during 1977 totaled 6.6 million short tons.

New construction projects included a 550,000-short-ton-per-year plant to be built by Juan Minetti S.A. with major equipment to be supplied by KHD Industrieanlagen AG Humboldt Wedag. Another announced project involves an expansion of a plant owned by Loma Negra Compañía Industrial Argentina, S.A. Expansion will be performed by Polysius Corp. and consists of adding a precalciner and preheater.[14]

Bahamas.—In mid-1977, United States Steel Corp. closed its wholly owned subsidiary, the Bahama Cement Co., in Freeport. The company announced that it is negotiating with a European firm to open part of the plant for use in mineral processing other than cement. The plant is not for sale.

Reportedly, Bahama Cement closed down because it had lost $500,000 in its operation in 1976 and had failed to receive authorization from the Price Commission for a 75 cent per 100-pound bag increase. Approximately, 25,000 tons were produced before the plant was closed.[15]

Benin.—The Arab Development Bank has extended an $8 million credit for the construction of a new cement plant in Cotonou. In addition, a joint Beninese-Nigerian cement clinker plant rated at 500,000 short tons per year is under construction.[16]

Bolivia.—Financing for a $48 million expansion of a cement plant at La Paz was approved by the Inter-American Development Bank. F. L. Smidth & Co. is to supply the complete 180,000 short tons per year program for the Sociedad Boliviana de Cementos, S. A. Facilities will include a rotary kiln, a four-stage preheater, a plantary cooler, raw and finish mills, and a electrostatic precipitator. Startup was scheduled for 1978.[17]

Brazil.—Camargo Correa Industria S.A. of São Paulo, has contracted with Bendy Engineering Co., to provide extensive engineering services for a 1.1-million-ton-per-year precalciner-preheater kiln addition to the Cimento Portland Eldorado plant at Apiai, São Paulo. The expansion includes primary crushing, an overland conveyor, raw and finish mills, and packing-shipping facilities.[18]

Pragoinvest reported that the first cement plant of Czechoslovak Concept using the dry method is operating successfully at Itapetinga in the State of Rio Grande do Norte. The plant consists of a raw material grinding plant equipped with a mechanical edge mill utilizing waste gases from the kiln, shaft preheater, rotary kiln, cooler, impact crusher, and finish mill.[19]

Canada.—At the end of 1977, the industry's total theoretical capacity was about 16.5 million short tons per year. Canada Cement Lafarge, Ltd., completed an expansion program at its Brookfield, Nova Scotia, plant which consisted of the installation of a second kiln, a new finish grinding mill, and clinker storage facilities.[20]

In Ontario, St. Marys Cement Co. increased the production rate at its Bowmanville plant by about 50,000 tons per year by improving the efficiency of the grinding circuit.

In early 1977, St. Lawrence Cement Co. announced the purchase of the Hudson, N.Y., plant of Universal Atlas Cement Div. of United States Steel Corp., for $8.2 million. The plant will be used as a distribution terminal and grinding plant until business volumes warrant a modernization program.

In March, Lake Ontario Cement, Ltd., purchased the Essexville, Mich. plant of Martin Marietta Cement Corp. for $7 million. Aetna Cement Corp. is the wholly owned subsidiary that will operate the plant using clinker output from Lake Ontario's Picton, Ontario operation.

Inland Cement Industries Ltd. (subsidiary of Genstar Ltd.) continued expansion at its Edmonton, Alberta plant. Equipment and facility additions include a dry-process kiln, a clinker grinding mill, and cement silos. At startup in 1980, the capacity will be about 1.1 million short tons per year.

Canada Cement Lafarge, Ltd., is expanding the Exshaw, Alberta, plant to about 740,000 short tons per year by 1980. Lafarge Consultants, Ltd., was appointed the engineering consultants for the expansion.

In September, an "Antidumping Proceeding Notice" was published in the Federal Register.[21] The notice was to advise the public that there were reasonable grounds to suspect that sales of portland cement from Canada to the United States was at less than fair value within the meaning of the Antidumping Act, 1921.

Colombia.—Société des Ciments Français, Paris, was awarded a contract with the ironworks company Acerias Paz del Rio as consulting engineers for a new cement plant at Belencito. The plant will have a capacity of 1,100 short tons per day of clinker and obtain blast furnace slags from the neighboring steel mill. Grinding capacity will be 2,200 short tons per day.[22]

Compañía Colombiana de Clinker opened a new cement plant in Cartagena in December.[23] It was originally designed to produce 660,000 short tons per year but it will be enlarged to produce 1.1 million short tons per year, with most of the production slated for export.

Costa Rica.—Allis-Chalmers Corp., Milwaukee, Wis., was awarded a contract by Corporacion Costarricense de Desarrollo to build a new cement plant in the Guanacasta Province.[24] Process, equipment, and engineering for the 1,430-short-ton-per-day plant includes a roller mill, a suspension preheater, a rotary kiln, a stoker cooler, a finish grinding mill, plant and process design, project management, equipment installation, and operator training.

Czechoslovakia.–Output of a new cement plant at Turna is 2,200 short tons per day. Pragoinvest built the completely computer-controlled operation. The kiln line consists of a double-flow shaft preheater, a 260-foot-long, oil-fired rotary kiln, and a grate cooler.[25]

A new 1.2-million-ton-per-year dry-process operation is being constructed at Prahovice. Startup is scheduled for 1979.

Ecuador.—La Cemento Nacional reportedly started its new 1,800-short-ton-per-day cement plant at Guayaquil. Allis-Chalmers supplied the rotary kiln, suspension preheater, stoker cooler, raw grinding mill, and finish mill.[26]

Allis-Chalmers was also awarded a contract by Cementos Selvalegre of Quito to build a new 380,000-short-ton-per-year cement plant. Major equipment includes a preheater, a rotary kiln, a stoker cooler, and raw and finish grinding mills. The operation is scheduled to be onstream in 1979.[27]

Egypt.—As a result of extensions to existing works and new cement plants now being built or in the planning stage, cement production in Egypt should increase by 6.2 million short tons in 1981.[28]

Suez Cement Co., Eastern plant south of Suez City, is building a new 1.1-million-short-ton-per-year plant. Fuller Co. is supplying a single preheater-precalciner kiln, and raw and finish mills. H.K. Ferguson Co., San Francisco, Calif., undertook an engineering and economic feasibility study, for a second plant for the Suez Cement Co. Size and location were not firmed.[29]

Expansions are planned for Tabbin, Alexandria, Tourah, all are due onstream in 1979.[30]

France.—S.A. des Ciments du Sud-Ouest converted one wet kiln to dry-process at Lexos. Design and engineering was by Lafarge Conseils et Etudes.[31] The pyroprocessing system utilizes the RSP calcining system developed by Onoda-Kawasaki, Japan, and consists of a four-stage preheater and rotary kiln rated at 825 short tons per day.

Ciments Francais is building a 1,980-short-ton-per-day preheater kiln system at Bussac. Polysius Corp. is supplying a Dopol cyclone-type preheater, rotary kiln, planetary coolers, raw mills, and separators.

Ciments d'Origny is expanding its semiwet process. Polysius Corp. is supplying the precalcining system, rotary kiln, and dryer. The system is rated at 1,925 short tons per day.

Ciments Lafarge France at its Haubourdin plant is converting from wet-process to semidry with pressure filters to produce filter cake for the preheating grate Lepol of Polysius. Lafarge Conseils et Etudes has been awarded the contract for design and engineering for a plant scheduled for startup at the end of 1978.

Gabon.—In Gabon's third 5-year plant for economic and social development, 1976-80, mention is made about clinker and cement plants at Owendo and Franceville.[32]

Société des Cimente du Gabon awarded a contract to Creusot-Loire Enterprises and Lafarge Conseil et Etudes, France, for a new wet-process plant at N'tuom. The kiln reportedly will have a rated daily capacity of 1,100 short tons.[33]

Greece.—Expansions were announced by Titan Cement Co. S.A. at its Kamari plant. F. L. Smidth is supplying a 3,300-short-ton-per-day rotary kiln equipped with a four-stage cyclone preheater and a Unax planetary cooler, and raw and finish mills with air separators. National Cement Co. has a new 1.65-million-short-ton-per-year plant program underway next to its dry-process Volos facility. The operation has the largest Loesche mill and the largest IHI SF flash calcining system ever installed outside of Japan. Fuller Co. is supplying the grinding mill systems. Halyps Cement Co. S.A. awarded contracts for equipment for a 1,650-short-ton-per-day expansion at its Paralia Aspropyrgou plant. Fives-Cail Babcock S.A. is providing the general engineering service and the cyclone preheater equipped kiln, and Claudius Peters is providing the blending system and grate cooler. Startup is scheduled for 1979.[34]

New plant construction has been announced by M.A. Karageorgia S.A. for a 1.1-million-short-ton-per-year operation at Messinia. Kaiser Engineers is handling engineering and construction management.[35]

Guatemala.—Cementos Novella, S.A. will expand its San Miguel plant by 1,760 short tons per day. F. L. Smidth & Co. will supply the complete process equipment and services. The expansion will include covered limestone storage, raw mill grinding circuits, a four-stage suspension preheater, Unax kiln with planetary coolers, and a dust collection system.[36]

Hungary.—Two new large-capacity, dry-process cement plants were announced for Hejöcsaba and Belapatfalva. Hejöcsaba is rated at 1.8 million short tons per year and features two Polysius kilns with Dopol suspension preheaters and planetary coolers. Belapatfalva will be a 1.3-million-short-ton-per-year operation equipped with two preheater kilns from the U.S.S.R. Startup is scheduled for 1978.[37]

India.—The Cement Machinery Div. of Larsen & Toubro was awarded seven major cement plant contracts. In the Northern Region a 600-short-ton-per-day, dry-process kiln equipped with a four-stage cyclone preheater and planetary cooler was being installed at Rajban for the Cement Corp. of India Ltd. At Neemuch and Akaltara three 1,200-short-ton-per-day, dry-process units are being built for the same company, while at Yerraguntla in the Southern Region a new raw mill and coal mill are being installed.

Also in the Southern Region at the Maihar Cement plant of Century Springs and Manufacturing Co., Ltd., two 1,200-short-ton-per-day dry-process units are being constructed.

At Rajasthan, the J. K. Cements Co. is expanding its plant by the addition of a 1,200-short-ton-per-day, four-stage preheater, dry-process kiln.[38]

Indonesia.—The cement industry has been among the most dynamic industries in Indonesia over the past 10 years, growing from 680,000 short tons per year in 1968 to 4.0 million short tons per year in 1977. New plants will bring the capacity to 5.6 million short tons by 1979.

A second cement plant is to be built at Padang by the State-owned P. T. Semen Padang Co. The 600,000-ton-per-year plant is due to come onstream in 1979.[39]

P. T. Semen Gresik is currently expanding the Gresik plant for the third time since 1957. The expansion project includes the construction of a dry-process plant by Morrison-Knudsen International. Equipment includes two four-stage preheaters and two kilns. The expansion will boost capacity to 1.5 million tons.[40]

Iran.—Hamadan Cement Co. awarded a contract for the building of a new 770,000-short-ton-per-year, dry-process plant at Hamadan to APCEM Engineering A.G. Construction of the plant will take about 3 years.[41]

Rey Cement Co. is expanding the Rey plant. Pragoinvest, Czechoslovakia, supplied the 2,200-short-ton-per-day rotary kiln equipped with a heat exchange unit. Startup is scheduled for 1978.

Fars & Khuzestan Cement Co. is building a new 3,200-short-ton-per-day plant at Behbahan. Ishikawajima-Harima Heavy Industries Co., Ltd. (IHI) Japan, will supply the clinker manufacturing and handling plant which includes a four-stage preheater and rotary kiln.

Shemal Cement Co. is building a 770,000-short-ton-per-year plant near Abe-Ali. The contract was awarded to KHD Industrieanlagen AG Humboldt Wedag.

Soufian Cement Co. is expanding its plant near Tabriz. Equipment supplier is F. L. Smidth and includes a raw mill, air separators, a rotary kiln with four-stage suspension preheater, and a planetary cooler. New added capacity will be 2,200 short tons per day.

Gharb Cement Inc., will build a new plant near Kermanshah. KHD Industrieanlagen AG will supply the equipment for the 2,400-short-ton-per-day plant.

Gorgan & Mazandaran Cement Corp. has awarded to KHD Industrieanlagen AG a contract to supply equipment to a new plant at Neka. The plant capacity is rated at 2,200 short tons per day with startup in 1979.[42]

Iraq.—F. L. Smidth & Co. is constructing a new plant for the Republic of Iraq at Kufa. Major equipment includes four rotary kilns with coolers, four raw mills, and six packing machines. Each kiln will have an output of 1,650 short tons per day.

Fives-Cail Babcock reported it had signed a contract in Iraq for a cement plant with a capacity of 1,650 short tons per day.

The Badoosh Cement plant in northern Iraq reportedly put onstream its new Polysius dry-process system rated at 1,650 short tons per day. The kiln is equipped with a counterflow preheater. Included in the expansion were new, Polysius built, raw and finish mills.[43]

Ireland.—Expansion by Cement Ltd., at its Platin plant, added 1 million tons per year to its capacity. Major equipment supplied by F. L. Smidth included a rotary kiln equipped with twin four-stage suspension preheaters and a planetary cooler.[44]

Japan.—Aso Cement Co. completed expansion of its Tagawa plant. Major equipment includes an F. L. Smidth rotary kiln equipped with twin cyclone preheaters and a precalciner.[45]

Korea, Republic of.—Sung Shin Chemical Co., Ltd., has arranged for Polysius to expand its Tanyang cement plant. The kiln has a capacity of 3,300 short tons per day, and is equipped with a preheater and planetary cooler.[46]

Ssang Yong Cement Industrial Co., Ltd., has awarded Polysius Corp. a contract for expansion of its Tonghae plant. The 9,200-short-ton-per-day operation will include two rotary kilns each equipped with cyclone preheaters and precalciners, and planetary coolers.[47]

Tong Yang Cement Manufacturing Co. Ltd. started expansion at its Sam Choh plant. Fuller Co. is supplying two rotary kilns with four-stage preheaters and coolers.[48]

Kuwait.—The Saudi Arabian Ministry for Industry and Electricity and Kuwait Cement Co. have formed a joint venture to develop a plant close to the Arabian Gulf Coast that will produce 7,700 short tons per day of clinker. Prospective Engineering Gestion has been engaged as consulting engineer for the project. The plant is scheduled to be operational in 1982.[49]

Libya.—Fives-Cail Babcock, France, is supplying the new plant at Homs with a four-stage cyclone preheater equipped rotary kiln with a grate cooler. The rated capacity is 3,300 short tons per day.

At Souk el Khamis a new 3,850-short-ton-per-day plant went onstream. Equipment supplied by KHD Industrieanlagen AG included two rotary kilns with preheaters.[50]

Malaysia.—A 500,000-ton-per-year cement plant is being developed in Perak by a joint venture consisting of Phillippine Investment Management Consultants, Ltd.; Engineering Development Corp.; and L. S. Diaz and Co.[51]

Mexico.—Cementos Guadalajara S.A. is expanding its Ensenada plant; F. L. Smidth is supplying the rotary kiln equipped with a four-stage cyclone preheater.

Cementos Maya S.A. will undertake an expansion of its Merida plant. Major equipment supplied by F. L. Smidth includes a 1,250-short-ton-per-day kiln equipped with a two-stage preheater and planetary cooler.

Cementos Mexicanos S.A. will expand its Monterrey plant with an F. L. Smidth supplied 1,350-ton-per-day rotary kiln, equipped with a four-stage cyclone preheater and a planetary cooler.[52]

Morocco.—The World Bank is financing a new cement project for Asment de Temara at Temara. Fuller Co. has been awarded the contract to supply equipment and services for the 1,700-short-ton-per-day kiln equipped with suspension preheater and grate kiln cooler. All equipment is designed to accommodate the later addition of a flash calciner. Startup is scheduled for 1978.[53]

Nepal.—Onoda Engineering and Construction Co. was awarded a contract for construction of a 275,000-short-ton-per-year cement plant with completion scheduled for 1981. The project is financed by the Asian Development Bank.[54]

Nigeria.—Ashaka Cement Co., Ltd., started up its new two-kiln operation near Ashaka. Plant capacity is rated at 880,000 short tons per year. The Blue Circle Group, England, participated as management partners.

Scheduled for startup in 1978 is a new plant at Yandev. The two kilns are rated at 1,600 short tons per day each. Major equipment was supplied by KHD Industrieanlagen AG, which included two rotary kilns equipped with four-stage preheaters, and two raw grinding mills.[55]

Associated Portland Cement Manufacturers Ltd. (APCM), have signed contracts with Nigeria to export 825,000 short tons of bulk cement to Nigeria each year for 3 years.[56]

Norway.—Norcem has decided to add a second kiln at its Raelingen plant. Construction began in the second half of 1977.

Production was down because of the closing of one kiln each at the Slemmestad and Dalen plants. The reason for the shutdown was that environmental investments required would remove any economic basis for continued production from the kilns.

A study concerning the building of a new cement factory in Nord-Trondelag was undertaken. The proposed plant site was selected for a coast location for transportation purposes.[57]

Oman.—Kuwait Cement Factory and the Sultanate of Oman are to setup a new company to construct a 1.1-million-short-ton-per-year cement plant near Muscat.[58]

Pakistan.—Pakistan's State Cement Corp. is expanding the Javedan and Mustehkam Cement factories by another 330,000 short tons per year. Fuller Co. supplied the rotary kiln with a four-stage preheater, cooler, and dust collectors for the Javedan plant. KHD Industrieanlagen will supply the major equipment for the Mustehkam expansion.[59]

Peru.—Cemento Yura S.A. will increase its production by 1,320 short tons per day with the installation of Fuller Co. supplied raw and finish mill, clinker cooler, raw material homogenizing, and preheater kiln feed systems.[60]

Cementos Lima S.A. is expanding its Atacongo plant by 3,300 short tons per day. Major equipment includes a precalciner kiln and grinding mills. Holderbank Management & Consulting Ltd. (Canada), is responsible for the engineering.

Cementos Norte Pacasmayo started up its expanded Pacasmayo plant. Plant capacity is now 3,300 short tons per year. Fuller Co. will supply the equipment, which includes raw and finish open-circuit mills, a rotary kiln, a preheater with flash calciner, coolers, and dust collectors.[61]

Poland.—The Gorazdrze Cement plant went onstream with its expanded operation. F. L. Smidth supplied two kilns equipped with a four-stage cyclone preheater. Each kiln is rated at 3,850 short tons per day.[62]

Qatar.—The Qatar National Cement Co. brought online its third kiln, bringing the output of the plant up to 1,200 short tons per day. The kiln was supplied by Buhler-MIAG of the Federal Republic of Germany.[63]

Saudi Arabia.—Against the backdrop of a projected annual requirement over the next few years of 11.1 million short tons of cement for Saudi construction projects, plans were finalized for the construction of two large cement plants in the Eastern Province area. One of the plants is the Saudi Kuwaiti Cement Manufacturing Co.'s new 7,700-short-ton-per-day plant on the Arabian Gulf Coast. PEG (Switzerland) is consulting engineer for the project scheduled to be operational in 1982. The other is the Saudi Bahrain Cement Co.'s plant at Abgeig. IHI, Japan, was awarded the contract for construction of the 6,600-short-ton-per-day plant. Operation is scheduled for 1981. Four kilns will be installed. Holderbank Management & Consulting Ltd., is acting as consultant on the project.[64]

Hyundai International Inc., the Republic of Korea, was awarded a contract to construct a 1.5-million-short-ton-per-year cement plant at Jizan for Southern Province Cement Works Co. Completion date is scheduled for 1981.[65]

Yanbu Cement Co., Ltd., and KHD Industrieanlagen have signed a contract for the construction of a new cement works on the Red Sea near Ra's Baridi. This new cement plant will have two kilns with a total output of 3,300 tons per day of clinker. It is to go into operation in 1980.[66]

El Kasseim Cement Co. placed an order with KHD Industrieanlagen for the erection of a new 2,200-short-ton-per-day cement works near Buraydah. Startup is scheduled for late 1979 or early 1980. The rotary kiln will be equipped with an inclined-grid cooler.[67]

South Africa, Republic of.—Anglo Alpha Cement Ltd. expanded its Duffield cement plant by 2,200 short tons per day with the installation of a dry-process kiln equipped with a four-stage cyclone preheater and planetary cooler supplied by F. L. Smidth. Holderbank Management & Consulting Ltd., was consultant for the mechanical and electrical portions of the system.

Cape Portland Cement Co. installed a Polysius preheater kiln system rated at 1,600 short tons per day. Included in the expansion were raw and finish grinding mills.[68]

Spain.—Hornos Ibericos S.A. began construction of a 3,600-short-ton-per-day plant near Almeria. KHD Industrieanlagen AG Humboldt Wedag, in cooperation with Centunion of Madrid, was awarded the turnkey contract. A large portion of the equipment will be manufactured in Spain.[69]

Sudan.—Maspio Cement Corp. is expanding the Atbara plant by installing an 825-ton-per-day F. L. Smidth rotary kiln equipped with a single-stage cyclone preheater and planetary cooler.[70]

Sweden.—Cementa AB is adding 5,200 short tons per day production equipment to its Slite plant. Polysius Corp. is supplying the rotary kiln with a precalcining and cyclone preheater unit. Startup is scheduled for 1979.[71]

Taiwan.—Cheng Tai Cement Co. Ltd. near Taipei completed its expansion, which consisted of a Fuller Co. rotary kiln with a four-stage preheater, a clinker cooler, and dust collectors.

Chia Hsin Cement Corp., Taipei, is expanding its plant with a Fuller Co. rotary kiln with a four-stage preheater and a clinker cooler. Hsin - Hsin Cement Co. awarded a contract to Polysius Corp., for a 2,400-short-ton-per-day rotary kiln equipped with a cyclone preheater and precalcining system, and a traveling grate cooler.[72]

Tanzania.—Tanzania Saruji Corp. is building a new plant at Tanga. F. L. Smidth is supplying the 1,830-short-ton-per-day rotary kiln with a four-stage cyclone preheater and a planetary cooler.

Tanzania Saruji Corp., awarded a contract to F. L. Smidth to supply an 830-short-ton-per-day rotary kiln equipped with a four-stage cyclone preheater and planetary cooler for a new plant at Mbeya.[73]

Togo, Ivory Coast, and Ghana.—Les Ciments de l'Afrique de l'Quest (CIMAO) is a regional clinker project formed by three countries for the purpose of utilizing a high-quality and abundant limestone deposit located near Tabligo, Togo. Clinker from the plant will be shipped to grinding plants located in Togo, Ghana, and the Ivory Coast.[74]

The plant under construction is a 1.3-million-short-ton-per-year clinker operation consisting of a two-kiln, dry-process system. Blue Circle Consultancy Services Div. is providing engineering services for the new plant scheduled for startup in 1979. Polysius is supplying the two-rotary kiln equipped with planetary coolers.[75]

Turkey.—The Turkish national cement enterprise (Turkiye Cimento Sanayii (TAS) has placed an order with the KHD Industrieanlagen AG, Cologne, for the erection of seven cement plants.

All plants will be dry-process systems using Hulmboldt preheaters. The plants will be built according to one concept retaining the same plant dimensions. Their clinker production will average about 1,925 short tons per day.[76]

The new cement plants will be erected according to a proven model, in cooperation with Turkish building contractors. A great portion of units and structural elements will be installed by Turkish companies on the basis of plans from KHD Industrieanlagen who will supply the essential plant sections from the Federal Republic of Germany.

By 1980, capacity of the Turkish cement industry is expected to be approximately 21.9 million short tons per year.

Canakkale Cimento Sanayii A.S., Istanbul, awarded a contract to Fuller Co. to supply the process equipment and engineering for a 2,750-short-ton-per-day cement plant. A rotary kiln with preheater and clinker cooler are among the major equipment supplied by Fuller on this project which are expected to be complete by 1978.

Eskisehir Cimento Fabrikasi completed an 880-short-ton-per-day expansion at its Eskisehir plant. Buhler-MIAG supplied a suspension preheater rotary kiln with grate cooler.[77]

United Arab Emirates.—Gulf Cement Co. Ltd. of the United Arab Emirates signed a contract to construct a 1.1-million-short-ton-per-year cement plant with Ube Industries, Japan. The project will be a full turnkey suspension preheater kiln system. The plant will be located at Ras al Kahaymah, where limestone is available in large quantities.[78]

Union Cement Co. started up its second 770-short-ton-per-day dry-process kiln with a one-stage preheater cyclone. The system was ordered from IHI. The company will add a kiln scheduled to come onstream in 1979. The new kiln will be the first cement works in the Middle East to employ the suspension flash calcining kiln system developed by IHI.

The Emirate of Sharja awarded a contract to Société Fives—Cail Babcock for a 770-short-ton-per-day dry-process plant scheduled to be operational in 1978. Equipment included a rotary kiln with planetary cooler.[79]

United Kingdom.—Ketton Portland Cement Co. started up its new dry-process kiln, the seventh kiln at its Lincolnshire site. F. L. Smidth was the main equipment manufacturer with design under the direction of Ketton's engineers.

Rugby Portland Cement Co., Ltd., is adding a Polysius grate preheater coupled with a F. L. Smidth rotary kiln with planetary preheaters. Operation is scheduled for 1978.[80]

Uruguay.—Administración Nacional de Combustibles, Alcohol y Portland awarded a contract to Fuller Co. to build a 550-short-ton-per-day addition to an existing 440-short-ton-per-day cement plant in Paysanda. Major equipment supplied by Fuller Co. ATX (Pty) Ltd. of the Republic of South Africa, are a rotary kiln with a four-stage preheater and cooler. Startup is scheduled for 1978.[81]

Venezuela.—Cementos Caribe C.A. is building a new dry-process plant rated for 1.1 million short tons per year at Puerto Cumarebo. Holderbank Management & Consulting Ltd. of Canada is providing the engineering and management. Humboldt Wedag U.S.A. has been awarded the equipment contract.

Cementos Catatumbo C.A. is building a new 495,000-short-ton-per-year plant in the State of Zulia. Lafarge Consultants, Ltd. (Canada), has contracted for design, procurement, project management, and startup assistance. The Wedag Div. of Deuty Corp. (U.S.A.) will supply the major equipment, including the preheater equipped kiln.

C.A. Vencemos Mara started up its expanded Maracaibo operation. The new kiln system added 825 short tons per day capacity. Major process equipment was supplied by F. L. Smidth and included a wet-process rotary kiln with a cooler and an electrostatic precipitator.

C.A. Venezolana de Cementos started production of its 950-short-ton-per-day expansion at Pertigalete. F. L. Smidth supplied the wet-process rotary kiln with planetary cooler.

Fabrica Nacional de Cementos awarded a contract to F. L. Smidth for rebuilding one of the kilns of the Ocumare plant. The one-stage cyclone kiln will be shortened and an integral precalcining system will be incorporated along with a four-stage preheater. The improvements will raise production from 1,100 to 1,760 short tons per day.[82]

Vietnam.—Technoimport of Hanoi ordered from Polysius AG, France, a rotary kiln to be added to the Kien-Luong cement plant of Cimenterie de Ha Tien. The kiln will have a capacity of 1.1 million short tons per year and will go into operation in 1980. Major equipment includes a precalcining system, a rotary kiln, and a grinding mill.

Technoimport has contracted with F. L. Smidth to supply equipment for a new 3,400-short-ton-per-day plant at Hoang Thach. Major equipment includes four-stage twin preheaters, a rotary kiln, and a planetary cooler.[83]

Yugoslavia.—Beocinska Cement started up a new 3,300-short-ton-per-day Polysius precalciner kiln at the Beocin plant. With the new kiln, total production capacity is now 2.3 million short tons per year.[84]

"Salonit ANHOVO" ANHOVO added a rotary kiln equipped with a heat exchanger. Pragoinvest of Czechoslovakia supplied the 2,200-short-ton-per-day kiln and accessories.[85]

Dalmacija Cement awarded a contract to Polysius to supply its expanding plant at Paitiyan with a 3,520-short-ton-per-day, dry-process kiln equipped with a precalcining preheater. The favorable coastal location of the plant is to assist both internal supply and exports to the Middle East.

Fabrika Cementa Novi Popovac is expanding the Popovac plant by adding a 2,200-short-ton-per-day rotary kiln. Major equipment is being supplied by F. L. Smidth and Pragoinvest and includes a rotary kiln equipped with a four-stage cyclone preheater, and a planetary cooler. Full capacity is expected in 1978.[86]

Table 21.—Hydraulic cement: World production, by country

(Thousand short tons)

Country	1975	1976	1977[p]
North America:			
Bahamas	[r]420	299	25
Canada	[r]10,985	10,609	10,588
Costa Rica	364	399	439
Cuba	2,296	2,757	[e]3,300
Dominican Republic	[r]647	585	961
El Salvador	[r]366	356	408
Guatemala	429	498	543
Haiti	[r]170	253	293
Honduras	328	245	416
Jamaica	[r]447	403	367
Mexico	12,800	13,871	14,580
Nicaragua	195	230	244
Panama	[r]305	343	365
Trinidad and Tobago	[r]285	265	238
United States (including Puerto Rico)	69,721	74,495	80,060
South America:			
Argentina	6,023	6,296	6,616
Bolivia	[r]294	243	292
Brazil	19,221	21,106	20,343
Chile	1,118	1,062	1,238
Colombia	[r]3,407	3,982	3,635
Ecuador	654	679	690
Paraguay	152	171	220
Peru	2,097	2,167	2,172
Surinam	34	[e]55	49
Uruguay	702	745	752
Venezuela	3,855	3,900	3,457
Europe:			
Albania[e]	717	882	882
Austria	6,206	6,482	6,606
Belgium	7,588	8,272	8,558
Bulgaria	4,804	4,815	5,146
Czechoslovakia	[r]10,257	10,529	10,754
Denmark	2,466	2,596	2,545
Finland	2,274	2,012	1,887
France	32,615	32,401	31,677
German Democratic Republic	[r]11,747	12,505	13,334
Germany, Federal Republic of	[r]36,927	37,649	35,454
Greece	[r]8,755	9,640	11,667
Hungary	4,144	4,738	5,093
Iceland	[r]175	160	153
Ireland	[r]1,721	1,730	1,759
Italy	37,738	40,044	42,113
Luxembourg	[r]378	330	320
Netherlands	4,085	3,837	4,295
Norway	2,994	2,961	2,572
Poland	20,393	21,826	23,479
Portugal	[r]3,801	4,093	4,736
Romania	12,699	13,832	15,295
Spain (including Canary Islands)	[r]26,558	[1]27,780	[1]30,859
Sweden	3,440	3,084	2,788
Switzerland	4,150	3,909	4,022
U.S.S.R	[r]134,545	136,958	140,000
United Kingdom	[r]18,619	17,394	17,040
Yugoslavia	7,788	8,414	8,903
Africa:			
Algeria	[r]1,045	1,433	[e]1,900
Angola[e]	[r]720	[r]720	720
Cameroon	[r]262	330	400
Cape Verde Islands[e]	4	4	4
Egypt	[r]3,951	3,706	3,590
Ethiopia	[r]160	164	[e]165
Ghana	[r]734	[r, e]720	670
Ivory Coast	[2]--	[2]--	--
Kenya	989	1,088	1,139
Liberia	99	[e]110	[e]110
Libya	[r]678	1,653	2,756
Madagascar	64	82	57
Malawi	[r]112	94	104
Mali	54	[e]55	55
Morocco	2,235	2,334	2,870
Mozambique	[r]310	239	[e]240
Niger	[r]20	40	[e]44
Nigeria	[r]1,504	1,402	[e]1,940
Rhodesia, Southern	[r]741	595	542
Senegal	[r]396	425	364
South Africa, Republic of	7,910	7,769	7,245
Sudan	[r]238	143	151

See footnotes at end of table.

Table 21.—Hydraulic cement: World production, by country —Continued

(Thousand short tons)

Country	1975	1976	1977[p]
Africa —Continued			
Tanzania	293	266	287
Togo	([2])	([2])	--
Tunisia	679	527	631
Uganda	108	97	[e]88
Zaire	692	[r] [e]720	539
Zambia	498	[e]424	[e]420
Asia:			
Afghanistan[3]	162	[e]184	150
Bangladesh	[r]186	254	356
Burma	[r]203	257	297
Democratic Kampuchea	55	55	55
China, People's Republic of[e]	33,100	[r]33,100	44,100
Cyprus	[r]674	1,130	1,184
Hong Kong	[r]634	843	1,134
India	[r]17,897	20,596	21,010
Indonesia	1,187	1,995	2,952
Iran	5,919	6,834	8,818
Iraq	2,629	2,756	[e]2,800
Israel	2,413	2,204	2,041
Japan	72,220	75,742	80,621
Jordan	631	588	624
Korea, North[e]	[r]7,700	[r]7,700	7,700
Korea, Republic of	11,165	13,088	15,651
Kuwait	314	[e]320	[e]320
Lebanon	[r]1,825	[e]1,880	1,499
Malaysia	1,594	1,917	1,918
Mongolia	175	[e]176	[e]176
Nepal	[r]11	33	46
Pakistan	[r]3,439	3,459	[e]3,400
Philippines	4,700	4,957	4,301
Qatar	181	190	[e]185
Saudi Arabia	[r]1,240	[e]1,322	[e]1,322
Singapore[e]	[r]1,455	[r]1,490	1,490
Sri Lanka	433	470	[e]440
Syria	1,096	1,224	[e]1,345
Taiwan	7,491	9,644	11,376
Thailand	[r]4,383	4,919	[e]5,600
Turkey	[r]11,786	13,649	15,248
Vietnam[e]	[r]770	[r]770	770
Yemen	[e]66	[e]66	66
Oceania:			
Australia	5,530	5,580	5,537
Fiji Islands	[r]82	76	85
New Caledonia	[r]64	60	[e]60
New Zealand	1,184	1,101	1,003
Total	[r]773,989	810,656	856,939

[e]Estimate. [p]Preliminary. [r]Revised.
[1]Excludes natural cement.
[2]Revised to none. Production reported in previous editions of this chapter was derived from imported clinker, which is produced and included elsewhere in this chapter.
[3]Year beginning March 21 of that stated.

TECHNOLOGY

Cement Manufacture.—The PCA formed a manufacturing process committee to establish a dialogue on ways to advance cement technology in the United States and Canada. Objectives are to recommend ways to improve cement manufacturing technology and efficiency and to reduce production costs. This work is to be performed in cooperation with original equipment and consulting engineers.[87]

Dundee Cement Co. presented details on its contributions toward energy conservation which includes using waste lubricating oil as part of the fuel requirements for kilns; burning chlorinated hydrocarbons and polychlorinated biphenyls (PCB) in the kiln, without adverse effects on air pollution levels; and using flyash from the powerplants in the manufacture of a special pozzolanic cement (Dundee 1-P), which is recommended for use in concrete for sanitary engineering structures in direct contact with sewage (sewage treatment plants and sewer pipes).[88]

A U.S. patent covering the firing of refuse-derived fuels in cement kilns was issued to the APCM, a British firm with worldwide cement industry interests. Firing refuse permits the replacement of at least 15% of conventional fuels in the production of quality cement clinker. Gordian Associates Inc., a New York based subsidiary of Pullman Inc., is the sole U.S. agent for the licensing of the APCM process.[89]

Asland S.A. Barcelona, Spain, developed a method to determine the initial (24 hours) and final (28 days) cement resistances in less than 6 hours. Standard machinery and techniques are applied, with the only variation that a water bath heated by three 1,500-watt resistors is used. It has two grids at different heights allowing water and steam treatment to be used at the same time. The mortar used is put into 4 by 4 by 16-cm molds which are covered with a rigid top. Within the 15 minutes following mixing completion, the mold is immersed in a boiling water bath for a maximum of 2 hours and 15 minutes. Half of the specimens so treated are broken within 15 minutes after having been taken out of the bath; they show resistances equivalent to those obtained after 24 hours in a standard test.

The other half are put into the autoclave at 21 atmospheres and 216 C for 15 minutes to 1 hour and 15 minutes according to the characteristics of the cement to be tested (coefficient of fineness, clinker percentages, etc.); they show resistances equivalent to those obtained after 28 days in a standard test. The reproducibility of this method has been checked over a period of 6 months by testing the various types of cements a minimum of 10 times, having found standard deviation and variance coefficient equal or lower to those obtained by official methods.[90]

Siemans AG has developed a system which allows the operators of its line process control computers to do their own programing. The Simat Cemat System is operated by a Siemans process computer 330 with peripheral storage. It not only covers all the tasks of measured-value monitoring, binary signal processing, open-loop control, controller identification, and text processing, but it also handles the operator's dialog through function keys and graphic, alphanumeric, and curve display units.

This system permits straightforward planning by reference to block diagrams, and all the program modules can be interconnected as desired even while the system is online. A clear self-documentation facilitates the correction and modification work.[91]

The 19th Institute of Electrical and Electronics Engineers Cement Industry Technical Conference held in Omaha, Nebr., in May included presentation of papers on Automation, Drives and Related Products, General Practices and Process Equipment, Maintenance and Safety, and Power Distribution and Related Products.[92]

The Verein Deutscher Zementwerke (VDZ-Association of German Cement Works) held its international congress on the Process Technology of Cement Manufacturing in September in Dusseldorf, the Federal Republic of Germany. The emphasis was on the practical aspects of cement manufacturing. Its objective was to shorten the innovation period of technologies available and to indicate trends which are of significance for technical development. Subjects covered included Raw Materials Quarrying and Preparation, Size Reduction, Pyro-Processing, Process Control, General Installations, Environmental Protection and Energy Utilization, and Influence of Process Technology on Cement Properties.[93]

The Pyroclon system is a technology of clinker burning in a rotary kiln equipped with a multicyclone raw meal preheater upstream and a clinker cooler downstream of the kiln developed by Humboldt. It is of interest to note that the Pyroclon system can be very suitably applied in connection with the conversion of wet-process cement works to the dry-process.

In this way, with the shortened rotary kiln, it is possible to attain increases of 300% to 400% in clinker output, while the specific heat consumption can be reduced by more than 50%.

Two types of plant design are possible: (1) Conversion from wet to dry grinding. Here a portion of the long rotary kiln is modified to serve as a rotary dryer in which exhaust gases from the preheater and from the clinker cooler are utilized for drying the material. If the raw material has a low moisture content, utilization of part of the kiln as a rotary cooler could be considered. This procedure is applied for dealing with fairly hard initial materials containing less than 20% moisture and not suitable for converting into slurry. (2) The existing wet preparation process for the raw materials is retained. The slurry thus produced is further processed by filter presses and a suspension dryer to make it suitable for feeding to a multistage Humboldt preheater. The rotary kiln, appropriately shortened, is also retained; other parts thereof can be modified to serve as coolers. This procedure is preferable for dealing with soft initial materials containing more than 20% moisture and suitable for converting into slurry.[94]

Concrete.—The St. Ives, Cambridgeshire, England, factory, is one of the first in the world to be especially built for the production of glass reinforced concrete (GRC) pipes. Advantages include lighter weight, no bell end, 30% less trenching, and 40% less bedding.

At the Lakeshore mine near Casa Grande, Ariz., shotcret (a mixture of aggregate, sand, and cement) is sprayed with a pressure gun onto excavated or exposed rock surfaces to act as a sealing agent, and is used as either a secondary or primary means of ground support. In weak areas, such as extraction drifts or slusher drifts, a 2- to 3-inch thickness has proved adequate for temporary support and preventing air slacking. In declines, maintenance bags, and production drifts for sublevel caving, shotcrete as a primary means of support has proven superior to the point loading system.[95]

A new method of monitoring the strength and safety of high alumina cement (HAC) concrete beams has been developed by Acoustic Emission Ltd., a subsidiary of Cambridge Consultants Ltd., and Tekell Holdings Ltd., England. The company found from laboratory and site tests on HAC that listening to the natural ultrasonic signals produced by the material under load allows them to determine its structural integrity with great accuracy and also to predict its likelihood of failure.[96]

A/S Norsk Hydro, in collaboration with the Norwegian cement producer A/S Aksjeselskapet Norcem, developed an additive to concrete which significantly improves its corrosion resistance. Production and marketing of the additive is under Norcem's direction. The additive is highly effective in an environment where corrosion is caused by nitrates.[97]

The British Standards Institution strongly recommended that calcium chloride no longer be used as a quick setting agent for concrete in which metal strengthening is embedded due to fears that it hastens metal corrosion.[98]

An infrared spectroscopic method to detect the presence of those siliceous minerals which present a danger of alkali-silica reaction in concrete was developed at the German State Atomic Research Center, Julich, the Federal Republic of Germany. This method allows the number of silanol groups in siliceous compounds to be directly measured. It has been established that only the amorphous and cryptocrystalline silicas cause the expansion phenomena in aggregates as a result of their reaction with alkalies in concrete. All these reactive silicas have a large number of silanol groups at their internal interfaces.

Miscellaneous.—Trelleborgs Gummifabriks AB developed and manufactured a new loading chute system for cement clinker. The chute, which is based on a flexible-wear rubber construction, controls approximately 1,000 tons per hour of material into ship holds. It is equipped with a special external dust air evacuator which has a capacity of 5,000 cubic meters per hour. The loader is designed to operate at temperatures up to 80°C and has position indicators that govern height and angular variations to compensate for ships' movements.[99]

A new and patented design of a cargo sling which locks a load of cement bags tightly together and holds them securely for an entire journey has been developed by Safex Equipment Ltd., a South Wales subsidiary of the "W" Ribbons Holding Group. The unique locking action of these cargo slings is claimed to make it virtually impossible for a unitized load of bagged cement to separate or break down in transit. The slings are of the "one trip" disposable type, thus avoiding administrative and operational problems of ensuring their return after shipment. Use of the slings enables preslinging at the cement plant of 21 110 pound bags of cement at a time.[1]

Dundee Cement Co. designed and implemented a unique system of unloading cement barges equipped with roll covers that can accept return cargo of grain or other bulk commodities. The system, named "Docksider," consists of a nozzle whose function is to mechanically aerate the cement and convey it to the suction point. When in front of the suction opening, the cement is lifted up through the conveying pipe and carried to one of two pressure vessels (reloaders). These pressure vessels have built in filters to clean the transport air before it enters the vacuum pump.

When one reloader is full, the suction is shifted to the other and the first reloader is emptied. The application of compressed air blows the cement through a pipeline to the selected storage silo. The movement of the barge and crane is initiated from a pendant-mounted push-button station from which the operator can control the unloading from a convenient location on the barge or from a platform on the dock.

Although the pneumatic system is not as flexible as a mechanical system in unloading a wide variety of bulk commodities, no problems should be encountered when unloading materials such as cement, salt, alumina, fertilizers, sand, and grain. Cement can be unloaded practically in capacities up to 400 tons per hour by one nozzle.[2]

The U.S. Department of Agriculture, based on reported findings achieved by three Georgia farmers, undertook an experiment of adding cement dust to cattle feed. Tests have shown that cattle gained weight 30% faster than those eating regular rations of grain and hay.

During the 112-day test at the Department's Beltsville, Md., research center, seven steers fed dust along with their rations gained about 3 pounds per day, compared with 2.3 pounds gained by seven animals fed normal rations. No abnormalities were found when the livers and other organs of the slaughtered cattle which had thrived on the dust were examined. In addition, the beef from the animals was of a higher grade than beef from cattle fed regular rations.

The department said the dust-fed cattle graded an average of "top choice" while the other cattle averaged in the "top good" grade.[3]

---

[1]Physical scientist, Division of Nonmetallic Minerals.
[2]Grancher, R. A. Why Shoot at the Cement Industry? Rock Prod., v. 80, No. 7, July 1977, pp. 84-86.
[3]Portland Cement Association. The U.S. Cement Industry, an Economic Report. 2d ed., Sect. A., March 1978, p. 22.
[4]Alam, M. Energy Savings in Wet Process Kilns. Pit & Quarry, v. 70, No. 1, July 1977, pp. 151-154.
[5]Stearn, E. W. Washington Letter. Rock Prod., v. 80, No. 10, October 1977, p. 20.
[6]Rock Products. V. 80, No. 12, December 1977, p. 29.
[7]Federal Register. Portland Hydraulic Cement From Canada, Antidumping Proceeding Notice. V. 42, No. 174, Sept. 8, 1977, p. 45059.
[8]Mill value is the actual value of sales to customers f.o.b. plant, less all discounts and allowances, less all freight charges to customers, less all freight charges from producing plant to distribution terminal if any, less total cost of operating terminal if any, less cost of paper bags and pallets.
[9]Grancher, R. A. International Cement Review. Rock Prod., v. 80, No. 4, April 1977, pp. 88-103.
[10]European Cement Association. The Cement Market and Outlook, 1977. Cembureau Bull., No. 61, 1978, 35 pp.
[11]Rock Products. Rock Newscope. V. 80, No. 1, January 1977, p. 17.
[12]U.S. Embassy, New Delhi, India. State Department Airgram A-95, Oct. 18, 1977, p. 3.
[13]Levine, S. The International Cement Scene. Pit & Quarry, v. 70, No. 7, January 1977, pp. 103-115.
[14]Rock Products. V. 80, No. 8, August 1977, p. 49.
[15]U.S. Embassy, Nassau, Bahamas. State Department Airgram A-27, Dec. 12, 1977, p. 2.
[16]U.S. Embassy, Cotonou, Benin. State Department Airgram A-14, Sept. 30, 1977, p. 1.
[17]Grancher, R. A. International Cement Review. Rock Prod., v. 81, No. 4, April 1978, p. 114.
[18]Rock Products. V. 80, No. 7, July 1977, p. 40.
[19]Levine, S. The International Cement Scene. Pit & Quarry, v. 71, No. 7, January 1978, p. 118.
[20]Stonehouse, D. H. Construction Materials. Can. Min. J., February 1978, pp. 72-73.
[21]Federal Register. V. 42, No. 174, Sept. 8, 1977, p. 45059.
[22]Pit & Quarry. V. 70, No. 5, November 1977, p. 21.
[23]International Finance Corp. Compania Colombiana de Clinker, S.A. (Colclinker), Colombia. Rept. No. IFC/P-264, May 4, 1977, 36 pp.
[24]Page 115 of work cited in footnote 17.
[25]Ironman, R. New Czech Cement Plant Goes Onstream. Rock Prod., v. 80, No. 8, August 1977, pp. 67-68.
[26]World Cement Technology. V. 8, No. 5, September-October 1977, p. 208.
[27]Page 115 of work cited in footnote 17.
[28]World Cement Technology. V. 8, No. 3, May-June 1977, p. 115.
[29]Page 17 of work cited in footnote 11.
[30]Page 115 of work cited in footnote 28.
[31]Page 114 of work cited in footnote 19.
[32]U.S. Embassy, Libreville, Gabon. State Department Airgram A-71, Dec. 1, 1977, p. 9.
[33]Page 108 of work cited in footnote 19.
[34]Page 100 of work cited in footnote 17.
[35]Page 114 of work cited in footnote 19.
[36]International Finance Corp., Cementos Novella, S.A. Guatemala. Rept. No. IFC/P-265, May 11, 1977, 33 pp.
[37]Page 100 of work cited in footnote 17.
[38]Page 116 of work cited in footnote 28.
[39]U.S. Embassy, Jakarta, Indonesia. State Department Airgram A-36, Apr. 7, 1978, pp. 12-13.
[40]Page 101 of work cited in footnote 17.
[41]Pit & Quarry. V. 70, No. 6, December 1977, p. 18.
[42]Pages 111-112 of work cited in footnote 17.
[43]Page 110 of work cited in footnote 17.
[44]Page 115 of work cited in footnote 19.
[45]Page 110 of work cited in footnote 19.
[46]Page 112 of work cited in footnote 28.
[47]Page 106A of work cited in footnote 6.
[48]Page 111 of work cited in footnote 19.
[49]Rock Products. V. 80, No. 11, November 1977, p. 84.
[50]Pages 105-106 of work cited in footnote 17.
[51]U.S. Embassy, Kuala Lumpur, Malayasia. State Department Airgram A-54, June 29, 1978, p. 6.
[52]Page 115 of work cited in footnote 17.
[53]World Bank. Morocco: Appraisal of the CIDR Cement Project. Rept. No. 1426-MOR, Mar. 4, 1977, pp. 1-29.
[54]U.S. Embassy, Kathmandu, Nepal. State Department Airgram A-31, Aug. 11, 1978, pp. 8-9.
[55]Page 108 of work cited in footnote 19.
[56]Industrial Minerals Company. News & Mineral Notes. June 1977, p. 66.
[57]A/S Norcem. Group Report. June 1977.
[58]U.S. Embassy, Muscat, Oman. State Department Airgram A-54, Oct. 5, 1977, p. 14.
[59]Page 111 of work cited in footnote 19.
[60]Page 20 of work cited in footnote 22.
[61]Pages 115-116 of work cited in footnote 17.
[62]Page 115 of work cited in footnote 19.
[63]Page 208 of work cited in footnote 26.
[64]U.S. Embassy, Jiddah, Saudi Arabia. State Department Airgram A-108, Nov. 11, 1977, p. 1.
[65]Engineering News Record. Aug. 25, 1977, p. 44.
[66]Page 30 of work cited in footnote 22.
[67]Page 111 of work cited in footnote 19.
[68]Page 108 of work cited in footnote 19.
[69]Page 100 of work cited in footnote 17.
[70]Page 108 of work cited in footnote 19.

[71]Page 100 of work cited in footnote 17.
[72]Page 112 of work cited in footnote 19.
[73]U.S. Embassy, Dar es Salaam, Tanzania. State Department Airgram A-45, Sept. 19, 1977, p. 9.
[74]World Bank. Republics of Togo, Ivory Coast, and Ghana Regional Clinker Project. Rept. No. P-1812-TO, June 14, 1976, 36 pp.
[75]U.S. Embassy, Lome, Togo. State Department Airgram A-42, July 21, 1978, p. 6.
[76]Rock Products. Rock Newscope. V. 80, No. 10, October 1977, p. 17.
[77]Pages 100-101 of work cited in footnote 17.
[78]Chemical Economy & Engineering Review. News Scope. V. 9, No. 11, November 1977, p. 31.
[79]Page 115 in work cited in footnote 28.
[80]Page 101 in work cited in footnote 17.
[81]Page 116 in work cited in footnote 17.
[82]Page 119 in work cited in footnote 19.
[83]Page 207 in work cited in footnote 26.
[84]Industrial Minerals. November 1977, p. 78.
[85]Page 101 in work cited in footnote 17.
[86]Page 116 in work cited in footnote 19.
[87]Mining Congress Journal. August 1977, p. 5.
[88]Dundee News. V. 13, No. 12, July 1977, pp. 1-2.
[89]Rock Products. V. 80, No. 8, September 1977, p. 30.
[90]Page 106D of work cited in footnote 6.
[91]Page 110 of work cited in footnote 6.
[92]Pit & Quarry. V. 70, No. 2, August 1977, pp. 67-73.
[93]Page 17 of work cited in footnote 92.
[94]Herchenbach, H. World Cement Technology. V. 8, No. 1, January-February 1977, pp. 11-15.
[95]Engineering & Mining Journal. V. 178, No. 7, July 1977, pp. 90-95.
[96]New Scientist. Mar. 24, 1977.
[97]Financial Times. Roskill Information Services Ltd. in England. Feb. 8, 1977.
[98]New Scientist. Apr. 7, 1977.
[99]Page 32 of work cited in footnote 94.
[1]Page 112 of work cited in footnote 28.
[2]World Cement Technology. V. 8, No. 6, November-December 1977, pp. 234-237.
[3]Washington Post. Section A. Dec. 15, 1977, p. 28.

Chromium

By John L. Morning[1]

Although domestic producers of chromium alloys operated at about the same level as in 1976, demand for chromium alloys increased about 9%. A high level of ferrochromium imports, primarily from the Republic of South Africa and Southern Rhodesia substantially added to supply.

In March, the President signed Public Law 95-12, which in essence repealed the Byrd Amendment that allowed the importation of Rhodesian chromium materials beginning in 1972. The new law also prohibits importation of steel mill products containing Rhodesian chromium.

World production of chromite exceeded 10 million short tons for the first time.

Table 1.—Salient chromite statistics

(Thousand short tons)

	1973	1974	1975	1976	1977
United States:					
Exports	21	18	139	124	187
Reexports	34	99	45	85	61
Imports for consumption	931	1,102	1,252	1,275	1,336
Consumption	1,387	1,450	881	1,006	1,000
Stocks, Dec. 31: Consumer	597	573	952	1,009	1,338
World: Production	7,381	8,244	r9,136	r9,454	10,804

rRevised.

Legislation and Government Programs.—On March 18, the President signed a bill, Public Law 95-12, that amended the United Nations Participation Act of 1945 to halt the importation of Rhodesian chromium. This in essence repealed the Byrd Amendment that was part of a military procurement bill, Public Law 92-156, that allowed the importation of strategic and critical materials from Rhodesia, beginning in 1972. In addition, the new law prohibits the importation from any country of ferrochromium and of steel mill products containing more than 3% chromium (primarily stainless steel) that contain Rhodesian chromium. The Department of the Treasury established a certification and monitoring system for enforcement of the law.

The Committee of Low-Carbon Ferrochromium Producers in January petitioned the International Trade Commission (ITC) for import relief under Section 201 of the Trade Act of 1974. After holding hearings, the ITC reported to the President that imports of low-carbon ferrochromium were not causing serious injury or the threat thereof to the domestic industry.

In another trade import action, the Committee of Producers of High-Carbon Ferrochromium in July also petitioned the ITC for import relief. After hearings were held in October, the majority of the ITC commissioners in a report to the President held that high-carbon ferrochromium imports were a substantial cause of the threat of serious injury to domestic producers. Early in 1978, the President determined that provision of import relief was not in the national economic interests of the United States.

Although there were no sales of Government stockpile excesses of chromium materials during the year, 198,371 tons of metallurgical-grade chromite, 106,072 tons of chemical-grade chromite, and 303,264 tons of refractory-grade chromite were delivered to purchasers under prior-year sales contracts.

Table 2.—U.S. Government chromium stockpile material inventories and goals

(Thousand short tons)

Material	Goal	Inventory by program, Dec. 31, 1977			
		National stockpile	Defense Production Act	Supplemental stockpile	Total[1]
Chromite, chemical-grade	734	242	--	--	242
Chromite, metallurgical-grade	2,550	2,164	381	323	2,869
Chromite, refractory-grade	642	301	--	100	401
Ferrochromium, high-carbon	236	126	--	276	403
Ferrochromium, low-carbon	124	128	--	191	319
Ferrochromium-silicon	69	26	--	33	58
Chromium metal	10	--	--	4	4

[1]Data may not add to totals shown because of independent rounding.

DOMESTIC PRODUCTION

Domestic mine production of chromite essentially ceased in 1961 when the last Government Defense Production Act contract was phased out. A small quantity, however, was produced in 1976 for export.

Although chromite was not produced domestically in 1977, the United States continued to be a substantial chromite consumer in producing chromium ferroalloys and metal, chromium-containing refractories, and chromium chemicals. The principal producers of these products follow:

Company	Plant
Metallurgical industry:	
Airco Alloys, Air Reduction Co., Inc	Calvert City, Ky. Niagara Falls, N. Y. Charleston, S. C.
Chromium Mining & Smelting Corp	Woodstock, Tenn.
Foote Mineral Co	Graham, W. Va.
Interlake, Inc	Beverly, Ohio.
Prairie Metals and Chemicals, Inc	Prairie, Miss.
Satralloy Corp	Steubenville, Ohio.
Shieldalloy Corp., Division of Metallurg, Inc	Newfield, N. J.
Union Carbide Corp	Niagara Falls, N. Y. Marietta, Ohio. Alloy, W. Va.
Refractory industry:	
Basic, Inc	Maple Grove, Ohio.
Corhart Refractories Co., Inc	Pascagoula, Miss.
Davis Refractories, Inc	Jackson, Ohio.
General Refractories Co	Baltimore, Md. Lehi, Utah.
Harbison-Walker Refractories (a division of Dresser Industries, Inc.)	Hammond, Ind. Baltimore, Md.
Kaiser Aluminum & Chemical Corp	Moss Landing, Calif. Columbiana, Ohio. Plymouth Meeting, Pa.
North American Refractories, Co. Ltd	Womelsdorf, Pa.
Chemical industry:	
Allied Chemical Corp	Baltimore, Md.
Diamond Shamrock Corp	Castle Hayne, N. C.
PPG Industries, Inc	Corpus Christi, Tex.

Table 3.—Production, shipments, and stocks of chromium ferroalloys and chromium metal

(Short tons)

Alloy	Production		Ship-ments	Producer stocks, Dec. 31
	Gross weight	Chromium content		
1976:				
Low-carbon ferrochromium	29,386	19,686	33,091	11,394
High-carbon ferrochromium	162,577	105,237	164,088	63,294
Ferrochromium-silicon	55,328	19,776	51,867	16,785
Other[1]	19,839	12,909	20,218	4,643
Total	267,130	157,608	269,264	96,116
1977:				
Low-carbon ferrochromium	24,068	16,135	22,392	12,412
High-carbon ferrochromium	179,606	112,450	193,035	40,802
Ferrochromium-silicon	53,123	18,897	44,798	23,595
Other[1]	15,865	10,611	16,605	3,234
Total	272,662	158,093	276,830	80,043

[1]Includes chromium briquets, chromium metal, exothermic chromium additives, and other miscellaneous chromium alloys.

CONSUMPTION AND USES

Domestic consumption of 1 million tons of chromite ore and concentrate, containing about 290,000 tons of chromium, was 1% below that of 1976. Of the total chromite consumed, the metallurgical industry used 57.8%; the refractory industry, 20.8%; and the chemical industry, 21.4%. The metallurgical industry consumed 578,000 tons of chromite, containing 163,000 tons of chromium, in producing 273,000 tons of chromium alloys and metal. About 43.9% of the metallurgical ore had a chromium-to-iron ratio of 3:1 and over, 26.4% had a ratio between 2:1 and 3:1, and 29.7% had a ratio of less than 2:1.

Producers of chromite-bearing refractories consumed 208,000 tons of ore containing 51,300 tons of chromium. The chemical industry consumed 214,000 tons of chromite containing 65,400 tons of chromium, in producing 157,037 tons of chemicals (sodium bichromate equivalent).

Chromium has a wide range of applications in the three consuming industries. In the metallurgical industry, its principal use was in stainless steel. Of the total chromium alloys consumed, stainless steel accounted for 71%, full-alloy steels for 15%, high-strength low-alloy and electric steels 3%, cast irons 3%, and other uses 8%. Total chromium alloy consumption increased 9% over that of 1976.

The refractory industry utilized chromium in the form of chromite for manufacturing refractory bricks to line metallurgical furnaces. Consumption of chromite for refractory purposes increased 3% over that used in 1976.

The chemical industry consumed chromite for manufacturing sodium bichromate and potassium dichromate which are base materials for a wide range of chromium chemicals. Chromite consumption in this industry increased 3% compared with that of 1976.

Development of a process to coat titanium with chromium was expected to find widespread use in the aerospace industry. The process does not cause embrittlement or affect strength or fatigue properties of the titanium. Because the chromium coating greatly lowers the surface friction of the titanium, the material was expected to be usable in a wide range of components where titanium has been unsuitable.

Chrysler Corp. planned to use a nickel-chromium-plated, stamped aluminum bumper on its 1979 R-body cars. Aluminum alloys were being tested with alloy 7146, a leading candidate. The bumpers were reportedly to have a nickel-chromium plating of about 0.002 inch, a little thicker than that on conventional plated steel.

KOLORIN, a trade-named process which reportedly adds a glowing color but allows the luster of stainless steel to show through, was being licensed worldwide including the United States. It comes in four basic shades; blue, gold, red, and green. Applications range from architectural accents to identification of surgical tools.

Table 4.—Consumption of chromite and tenor of ore used by primary consumer groups in the United States

Year	Metallurgical industry		Refractory industry		Chemical industry		Total	
	Gross weight (thousand short tons)	Average Cr_2O_3 (percent)	Gross weight (thousand short tons)	Average Cr_2O_3 (percent)	Gross weight (thousand short tons)	Average Cr_2O_3 (percent)	Gross weight (thousand short tons)	Average Cr_2O_3 (percent)
1973	920	48.1	261	35.0	206	45.3	1,387	45.2
1974	904	47.0	295	35.2	251	44.8	1,450	44.2
1975	532	44.6	183	34.5	166	44.9	881	42.5
1976	597	43.4	202	35.0	207	44.8	1,006	42.0
1977	578	41.3	208	36.0	214	44.7	1,000	40.9

Table 5.—U.S. reported consumption of chromium ferroalloys and metal in 1977, by end use and form

(Short tons, gross weight)

	Low-carbon ferrochromium	High-carbon ferrochromium	Ferrochromium silicon	Other	Total
Steel:					
Carbon	1,520	3,759	919	203	6,401
Stainless and heat resisting	36,892	237,317	48,141	492	322,842
Full alloy	15,588	44,422	3,796	5,130	68,936
High-strength low-alloy and electric	1,755	9,303	2,065	1,798	14,921
Tool	1,122	3,812	149	17	5,100
Cast irons	1,213	11,684	139	581	13,617
Superalloys	3,972	4,971	180	2,117	11,240
Alloys (excluding steels and superalloys):					
Welding and alloy hard-facing rods and materials	704	986	--	326	2,016
Other alloys[1]	1,311	1,286	18	2,583	5,198
Miscellaneous and unspecified	2,454	597	44	53	3,148
Total	66,531	318,137	55,451	[2]13,300	453,419
Chromium content	44,988	194,793	20,571	8,282	268,634
Stocks, Dec. 31, 1977	6,247	66,114	4,777	[3]2,228	79,366

[1]Includes magnetic and nonferrous alloys.
[2]Includes 3,948 tons of chromium metal.
[3]Includes 1,041 tons of chromium metal.

STOCKS

Chromite stocks increased 33% over that of 1976 as imports exceeded consumption. All three consuming industries registered higher stocks; the metallurgical industry stocks were up 18%, the chemical industry 138%, and the refractory industry 28%. Ferrochromium stocks were mixed as consumer stocks were 13% higher than in 1976, while producer stocks were 17% lower. Stocks of chromium chemicals (sodium bichromate equivalent) at producing plants decreased from 16,257 tons in 1976 to 8,897 tons in 1977.

Table 6.—Consumer stocks of chromite, December 31

(Thousand short tons)

Industry	1973	1974	1975	1976	1977
Metallurgical	339	340	701	762	900
Refractory	154	169	154	136	174
Chemical	104	64	97	111	264
Total	597	573	952	1,009	1,338

Table 7.—Consumer stocks of chromium ferroalloys and chromium metal, December 31

(Short tons, gross weight)

Product	1973	1974	1975	1976	1977
Low-carbon ferrochromium	15,802	14,937	10,974	10,100	6,247
High-carbon ferrochromium	24,162	25,280	50,076	52,553	66,114
Ferrochromium-silicon	6,740	10,227	4,418	3,995	4,777
Other[1]	1,752	3,303	2,352	3,300	2,228
Total	48,456	53,747	67,820	69,948	79,366

[1]Includes chromium briquets, chromium metal, exothermic chromium additives, and other miscellaneous chromium alloys.

PRICES

Published prices for Russian and Turkish chromite in 1977 remained at the same level as in 1975. Russian chromite was quoted during the year at $150 per metric ton, f.o.b. Black Sea ports, while Turkish chromite was quoted at $132 to $142 per long ton, f.o.b. Turkish ports. The published price of South African Transvaal chromite began the year at $38 to $46 per long ton, and moved higher in March to $56 to $61 per ton for the balance of the year.

Despite a strong, but not a record, demand year for chromium alloys, ferrochromium prices decreased under pressure of large imports of lower-cost foreign material. However, the quoted price of ferrochromium silicon remained unchanged during the year. Prices of selected chromium alloys and metal as published in Metals Week follow:

Material	January	December
	Cents per pound of chromium	
Domestic charge chromium (50%-55% chromium)	42.25	40
Imported charge chromium (50%-55% chromium)	36.5	32.5
Imported charge chromium (55%-60% chromium)	37.5	33.5
Imported charge chromium (60%-65% chromium)	38.25	35
Domestic charge chromium (66%-70% chromium)	43	41
Domestic low-carbon ferrochromium (0.025% carbon)	90	80
Imported low-carbon ferrochromium (0.05% carbon)	64	57
Domestic low-carbon ferrochromium (0.05% carbon)	85	75
Simplex	85	75
	Cents per pound of product	
Ferrochromium-silicon	29.45	29.45
Aluminothermic chromium metal	263	263
Electrolytic chromium metal	263	263-279

FOREIGN TRADE

Exports of chromite in 1977 increased 51% in quantity and 80% in value compared with those of 1976. Reexports were lower, however, decreasing 28% in quantity and 10% in value. Most export shipments were to Canada (49%), Sweden (20%), and the Federal Republic of Germany (20%). Smaller quantities were shipped to seven other countries. Reexports were shipped to four countries: Mexico (70%), Canada (15%), Spain (12%), and Brazil (3%).

Ferrochromium exports totaled 12,472 tons, valued at $7.3 million, and went to 13 countries. Shipments decreased 8% in quantity and 17% in value compared with those of 1976. Canada (59%), the Republic of Korea (18%), and the Federal Republic of Germany (13%) were the leading recipients.

Exports of chromium and chromium alloys (wrought and unwrought) totaled 579 tons valued at $1.4 million. Of the 34 countries receiving shipments, Canada accounted for 22%, Jamaica 18%, France 13%, the Federal Republic of Germany 7%, the United Kingdom 6%, Iran 5%, and Japan 4%.

Exports of pigment-grade chromium chemicals totaled 551 tons valued at $1.2

million. Japan (51%), Canada (23%), and France (12%) received 86% of the shipments; the balance was dispersed among 22 countries. Exports of nonpigment-grade chromium chemicals totaled 4,473 tons valued at $7.4 million. Japan received 23%, the Republic of Korea 20%, Canada 20%, and Taiwan 15%. The balance was received by 36 countries.

Exports of sodium dichromate increased 10% compared with that of 1976, rising to 15,676 tons valued at nearly $8 million. Canada was the leading recipient with 36% of the shipments. Other countries receiving significant shipments were the People's Republic of China (24%), Argentina (13%), the Republic of Korea (9%), and Colombia (8%). Thirty other countries received the balance.

Imports of chromite in 1977 increased nearly 5% in quantity and decreased 2% in value over those of 1976. The Republic of South Africa supplied 49% of the total, followed by Finland with 20%. Shipments from the U.S.S.R. were sharply reduced as 80,000 tons were received, compared with 189,000 tons in 1976. Turkey also exported less chromite to the United States than in the previous year.

Record shipments of ferrochromium were imported during the year as 224,082 tons were received. Of the low-carbon ferrochromium shipments, Southern Rhodesia supplied 26%, Japan 21%, the Republic of South Africa 19%, and Sweden 14%. Five other countries supplied the balance. High-carbon ferrochromium was received from the Republic of South Africa (56%), Southern Rhodesia (21%), Yugoslavia (12%), and Brazil (6%). Six other countries supplied the balance.

Ferrochromium-silicon imports decreased 74% compared with those of 1976, to 4,140 tons valued at $8.7 million. Southern Rhodesia supplied 62%, the Republic of South Africa 36%, and Canada 2%.

Table 8.—U.S. exports and reexports of chromite ore and concentrates

(Thousand short tons and thousand dollars)

Year	Exports		Reexports	
	Quantity	Value	Quantity	Value
1975	139	6,896	45	2,111
1976	124	5,609	85	5,475
1977	187	10,105	61	4,913

Table 9.—U.S. imports for consumption of chromite, by grade and country

(Thousand short tons and thousand dollars)

Country	Not more than 40% Cr_2O_3			More than 40% but less than 46% Cr_2O_3			46% or more Cr_2O_3			Total		
	Gross weight	Cr_2O_3 content	Value	Gross weight	Cr_2O_3 content	Value	Gross weight	Cr_2O_3 content	Value	Gross weight	Cr_2O_3 content	Value
1976:												
Albania	--	--	--	18	8	1,858	--	--	--	18	8	1,858
Canada	([1])	([1])	1	--	--	--	([1])	([1])	1	([1])	([1])	2
Colombia	4	1	211	--	--	--	--	--	--	4	1	211
Finland	120	36	4,437	--	--	--	49	35	1,462	169	71	5,899
India	18	7	845	--	--	--	--	--	--	18	7	845
Philippines	163	53	5,614	--	--	--	3	2	169	166	55	5,783
Rhodesia, Southern	12	4	369	9	4	379	14	7	650	35	15	1,398
South Africa, Republic of	26	9	732	318	141	9,737	94	44	3,617	438	194	14,086
Sweden	26	4	68	--	--	--	--	--	--	26	4	68
Turkey	115	44	8,334	31	14	3,161	66	31	7,461	212	89	18,956
U.S.S.R	69	27	4,885	--	--	--	120	62	16,084	189	89	20,969
Total	553	185	25,496	376	167	15,135	346	181	29,444	1,275	533	70,075
1977:												
Albania	([1])	([1])	1	25	11	2,488	--	--	--	25	11	2,489
Colombia	4	1	255	--	--	--	--	--	--	4	1	255
Finland	269	71	8,835	--	--	--	--	--	--	269	71	8,835
Greece	3	1	321	--	--	--	--	--	--	3	1	321
Norway	([1])	([1])	1	--	--	--	--	--	--	([1])	([1])	1
Philippines	166	53	8,202	2	1	103	4	2	265	172	56	8,570
South Africa, Republic of	19	7	1,047	521	231	20,946	119	68	6,538	659	306	28,531
Turkey	41	16	2,952	40	17	3,202	43	20	4,957	124	53	11,111
U.S.S.R	30	12	1,900	--	--	--	50	27	6,684	80	39	8,584
Total	532	161	23,514	588	260	26,739	216	117	18,444	1,336	538	68,697

[1]Less than 1/2 unit.

Table 10.—U.S. imports for consumption of ferrochromium, by country

Year and country	Low-carbon ferrochromium (less than 3% carbon)			High-carbon ferrochromium (3% or more carbon)		
	Gross weight (short tons)	Chromium content (short tons)	Value (thousands)	Gross weight (short tons)	Chromium content (short tons)	Value (thousands)
1976:						
Brazil	937	530	$722	26,896	15,459	$10,126
Canada	(1)	(1)	1	(1)	(1)	1
France	3,426	2,460	3,335	--	--	--
Germany, Federal Republic of	3,695	2,667	3,899	1,661	1,075	1,081
India	--	--	--	440	284	142
Italy	20	14	20	1,098	707	481
Japan	28,986	19,359	23,582	9,849	6,045	5,098
Mozambique	--	--	--	1,462	816	616
Norway	2,857	1,974	2,414	1,156	787	687
Rhodesia, Southern	8,194	5,785	8,098	39,193	26,561	15,132
South Africa, Republic of	11,022	6,829	8,168	75,706	41,380	26,650
Sweden	3,008	2,218	3,470	--	--	--
Turkey	1,109	777	989	--	--	--
United Kingdom	(1)	(1)	1	--	--	--
Yugoslavia	496	348	85	21,385	14,193	10,021
Total	63,750	42,961	54,784	178,846	107,307	70,035
1977:						
Brazil	--	--	--	10,797	6,072	3,706
Canada	--	--	--	2	1	7
Finland	20	14	20	--	--	--
France	824	601	773	--	--	--
Germany, Federal Republic of	2,215	1,617	2,365	1,444	916	975
Italy	38	28	38	--	--	--
Japan	7,669	5,136	6,738	275	176	163
Norway	3,840	2,561	3,348	1,328	908	657
Rhodesia, Southern	9,464	6,692	7,496	40,450	27,036	16,109
South Africa, Republic of	6,844	4,187	4,513	106,376	56,807	35,578
Spain	--	--	--	1,103	599	463
Sweden	4,854	3,527	5,321	3,409	2,078	1,496
Yugoslavia	--	--	--	23,130	15,254	10,762
Total	35,768	24,363	30,612	188,314	109,847	69,916

[1]Less than 1/2 unit.

Imports of chromium metal (wrought and unwrought) and waste and scrap, increased to 2,433 tons valued at $10.9 million, from 2,306 tons valued at $9.1 million in 1976. The United Kingdom supplied 54% and Japan 38% of the shipments. Five other countries supplied the balance.

Chromium carbide imports, totaling 555 tons valued at $3.6 million, increased threefold over those of 1976. The Federal Republic of Germany supplied 81% and the United Kingdom 18%. Four other countries supplied the balance.

Imports of chromium-containing pigments in 1977 were as follows: Chrome green, 87 tons; chrome yellow, 2,852 tons; chromium oxide green, 1,035 tons; molybdenum orange, 246 tons; strontium chromate, 277 tons; and zinc yellow, 1,626 tons. Total value of these products was $7.8 million, 27% lower than in 1976. Chrome yellow accounted for 44% of total value of these products, followed by zinc yellow with 23%.

Sodium chromate and dichromate imports totaled 113 tons valued at $63,000. The Republic of South Africa supplied 98% of the imports. The balance was supplied by five other countries. Three tons of potassium dichromate valued at $4,700 was imported from the Federal Republic of Germany and Sweden.

Table 11.—U.S. import duties

Tariff classification	Article	Rate of duty Jan. 1, 1977[1]
	CHROMIUM ORES AND METAL PRODUCTS	
601.15	Chromium ore	Free.
607.30	Ferrochromium, less than 3% carbon	4% ad valorem.
607.31	Ferrochromium, over 3% carbon	0.625 cent per pound on chromium content.
632.18	Unwrought chromium other than alloys: Waste and scrap[2]	5% ad valorem.
	CHROMIUM CHEMICAL AND RELATED PRODUCTS	
420.08	Potassium chromate and dichromate	1.1 cents per pound.
420.98	Sodium chromate and dichromate	0.87 cent per pound
422.92	Chromium carbide	6% ad valorem.
	CHROMIUM PIGMENTS	
473.10	Chromium green	5% ad valorem.
473.12	Chromium yellow	Do.
473.14	Chromium oxide green	Do.
473.16	Hydrated chromium oxide green	Do.
473.18	Molybdenum orange	Do.
473.19	Strontium chromate	Do.
473.20	Zinc yellow	Do.

[1]Not applicable to centrally planned economy countries.
[2]Duty temporarily suspended on waste and scrap.

WORLD REVIEW

Australia.—Chromite occurs as a subsidiary mineral in ultrabasic rocks on the Island of Tasmania, but rarely in sufficient concentration to warrant mining. Small deposits of chromiferous gravels of economic-grade, and lower-grade alluvium overlie serpentine rocks near Beaconfield and larger low-grade deposits of alluvial chromite occur in gravel deposits at Montagu Swamp. Chromite also occurs at Adamsfield, Tasmania.

Brazil.—Brazil's principal chromite resources are located in Bahia. Cia. Ferro Ligas da Bahia S.A. (Ferbasa), the dominant chromite producer, was also the sole producer of ferrochromium. Ferbasa operates two mines near Campo Formosa and seven mines in the Jacurici Valley. Reported measured and indicated reserves of Ferbasa total 44 million tons grading 20% Cr_2O_3, including 11 million tons grading 20% Cr_2O_3 measured at Campo Formosa, and 1.7 million tons grading 38% Cr_2O_3 measured at Jacurici Valley.

Canada.—A review of research on Canadian chromite was published.[2] The Bird River chromite deposit in Manitoba is a low-grade, high-iron chromite, containing over 16 million tons of chromite ranging from 18% to 25% Cr_2O_3. Research demonstrated that chromium additives for the steel industry, chromium metal, and sodium dichromate can be produced from Bird River chromite concentrate of low chromium content and low chromium-to-iron ratio.

Greece.—The Hellenia Industrial and Mining Investment Co. reportedly was studying the feasibility of a 33,000-ton-per-year ferrochromium plant.

India.—In an effort to conserve chromite resources for a planned 500,000-ton-per-year pelletizing plant in Orissa, the Government placed restrictions on export of low-grade lump chromite ore and beneficiated chromite concentrate. The Government also banned exporting chromite containing more than 40% Cr_2O_3 and less than 12% silica.

Mysore Minerals Ltd., a State-owned company of the Karnataka State Government in southern India was studying the feasibility of a charge-chromium smelter in the Byrapura district with help from Japanese interests. Feasibility depends on obtaining power from a neighboring State, since Karnataka is deficient in electrical power. According to reports, chromite resources in the State total about 550,000 tons of low-grade chromite.

The Orissa Government reserved 564 square miles of potential chromium-bearing areas in Cuttack, Dhenkanal, and Keonjhar districts for exploration by public sector organizations. The State has considerable tonnage of chromite resources, but only 4 million tons of reserves. India's demand for chromite was expected to rise threefold within the next 10 years. A crash program by Orissa's Directorate of Mines in collaboration with the Geological Survey of India, the Mineral Exploration Corp., and Orissa Mining Corp. was expected to improve India's reserve position by the middle 1980's.

Indonesia.—Reportedly, Japanese and Indonesian interests joined together to explore for chromite in Sulawesi, Indonesia. P.T. Perto (Indonesia) has mining rights in an 80,000-square-mile area. Initial surveys indicate chromite deposits containing 200,000 tons of ore grading 33% Cr_2O_3. If sufficient chromite is found in a 2-year program, a joint venture would be formed for commercial development.

Japan.—The Rare Metals Association (RMA), formed in 1976 with some assistance from government funding, was established as a stockpiling corporation for chromium, nickel, cobalt, and tungsten. During the year, RMA acquired nearly 2,900 tons of ferrochromium.

Mexico.—During 1977, Ferroaleaciones de Mexico was considering building a ferrochromium plant to expand its line of ferroalloys.

Pakistan.—The Baluchistan Development Authority announced a plan to develop chromite mines at Muslimbagh in the Zhob district of Pakistan. Also planned was a 60-ton-per-day concentrator and a refractory brick manufacturing plant.

Philippines.—Chromite production in the Philippines was slightly higher in 1977 than in 1976. Seventy-five percent was refractory-grade and 25% metallurgical-grade. Six companies produced refractory-grade chromite although the traditional supplier, Consolidated Mines Ltd., accounted for 88% of the output. Twelve companies produced metallurgical chromite of which Acoje Mining Co. Inc., a long-time producer, accounted for 63% of the total.

Philippine chromite producers petitioned the National Economic and Development Authority and the Department of Finance to withdraw or reduce the 20% export tax on chromite. The producers were backed by the Philippine Chamber of Mines and the Philippine Export Council. The tax reportedly is levied on the difference between current export prices and world market prices, and was considered by producers to hinder expansion plans.

Chromite exploration at Acoje in 1977 strengthened the firm's reserve position, as reserves increased from 1.9 million tons to 2.4 million tons. During the year, 345,000 tons of ore was milled to produce 94,000 tons of concentrate. Over 100,000 tons of chromite was sold or shipped during the year. Much of the new equipment ordered under Acoje's expansion program was on site and being installed. A novel slimes retreatment plant being installed was reportedly the first of its kind worldwide.

Rhodesia, Southern.—Anglo American Corp. reportedly stopped prospecting activities in Rhodesia owing to the security situation. About 100 employees were affected. In a parallel move, the Department of Geological Survey also suspended mapping operations in some areas.

Rio Tinto (Rhodesia) put its North Dyke chromite mines on a standby basis, as well as a pilot ferrochromium smelter. These developments were attributed to a slowdown in exports of chromium from Rhodesia. Rio Tinto showed a loss on its chromium operations in 1976 and the first 6 months of 1977.

South Africa, Republic of.—Chromite production increased significantly during the year to 3,656,000 tons, an increase of 38% compared with 1976. Forty-five percent contained less than 44% Cr_2O_3, 53% between 44% and 48% Cr_2O_3, and the remaining 2% over 48% Cr_2O_3.

The Tubatse ferrochromium plant at Steelport in the eastern Transvaal, jointly owned by Union Carbide Corp. and General Mining and Finance Corp. Ltd. officially opened in May. The facilities were described.[3] A feature of the plant is the air pollution control system which reportedly uses the latest technology so that the plant can meet the same standards as those of the United States.

South Africa Armco Steel Corp. (ARMCO) reportedly purchased substantial mineral rights to chromite deposits in the Marico district of the western Transvaal. ARMCO Broone (Pty), South African subsidiary of ARMCO, purchased 50% of a farm that was jointly owned by Vereeniging Refractories Ltd. and located between the chromite mines of Marico Minerals Co. and Zeerust Chrome Mine Ltd. ARMCO also purchased mineral rights of five other farms in the district.

Middleburg Steel and Alloys (Pty) Ltd., South Africa's sole producer of low-carbon ferrochromium, temporarily suspended production due to low world demand.

South African Manganese Amcor Ltd.

(SAMANCOR) reportedly purchased two chromite properties in the Rustenburg area formerly owned by Consolidated Chrome Corp.

Sudan.—Contracts were reportedly signed between a Japanese group and the Sudanese Government for a feasibility study of a ferrochromium industry, based on chromite deposits in the Ingessana Hills area.

United Arab Emirates.—The Ministry of Petroleum and Mineral Resources of the United Arab Emirates awarded a contract to Hunting Geology and Geophysics Ltd. (United Kingdom) to investigate mineral deposits throughout the Emirates. An earlier survey in the six northern Emirates located deposits of chromite, copper, and industrial minerals.

Table 12.—Chromite: World production, by country

(Thousand short tons)

Country[1]	1975	1976	1977[p]
Albania[e] [2]	859	875	970
Argentina	(3)	--	--
Brazil	191	205	[e]210
Colombia[e]	13	11	11
Cuba[e]	35	35	35
Cyprus	30	10	15
Egypt	(4)	[e]1	--
Finland	365	456	655
Greece[5]	[r]39	38	[e]44
India[e]	[r]551	443	387
Iran	190	176	[e]180
Japan	26	24	20
Madagascar	214	244	198
New Caledonia	2	11	[e]11
Pakistan	11	12	[e]13
Philippines	573	471	592
Rhodesia, Southern[e]	650	670	660
South Africa, Republic of	2,288	2,656	3,656
Sudan	17	24	[e]30
Thailand	(4)	--	--
Turkey[6]	[r]790	[r]780	700
U.S.S.R.[e]	2,290	[r]2,300	2,400
Vietnam[e]	NA	10	15
Yugoslavia	2	2	[e]2
Total	[r]9,136	9,454	10,804

[e]Estimate. [p]Preliminary. [r]Revised. NA Not available.

[1]In addition to the countries listed, Bulgaria and North Korea may also produce chromite, but production is not reported and available information is inadequate for formulation of reliable estimates of output levels.

[2]Figures represent crude ore output, not marketable production.

[3]Revised to zero.

[4]Less than 1/2 unit.

[5]Exports of direct-shipping ore plus production of concentrates.

[6]Estimated production of marketable product (direct-shipping ore plus concentrates) based on reported production of run-of-mine ore, which was as follows in thousand short tons: 1975—1,043; 1976—1025; 1977—(estimated) 911. Revised estimated for marketable output for prior recent years are as follows in thousand short tons: 1971—875; 1972—575; 1973—475; 1974—600.

TECHNOLOGY

During the year, Bureau of Mines researchers investigated recovery of chromium from laterite processing residues, improved methods for recovering chromite from low-grade ore, recovery of chromite from used refractories, recovery of chromium from metallurgical and tanning wastes, and conservation of chromium through surface alloying.

An industry-American Society for Testing and Materials, National Bureau of Standards (NBS), cooperative analytical program was completed, leading to the NBS Certificate of Analysis for Standard Reference Material 64c, High-Carbon Ferrochromium. Characterization and certification testing procedures were described.[4]

A vacuum carbon reduction of chromium oxide process to produce chromium metal was announced by Union Carbide Corp. The process involves the same technology as the firm's proprietary low-carbon ferrochromium Simplex process. The new process involves mixing chromium oxide and carbon prior to compacting the mixture into briquets. The briquets are then heated in a large vacuum furnace. As the carbon reacts with the oxygen, carbon monoxide gas is removed from the system, leaving pure chromium metal. The new product will be used to supplement the firm's 2,800-ton-per-year electrolytic chromium metal capacity.

Chromized steel may replace Type 409 stainless steel in automobile usage for catalyst retainers, exhaust pipes, and couplings and fittings of various converter assemblies. Chromized steel has a ferritic stainless steel coating on a special titanium-stabilized carbon steel base. Ferrochromium powder is applied to both surfaces of the base and then diffused into the steel at high temperature in a special atmosphere.

A possible substitute for stainless steel by a diffusion alloying process reportedly gave ordinary carbon steel the resistance properties of stainless steel. The process employs a liquid lead medium heated to 1,950° F to transport the alloying material to the surface of the steel where alloying takes place by diffusion.

The removal of chromium and cyanide from waste water by the precipitation-flotation method was investigated and experimental results were described.[5] Both chromium and cyanide were successfully eliminated.

---

[1]Physical scientist, Division of Ferrous Metals.

[2]Raicevics, D. Methods for Chromium Recovery From Manitoba Bird River Chromite Deposits. Can. Min. J., v. 98, No. 1, November 1977, pp. 61-68.

[3]Coal Gold+Base Minerals of Southern Africa. Rigid Pollution Standards Set at Tubatse. V. 25, No. 5, May 1977, pp. 49, 55, 57.

[4]Cumbo, J. E., and R. E. Michaelis. Production, Characterization, and Certification of NBS-SRM 64c, High-Carbon Ferrochromium. Electric Furnace Proc., AIME, v. 35, 1977, pp. 52-56.

[5]Nakahiro, Y., T. Wakamatsu, and S. Mukai. Study on the Removal of Chromium and Cyanide From Waste Water by the Precipitation-Flotation Method. 12th Internat. Miner. Process. Cong., São Paulo, Brazil, 1977, 30 pp.

Clays

By Sarkis G. Ampian[1]

Clays in one or more of six classification categories (kaolin, ball clay, fire clay, bentonite, fuller's earth, or common clay and shale) were produced in 47 States and Puerto Rico. Clay production was not reported in Alaska, the District of Columbia, Rhode Island, or Vermont. The States leading in output were Georgia, 7.6 million tons; Texas, 3.8 million tons; and Ohio, 3.6 million tons; followed in order by North Carolina, Wyoming, Alabama, and California. Georgia also led in total value of clay output with $288.2 million; Wyoming was second with $48.4 million. Compared with 1976 figures, clay production increased in 29 States and value increased in 32 States. Total quantity of clays sold or used by domestic producers in 1977 was 1% higher; total value rose 13% to an alltime high. Increases in value per ton were reported for all clays in 1977 owing to increased labor, fuel, and material costs. The energy crisis, or more specifically, the increasing shortage and costs of fuels, continued to cause considerable concern among clay producers and clay product manufacturers. Industrywide efforts were made both to economize and to obtain standby fuels. The costs of environmental protection equipment and environmental restrictions and rising capital costs also continued to adversely affect production during 1977.

Production of the specialty clays—kaolin, ball clay, bentonite, fire clay, and fuller's earth—and common clay and shale, all increased with the exception of fire clay. A small upturn in construction that increased demand for building materials (brick, lightweight aggregate, vitrified clay pipe, clay floor and wall tile, etc.) was responsible for the rise in production of common clay and shale. Production of ball clay increased 12%, bentonite, fuller's earth, and kaolin 6% each, and common clay and shale increased slightly. Fire clay decreased 12%, largely because lower steel production rates brought about by strikes at most iron ore mines and plants in the Lake Superior district reduced refractory demand. Although bentonite shipments to the struck

Table 1.—Salient clay and clay products statistics in the United States[1]

(Thousand short tons and thousand dollars)

	1973	1974	1975	1976	1977
Domestic clays sold or used by producers:					
Quantity	64,351	60,796	49,047	52,389	53,196
Value	$354,058	$422,542	$424,556	$528,745	$579,170
Exports:					
Quantity	2,097	2,451	2,315	2,487	2,561
Value	$79,774	$114,212	$120,298	$151,953	$160,790
Imports for consumption:					
Quantity	53	43	38	39	36
Value	$1,879	$2,193	$1,947	$1,814	$1,917
Clay refractories, shipments: Value	$327,265	$410,153	$409,879	$448,471	$465,442
Clay construction products, shipments: Value	$772,723	$694,737	$655,779	$783,644	$993,508

[1]Excludes Puerto Rico.

pelletizing plants were curtailed from August 1 until settlement during December, the short-fall in this end use was taken up by increased demand in other areas, such as drilling muds and foundry sands. The coal strike that began at yearend also led to reduced fire clay and iron ore pelletizing demands.

Kaolin in 1977 accounted for only 12% of the total clay production but for 52% of the value.

Table 2.—Clay sold or used by producers in the United States in 1977, by State[1]

(Short tons)

State	Ball clay	Bentonite	Common clay and shale	Fire clay	Fuller's earth	Kaolin	Total	Total value
Alabama	--	W	2,079,973	266,534	--	330,298	[2]2,676,805	[2]$21,984,807
Arizona	W	33,322	W	W	--	--	131,742	668,952
Arkansas	--	--	908,413	--	--	79,678	988,091	5,406,935
California	148	95,269	2,411,653	--	--	68,950	2,576,020	12,178,572
Colorado	--	W	926,608	34,036	--	--	[2]960,644	[2]4,712,339
Connecticut	--	--	95,163	--	--	--	95,163	250,023
Delaware	--	--	10,935	--	--	--	10,935	6,561
Florida	--	--	119,411	--	433,795	27,370	580,576	[3]22,312,987
Georgia	--	--	1,993,185	--	576,731	4,983,610	7,553,526	288,223,200
Hawaii	--	--	W	--	--	--	W	W
Idaho	--	W	W	W	--	W	22,543	92,127
Illinois	--	--	913,837	36,543	W	--	[4]950,380	[4]5,117,809
Indiana	--	--	1,266,323	1,205	--	--	1,267,528	2,236,552
Iowa	--	--	882,505	--	--	--	882,505	2,460,989
Kansas	--	W	1,117,433	--	--	--	[2]1,117,433	[2]1,965,100
Kentucky	W	--	618,921	96,533	--	--	[5]715,454	[5]2,499,768
Louisiana	--	--	401,373	--	--	--	401,373	784,976
Maine	--	--	98,081	--	--	--	98,081	160,427
Maryland	W	--	892,859	--	--	--	[5]892,859	[5]2,343,614
Massachusetts	--	--	149,389	--	--	--	149,389	274,856
Michigan	--	--	2,007,391	--	--	--	2,007,391	5,125,835
Minnesota	--	--	162,637	--	--	W	[3]162,637	[3]276,483
Mississippi	W	340,130	1,142,869	--	W	--	1,707,554	16,030,657
Missouri	--	--	1,431,734	871,516	W	69,068	[4]2,372,318	[4]16,891,956
Montana	--	195,262	28,231	730	--	--	224,223	3,557,444
Nebraska	--	--	160,571	--	--	--	160,571	367,533
Nevada	--	9,635	W	--	W	W	53,518	521,367
New Hampshire	--	--	W	--	--	--	W	W
New Jersey	--	--	52,024	16,088	--	--	68,112	374,248
New Mexico	--	--	69,415	W	--	--	[6]69,415	[6]112,734
New York	W	--	564,369	--	--	--	[5]564,369	[5]1,728,329
North Carolina	--	--	3,022,055	--	--	W	[3]3,022,055	[3]4,989,585
North Dakota	--	--	W	--	--	--	W	W
Ohio	--	--	2,841,822	725,689	--	--	3,567,511	12,834,544
Oklahoma	--	--	1,015,891	--	--	--	1,015,891	1,686,862
Oregon	--	--	118,916	--	--	--	118,916	192,578
Pennsylvania	--	--	1,743,184	561,206	--	W	[3]2,304,390	[3]13,074,564
Puerto Rico	--	--	271,993	--	--	--	271,993	387,246
South Carolina	--	--	1,447,827	--	W	723,535	[4]2,171,362	[4]18,705,139
South Dakota	--	W	197,440	--	--	--	[2]197,440	[2]232,727
Tennessee	628,428	W	949,668	--	W	--	1,681,088	17,784,727
Texas	W	39,592	3,585,633	56,097	W	W	3,809,929	16,271,957
Utah	--	6,880	222,670	14,134	W	W	249,394	828,261
Virginia	--	--	889,812	--	--	--	889,812	1,293,836
Washington	--	--	309,346	W	--	--	[6]309,346	[6]1,091,008
West Virginia	--	--	389,041	W	--	--	[6]389,041	[6]599,333
Wisconsin	--	--	W	--	--	--	W	W
Wyoming	--	2,761,838	203,871	--	--	--	2,965,709	48,368,571
Undistributed	265,651	264,559	230,559	285,296	417,800	206,049	[7]1,043,204	[7]22,549,843
Total	894,227	3,746,487	37,945,031	2,965,607	1,428,326	6,488,558	53,468,236	579,557,961

W Withheld to avoid disclosing company proprietary data; included with "Undistributed."
[1]Includes Puerto Rico.
[2]Excludes bentonite.
[3]Excludes kaolin.
[4]Excludes fuller's earth.
[5]Excludes ball clay.
[6]Excludes fire clay.
[7]Incomplete total; remainder included with State totals.

Table 3.—Number of mines from which producers sold or used clay in the United States in 1977, by State

State	Ball clay	Bentonite	Common clay and shale	Fire clay	Fuller's earth	Kaolin	Total
Alabama	--	1	36	5	--	5	47
Arizona	1	4	2	1	--	--	8
Arkansas	--	--	11	--	--	6	17
California	1	7	53	--	--	7	68
Colorado	--	2	46	6	--	--	54
Connecticut	--	--	3	--	--	--	3
Delaware	--	--	1	--	--	--	1
Florida	--	--	3	--	3	1	7
Georgia	--	--	28	--	7	52	87
Hawaii	--	--	1	--	--	--	1
Idaho	--	2	2	1	--	1	6
Illinois	--	--	18	2	2	--	22
Indiana	--	--	23	3	--	--	26
Iowa	--	--	15	--	--	--	15
Kansas	--	1	18	--	--	--	19
Kentucky	5	--	11	7	--	--	23
Louisiana	--	--	13	--	--	--	13
Maine	--	--	6	--	--	--	6
Maryland	1	--	9	--	--	--	10
Massachusetts	--	--	3	--	--	--	3
Michigan	--	--	9	--	--	--	9
Minnesota	--	--	3	--	--	1	4
Mississippi	2	3	18	--	2	--	25
Missouri	--	--	19	53	1	8	81
Montana	--	4	8	1	--	--	13
Nebraska	--	--	6	--	--	--	6
Nevada	--	6	2	--	1	1	10
New Hampshire	--	--	1	--	--	--	1
New Jersey	--	--	1	3	--	--	4
New Mexico	--	--	4	2	--	--	6
New York	1	--	12	--	--	--	13
North Carolina	--	--	43	--	--	2	45
North Dakota	--	--	4	--	--	--	4
Ohio	--	--	68	24	--	--	92
Oklahoma	--	--	14	--	--	--	14
Oregon	--	--	14	--	--	--	14
Pennsylvania	--	--	33	33	--	1	67
Puerto Rico	--	--	2	--	--	--	2
South Carolina	--	--	34	--	1	13	48
South Dakota	--	2	4	--	--	--	6
Tennessee	18	1	17	--	1	--	37
Texas	1	7	81	4	3	1	97
Utah	--	2	17	9	2	3	33
Virginia	--	--	27	--	--	--	27
Washington	--	--	11	2	--	--	13
West Virginia	--	--	8	4	--	--	12
Wisconsin	--	--	1	--	--	--	1
Wyoming	--	55	4	--	--	--	59
Total	30	97	767	160	23	102	1,179

DOMESTIC PRODUCTION, PRICES, AND FOREIGN TRADE, BY TYPE OF CLAY

KAOLIN

Domestic production of kaolin in 1977 increased 6%, and the value increased 7%. The average unit value for all grades of kaolin in 1977 was $46.82 per ton, $0.65 higher than in 1976. Kaolin was produced at mines in 14 States. Two States, Georgia (77%) and South Carolina (11%), accounted for 88% of the total U.S. production in 1977. Alabama ranked third; North Carolina, fourth; and Arkansas, fifth. Output in 1977 increased in Alabama, Arkansas, Florida, Georgia, Minnesota, Missouri, Nevada, North Carolina, Pennsylvania, South Carolina, and Texas but declined in California, Idaho, and Utah.

Kaolin is defined as a white, claylike material approximating the mineral kaolinite. It has a specific gravity of 2.6 and a fusion point of 1,785°C. The other kaolin-group minerals, such as halloysite and dickite, are encompassed.

In 1977, Thiele Kaolin Co. completed the expansion of its Reedy Creek plant near Wrens, Ga., to include production of slurry kaolin. Anglo-American Clay Corp., a subsidiary of English China Clays Co. (ECC), also completed an enlargement of its Georgia flotation facility, which produces high-brightness coating-quality clays. Anglo-American also planned to produce calcined kaolins by scheduling a new Georgia facility for completion in 1979. A new calciner was brought onstream by Engelhard Minerals and Chemicals Corp. at McIntyre, Ga.[2] Calcined or dehydroxylated kaolins are finding increasing uses as an extender and replacement for TiO_2 pigment in paints and in a kaolin-based petroleum-cracking catalyst.

High-gradient magnetic separators (HGMS) continue making inroads into kaolin processing. Georgia Kaolin Co. installed a second magnet at its American Industrial Clay Co. facility near Sandersville, Ga., and ordered another for its Dry Branch, Ga., operation. Engelhard Minerals ordered a second magnet for its McIntyre facility for late 1978 startup. There are now eight production magnets installed in the Georgia kaolin operation and two in England.[3]

Agreement was also reached in 1977 for Nord Resources Corp. to buy the Twiggs County waterwashed paper-grade kaolin operation in Georgia from Cyprus Industrial Minerals Co.[4] The sale included plant, land, building, machinery, equipment, kaolin leases, and working capital. The sale excluded the Sandersville, and Jeffersonville, Ga., and Aiken, S.C. airfloat operations of Cyprus.

Four unnamed domestic alumina producers were reportedly acquiring claims in the kaolin belt of Georgia, between Macon and Augusta.[5] Exploration and interest were reported to be on the high-alumina "gray" kaolins, which are unsuitable for most of the conventional filler and extender kaolin uses.

Exports of kaolin, as reported by the U.S. Department of Commerce, increased from 839,000 tons valued at $57.6 million in 1976 to 951,670 tons valued at $71.9 million in 1977. The tonnage of kaolin exported in 1977 increased 13%, while the value rose 25% over that shipped in 1976. The unit value of kaolin exported was attributed to both the greater percentage of the higher quality paper-coating grades shipped and higher prices.

Kaolin, including calcined, was exported to 66 countries. The major recipients were Japan, 33%; Canada and Italy, 16% each; the Federal Republic of Germany, 10%; Mexico, 5%; and the remaining countries, 20%. Exports increased to 46 countries and decreased to 20 countries. Kaolin producers reported the end use for their exports as follows: Paper coating, 57%; foundry sand, 23%; rubber, 5%; and others, including adhesives, ceramics, paint, paper filling, and plastics, 15%.

Kaolin imports in 1977 decreased from 23,106 tons valued at $836,000 in 1976 to 19,663 tons valued at $874,742. The United Kingdom supplied 95%; Canada, 4%; and three other countries, 1%.

Kaolin prices quoted in the trade journals in 1977, remained unchanged from 1976. Chemical Marketing Reporter, December 26, 1977, quoted prices as follows:

Waterwashed, fully calcined, bulk carload lots, f.o.b. Georgia, per ton	$145.00-$182.50
Paper-grade, uncalcined, same basis, per ton:	
No. 1 coating	61.50
No. 2 coating	47.00
No. 3 coating	43.00- 46.00
Filler, general purpose, same basis, per ton	30.00- 31.00
Delaminated, waterwashed, uncalcined, paint-grade, 1-micrometer average, same basis, per ton	115.00
Dry-ground, air-floated, soft, same basis, per ton	20.00
National Formulary, powder, 50-pound bags, 5,000-pound lots, works, per pound	.07
National Formulary, colloidal, 150-pound drums, works, per pound	.36

The average unit value reported by domestic kaolin producers was $46.82 per ton, an increase of $0.65 above the 1976 value.

Table 4.—Kaolin sold or used by producers in the United States, by State

State	1976 Short tons	1976 Value	1977 Short tons	1977 Value
Alabama	134,408	$3,601,617	330,298	$13,393,459
Arkansas	48,486	2,160,519	79,678	4,214,770
California	128,808	5,605,286	68,950	1,357,043
Florida	24,550	1,032,759	27,370	W
Georgia	4,924,648	250,864,949	4,983,610	261,864,326
Idaho	W	W	W	W
Missouri	67,519	1,067,600	69,068	1,172,775
Nevada	W	W	W	W
South Carolina	623,222	13,180,173	723,535	15,178,925
Other States[1]	176,119	5,390,466	206,049	6,609,336
Total	6,127,760	282,903,369	6,488,558	303,790,634

W Withheld to avoid disclosing company proprietary data; included with "Other States."
[1]Includes Minnesota, North Carolina, Pennsylvania, Texas, Utah, and data indicated by symbol W.

Table 5.—Kaolin sold or used by producers in the United States, by kind

Kind	1976 Short tons	1976 Value	1977 Short tons	1977 Value
Airfloat	1,252,433	$28,642,768	1,401,550	$35,778,431
Calcined[1]	1,067,931	75,034,960	1,127,980	78,999,878
Delaminated	396,444	27,494,005	420,133	28,960,143
Unprocessed	624,629	6,992,100	776,035	5,446,971
Waterwashed	2,786,323	144,739,536	2,762,860	154,605,211
Total	6,127,760	282,903,369	6,488,558	303,790,634

[1]Includes both low-temperature filler and high-temperature refractory grades.

Table 6.—Calcined kaolin sold or used by producers in the United States in 1977, by kind

State	High temperature Short tons	High temperature Value	Low temperature Short tons	Low temperature Value
Georgia	443,824	$26,455,984	212,234	$31,212,568
Other States	[1]416,811	[1]18,227,670	[2]55,111	[2]3,103,656
Total	860,635	44,683,654	267,345	34,316,224

[1]Includes Alabama, Arkansas, and California.
[2]Includes Idaho, Pennsylvania, and Texas.

Table 7.—Georgia kaolin sold or used by producers, by kind

Kind	1976 Short tons	1976 Value	1977 Short tons	1977 Value
Airfloat	746,037	$14,754,411	882,228	$20,709,493
Calcined[1]	787,158	62,089,465	656,058	57,668,552
Delaminated	396,444	27,494,005	420,133	28,960,143
Unprocessed	256,740	3,852,894	308,087	1,077,116
Waterwashed	2,738,269	142,674,174	2,717,104	153,449,022
Total	4,924,648	250,864,949	4,983,610	261,864,326

[1]Includes both low temperature filler and high-temperature refractory grades.

Table 8.—Georgia kaolin sold or used by producers, by kind and use

(Short tons)

Use	1976 Airfloat	1976 Un-processed	1976 Water-washed[1]	1976 Total	1977 Airfloat	1977 Un-processed	1977 Water-washed[1]	1977 Total
Domestic:								
Adhesives	46,091	--	10,214	56,305	38,582	--	18,998	57,580
Alum (aluminum sulfate) and other chemicals	52,982	140,426	49,407	242,815	243	214,941	20,831	236,015
Animal feed	W	--	W	7,598	W	--	--	W
Asphalt tile and linoleum	W	--	--	W	36,128	--	--	36,128
Catalysts (oil refining)	W	W	40,965	91,579	W	--	W	87,046
Cement, portland	--	W	--	W	--	--	--	--
China and dinnerware; crockery and earthenware	r64,700	--	r12,762	r77,462	18,459	--	18,121	36,580
Electrical porcelain	2,564	--	1,469	4,033	W	--	W	23,147
Face brick	--	38,511	22	38,533	W	31,980	W	32,412
Fiberglass and mineral wool	r86,314	--	--	r86,314	58,221	--	--	58,221
Firebrick, block, shapes	4,168	5,760	185	10,113	14,177	13,904	23,457	51,538
Floor and wall tile, ceramic	--	--	3,359	3,359	W	--	W	8,725
Flue linings and high-alumina brick	51,100	8,696	--	59,796	39,327	14,168	--	53,495
Foundry sand	861	--	24	885	1,798	--	100	1,898
Glazes, glass, enamels, hobby ceramics	W	--	--	W	11,590	W	--	W
Grogs and crudes, refractory	--	423,770	--	423,770	3,024	295,418	--	298,442
Ink	W	--	W	10,555	W	--	W	12,000
Kiln furniture, mortar, cement	W	17,987	W	19,030	13,745	W	--	W
Medical, pharmaceutical, cosmetic	502	--	1,567	2,069	W	--	W	1,842
Paint	78,985	--	92,543	171,528	12,413	--	98,754	111,167
Paper coating	14,168	--	1,570,235	1,584,403	63,918	--	1,748,921	1,812,839
Paper filling	92,635	--	733,470	826,105	144,690	--	650,942	795,632
Plastics	4,794	--	54,680	59,474	3,212	--	55,096	58,308
Pottery	--	--	W	W	5,921	--	--	5,921
Roofing granules	32,993	--	--	32,993	W	--	W	19,590
Roofing and structural tile	W	--	--	W	35,561	--	--	35,561
Rubber	72,489	--	8,861	81,350	73,204	--	9,037	82,241
Sanitary ware	40,511	W	W	65,377	108,616	W	W	142,119
Miscellaneous airfloat: Fertilizer, oil and grease absorbents, pesticides and related products, unknown	r9,975	--	--	r9,975	15,725	--	--	15,725
Miscellaneous, unprocessed: Mortar and cement, sewer pipe (1976), data indicated by symbol W	--	r40,757	--	r [2]113,408	--	31,951	--	[2]22,039
Miscellaneous, waterwashed: Gypsum products; mineral oil filtering, clarifying, and decolorizing (1976); pesticides and related products (1977); refractory mortar and cement (1976); waterproofing and sealing; textiles (1976); wire and cable; agriculture (1976); unknown	--	--	r87,761	r87,761	--	--	101,006	101,006
Undistributed	r74,153	--	r93,174	([2])	85,632	--	65,406	([2])
Total	729,985	r675,907	r2,760,698	4,166,590	784,186	602,362	2,810,669	4,197,217

Exports:								
Foundry sand	--	r116,525	--	116,525	--	148,406	--	148,406
Paint	--	--	16,038	16,038	--	--	30,714	30,714
Paper coating	6,730	--	298,465	305,195	--	--	507,517	507,517
Paper filling	402	--	230,271	230,673	8,423	--	31,031	39,454
Plastics	--	--	18,601	18,601	--	--	20,348	20,348
Refractories	8,400	--	1,279	9,679	8,300	--	1,739	10,039
Rubber	112	--	40,337	40,449	198	--	862	1,060
Undistributed	408	4,603	15,887	20,898	152	3,850	24,853	28,855
Total	16,052	r121,128	r620,878	758,058	17,073	152,256	617,064	786,393
Grand total	746,037	r797,035	r3,381,576	4,924,648	801,259	754,618	3,427,733	4,983,610

[r]Revised. W Withheld to avoid disclosing company proprietary data; included with "Undistributed."
[1]Includes calcined and delaminated.
[2]Incomplete total; remainder included in totals for specific uses.

Table 9.—South Carolina kaolin sold or used by producers, by kind

Kind	1976		1977	
	Short tons	Value	Short tons	Value
Airfloat	445,881	$12,084,315	486,967	$13,736,001
Unprocessed	177,341	1,095,858	236,568	1,442,924
Total	623,222	13,180,173	723,535	15,178,925

Table 10.—South Carolina kaolin sold or used by producers, by kind and use

(Short tons)

Kind and use	1976	1977
Airfloat:		
Adhesives	19,329	18,814
Animal feed and pet absorbent	28,542	23,410
Ceramics[1]	12,560	18,409
Fertilizers	9,150	12,170
Fiberglass	53,369	77,139
Paint	736	1,644
Paper filling	3,287	4,389
Pesticides and related products	25,136	16,181
Plastics	2,247	11,614
Rubber	215,941	237,377
Other refractories[2]	1,911	6,541
Other uses[3]	6,754	6,023
Exports[4]	66,919	55,256
Total	445,881	488,967
Unprocessed: Face brick, firebrick, block, and shapes, and high-alumina refractories (1976)	177,341	234,568
Grand total	623,222	723,535

[1]Includes floor and wall tile (1976), pottery (1977), quarry tile (1977), roofing granules, sanitary ware, and miscellaneous.

[2]Includes high-alumina refractories, refractory mortar and cement, foundry sand (1977), refractory grogs and crudes (1976), and miscellaneous.

[3]Includes common brick, crockery and other earthenware, drilling mud (1976), linoleum (1976), asphalt and roof tile, and ink.

[4]Includes ceramics, pesticides and related products, rubber, and miscellaneous.

Table 11.—Kaolin sold or used by producers in the United States, by kind and use

(Short tons)

Use	1976				1977			
	Airfloat	Unprocessed[1]	Water-washed[2]	Total	Airfloat	Unprocessed[1]	Water-washed[2]	Total
Domestic:								
Adhesives	65,420	--	10,566	75,986	57,396	W	19,390	W
Alum (aluminum sulfate) and other chemicals	W	252,519	W	252,519	283	288,885	21,652	310,820
Animal feed	30,697	--	9,257	39,954	27,278	--	4,403	31,681
Brick, common and face	299	225,454	22	225,775	1,895	338,235	30	340,160
Catalysts (oil and gas refining)	W	43,449	W	43,449	37,210	2,485	49,836	89,531
Cement, portland	W	W	W	17,170	--	W	W	19,862
Ceramic (hobby and artware)	W	W	--	2,062	W	W	--	12,038
China and dinnerware	7,031	--	14,164	21,195	7,305	4,876	16,061	28,242
Crockery and other earthenware	64,625	3,059	1,670	69,354	18,804	16,000	2,060	36,864
Electrical porcelain	11,947	--	1,469	13,416	23,751	7,315	1,998	33,064
Fertilizers[3]	9,399	W	W	20,186	12,907	--	10,652	23,559
Fiberglass; mineral wool and other insulation	163,394	--	r7,025	r170,419	137,681	--	7,322	145,003
Firebrick, block, shapes	4,186	9,573	185	13,944	14,177	314,066	--	328,243
Floor and wall tile, ceramic	8,299	--	3,359	11,658	8,185	--	7,382	15,567
Flue linings and high-alumina brick	51,300	20,012	--	71,312	43,327	89,561	--	132,888
Foundry sand	W	W	W	5,503	4,974	--	100	5,074
Glazes, glass, enamels	W	--	W	3,937	1,058	--	3,276	4,334
Grogs and crudes, refractory	--	r572,708	--	572,708	3,024	296,787	3,127	302,938
Gypsum products	1,227	--	3,574	4,801	1,669	7,112	149	8,930
Ink	W	--	W	11,211	1,566	--	11,142	12,708
Kiln furniture	1,646	--	--	1,646	613	--	--	613
Linoleum and asphalt tile	r32,088	--	--	r32,088	36,128	--	--	36,128
Medical, pharmaceutical, cosmetic	502	--	1,567	2,069	1,491	--	351	1,842
Mortar and cement, refractory	1,711	21,107	592	23,410	15,513	19,623	--	35,136
Paint	79,721	22,900	108,681	211,302	14,077	110	148,669	162,856
Paper coating	14,168	--	1,570,235	1,584,403	65,470	--	1,748,921	1,814,391
Paper filling	92,635	--	826,105	918,740	149,079	--	650,942	800,021
Pesticides and related products	27,070	6,561	--	33,631	19,401	2,376	535	22,312
Plastics	7,041	--	54,680	61,721	14,826	--	55,096	69,922
Pottery	W	--	W	41,772	10,214	8,755	--	18,969
Roofing granules	33,403	--	--	33,403	20,569	--	21	20,590
Roofing tile and structural tile	1,125	--	--	1,125	36,639	--	--	36,639
Rubber	288,430	--	15,189	303,619	310,625	--	15,994	326,619
Sanitary ware	53,172	W	W	81,851	123,358	15,400	21,898	160,656
Textiles	--	--	1,480	1,480	--	--	--	--
Waterproofing and sealing	W	--	W	197	--	--	130	130
Miscellaneous	r115,710	411	r231,847	r 4 226,650	108,728	4,876	44,806	4 203,296
Total	1,166,246	r1,177,753	r2,861,667	5,205,666	1,329,221	1,416,462	2,845,943	5,591,626

See footnotes at end of table.

Table 11.—Kaolin sold or used by producers in the United States, by kind and use —Continued

(Short tons)

Use	1976				1977			
	Airfloat	Un-processed[1]	Water-washed[2]	Total	Airfloat	Un-processed[1]	Water-washed[2]	Total
Exports:								
Ceramics	W	W	--	11,253	307	3,910	3,284	7,501
Chemical manufacturing	--	--	--	--	969	--	--	969
Foundry sand; grogs, crudes, other refractories	8,400	--	95,180	103,580	8,300	198,983	3,101	210,384
Paint	--	--	16,038	16,038	56	--	30,714	30,770
Paper coating	6,730	--	298,465	305,195	--	--	507,517	507,517
Paper filling	402	--	230,271	230,673	8,723	--	31,031	39,754
Plastics	--	--	18,601	18,601	300	--	20,348	20,648
Rubber	45,773	14,981	25,356	86,110	41,483	--	862	42,345
Other	24,882	4,603	132,412	[4]150,644	12,191	--	24,853	37,044
Total	86,187	19,584	816,323	922,094	72,329	202,893	621,710	896,932
Grand total	1,252,433	[r]1,197,337	[r]3,677,990	6,127,760	1,401,550	[5]1,619,355	[6]3,467,653	6,488,558

[r]Revised. W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous."
[1]Includes high-temperature calcined and delaminated.
[2]Includes low-temperature calcined and delaminated.
[3]Includes soil conditioners and mulches.
[4]Incomplete total; remainder included with totals for specific uses.
[5]Includes 843,320 short tons of high-temperature calcined and delaminated.
[6]Includes 267,345 short tons of low-temperature calcined and delaminated.

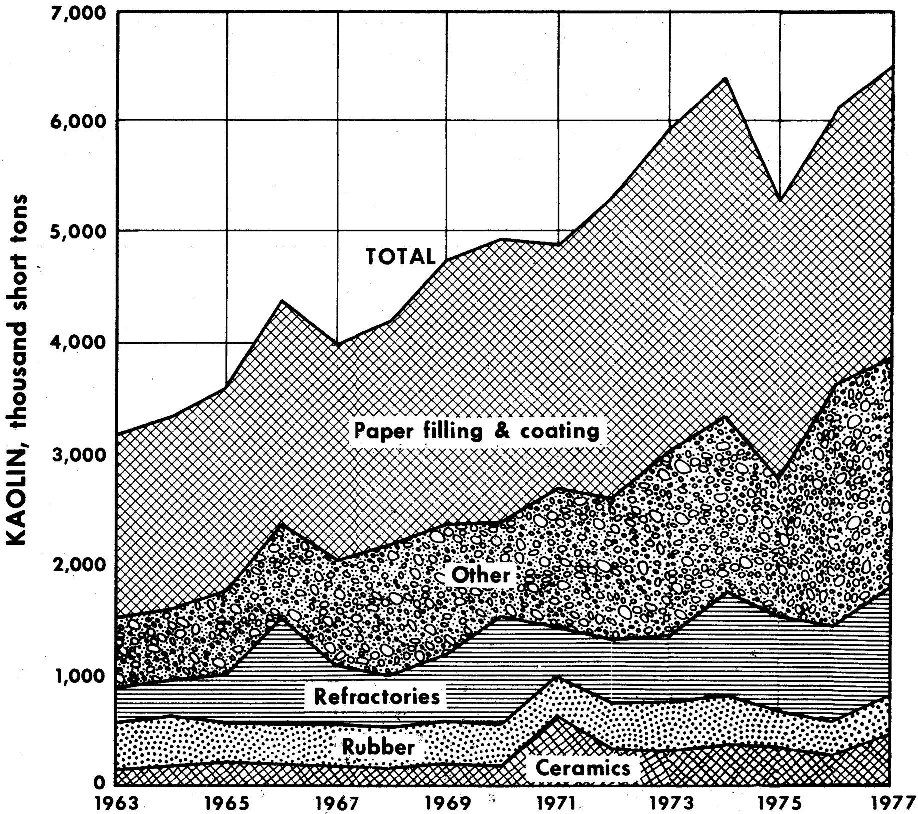


Figure 1.—Kaolin sold or used by domestic producers for specified uses.

BALL CLAY

Production and value reported for domestically mined ball clay in 1977 increased 12% and 21% respectively. Tennessee provided 70% of the Nation's output, followed in order by Kentucky, Mississippi, Texas, Maryland, New York,[6] California, and Arizona. Production in Arizona, Tennessee, and Texas increased over that reported in 1976, but California, Kentucky, Maryland, Mississippi, and New York production decreased.

Ball clay is defined as a plastic, white-firing clay used principally for bonding in ceramic ware. The clays are of sedimentary origin and consist mainly of the clay mineral kaolinite and sericite micas.

In 1977, Kentucky-Tennessee Clay Co., Inc., Mayfield, Ky., purchased Bell Clay Co. from NL Industries Inc.[7] Bell Clay Co., a ball clay producer, has plants and offices in Gleason, Tenn., and holdings in Weakley and other surrounding counties in western Tennessee. The acquired plants and equipment will be operated by Kentucky-Tennessee, another ball clay producer, in conjunction with their Gleason operations.

The average unit value for ball clay reported by domestic producers rose in 1977 to $20.83 per ton, an increase of $1.60 per ton. Chemical Marketing Reporter, December 27, 1976, listed ball clay prices unchanged from 1976 as follows:

Domestic, air-floated, bags, carload lots, Tennessee, per ton	$18.00-$22.00
Domestic, crushed, moisture-repellent, bulk, carload lots, Tennessee, per ton	8.00- 11.25
Imported, air-floated, bags, carload lots, Atlantic ports, per ton	70.00
Imported, lump, bulk, Great Lakes, per ton	40.50

Ball clay exports in 1977 amounted to 117,333 short tons valued at $2.7 million, compared with 157,000 tons worth $3.6 million in 1976. The tonnage and value exported decreased 25% compared with those of 1976. Unit value increased $0.32 per ton. These shipments were made to 11 countries. The major recipients were Mexico, 62% and Canada, 35%; nine countries accounted for the remaining 3%.

Ball clay imports, from Canada and the United Kingdom, increased from 10,644 tons valued at $342,000 in 1976 to 11,338 tons valued at $432,340.

Table 12.—Ball clay sold or used by producers in the United States, by type and State

Year and State	Airfloat		Unprocessed		Total	
	Short tons	Value	Short tons	Value	Short tons	Value
1976						
Tennessee	295,777	$6,290,301	217,968	$3,706,073	513,745	$9,996,374
Texas	549	9,300	15,224	99,900	15,773	109,200
Other States	[1]194,409	[1]4,391,663	[2]76,944	[2]907,140	271,353	5,298,803
Total	490,735	10,691,264	310,136	4,713,113	800,871	15,404,377
1977						
Tennessee	428,610	9,400,964	199,818	3,110,204	628,428	12,511,168
Texas	--	--	W	W	W	W
Other States	[1]171,996	[1]4,954,518	[2]93,803	[2]1,164,805	265,799	6,119,323
Total	600,606	14,355,482	293,621	4,275,009	894,227	18,630,491

W Withheld to avoid disclosing company proprietary data; included with "Other States."
[1]Includes Kentucky, Maryland, and Mississippi.
[2]Includes Arizona, California, Kentucky, Mississippi, and New York.

Table 13.—Ball clay sold or used by producers in the United States, by kind and use

(Short tons)

Use	1976			1977		
	Air-float	Un-processed	Total	Air-float	Un-processed	Total
Adhesives	782	--	782	200	--	200
Animal feed	W	--	W	W	--	W
Brick, face	--	W	W	--	W	W
China and dinnerware	50,664	--	50,664	W	W	42,114
Crockery and other earthenware	2,650	1,216	3,866	6,665	--	6,665
Drilling mud	W	--	W	W	--	W
Electrical porcelain	W	W	29,470	13,489	5,781	19,270
Fiberglass and catalysts (oil refining)	--	--	--	123,353	--	123,353
Firebrick, block, shapes	--	5,738	5,738	W	W	7,186
Glazes, glass, enamels	W	W	2,803	W	W	1,332
Grogs and crudes, high-alumina; mortar and cement refractories	W	W	20,700	60,181	12,000	72,181
Kiln furniture	W	W	7,476	W	W	6,400
Paper coating and filling	9,290	--	9,290	82,091	--	82,091
Pesticides and related products	W	--	W	--	--	--
Pottery	174,142	87,110	261,252	113,154	146,453	259,607
Rubber	W	--	W	W	--	W
Sanitary ware	14,624	63,749	78,373	--	74,345	74,345
Sewer pipe	--	465	465	--	--	--
Tile:						
Floor and wall	68,915	22,473	91,388	33,063	17,997	51,060
Quarry	--	992	992	--	--	--
Other	326	2,494	2,820	3,240	--	3,240
Miscellaneous	[r]77,942	110,486	[r] [1]127,979	105,335	3,146	[1]51,449
Exports	91,400	15,413	106,813	59,835	33,899	93,734
Total	490,735	310,136	800,871	600,606	293,621	894,227

[r]Revised. W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous."
[1]Incomplete total; remainder included with total for each specific use.

FIRE CLAY

Fire clay sold or used by domestic producers in 1977 was reported at 2,965,607 tons valued at $37.0 million. Fire clay is defined as detrital material, either plastic or rock-like, containing low percentages of iron oxide, lime, magnesia, and alkalies to enable the material to withstand temperatures of 1,500° C or higher. Fire clay is basically kaolinite but usually contains other materials such as diaspore, ball clay, bauxite clay, and shale. Fire clays commonly occur as underclay below coal seams and thus are generally used for refractories. Some fire clay was previously reported in other end uses.

Fire clay production was reported in 1977 from mines in 17 States. The first four States in rank, Missouri, Ohio, Pennsylvania, and Alabama, accounted for 82% of the total domestic output.

Exports of fire clay increased from 296,000 tons worth $12.9 million in 1976 to 307,383 tons valued at $11.6 million in 1977. Fire clay exports increased 4% in tonnage and decreased 10% in value. The price of exported fire clay decreased by $5.67 to $37.89 per ton, indicating a larger percentage of standard quality shipped.

Fire clay was exported to 42 countries, with Canada, the Federal Republic of Germany, and Mexico receiving 36%, 22%, and 17%, respectively. No imports of fire clay were reported during 1977.

There are no price quotations in domestic journals for fire clay, but the per-ton value reported by producers ranged from $3 to about $50. The reported average unit value for fire clay produced in the United States increased 4% from $11.97 per ton in 1976 to $12.49 in 1977.

Table 14.—Fire clay sold or used by producers in the United States, by State[1]

State	1976		1977	
	Short tons	Value	Short tons	Value
Alabama	372,971	$4,049,077	266,534	$3,024,438
California	86,189	383,648	--	--
Colorado	29,317	421,722	34,036	188,359
Illinois	50,883	381,752	36,543	327,363
Indiana	2,065	20,780	1,205	20,351
Kentucky	85,814	580,457	96,533	622,081
Missouri	809,273	11,723,406	871,516	12,529,415
Montana	1,266	5,792	730	3,402
New Jersey	11,549	80,712	16,088	114,128
Ohio	700,078	5,330,220	725,689	6,016,198
Pennsylvania	838,757	11,928,949	561,206	8,773,523
Texas	54,335	259,580	56,097	277,748
Utah	4,590	26,889	14,134	87,200
Other States[2]	[r]305,163	[r]4,925,988	285,296	5,068,207
Total	3,352,250	40,118,972	2,965,607	37,052,413

[r]Revised.
[1]Refractory uses only.
[2]Includes Idaho, New Mexico, Washington, and West Virginia.

BENTONITE

Bentonite production in 1977 increased 6% in tonnage and 14% in value over that of 1976. A general increase in domestic consumption, particularly in foundry sand and drilling mud, and in exports was noted, along with a large increase in animal feed and a slight increase in waterproofing and sealing.

Bentonite was produced in 14 States. Increased bentonite production was reported for Alabama, Arizona, California, Colorado, Idaho, Montana, Nevada, Texas, Utah, and Wyoming. Production decreased in Kansas, Mississippi, South Dakota, and Tennessee.

Generally, the high-swelling or sodium bentonites are produced chiefly in Wyoming, Montana, California, and South Dakota. The calcium or low-swelling bentonites are produced in the other States.

Federal Bentonite Div.[8] started developing a sodium bentonite property near Glasgow, Mont.[9] In another move, Federal bought certain assets of the Hallett Minerals Co., in particular its Vananda mining, crushing, and drying operation at Forsyth, Mont., and its milling facilities at Burnett, Minn. The Glasgow project, scheduled for completion in early 1978, will include the necessary facilities to feed its newly acquired mill in Minnesota.

American Colloid Co., which operates bentonite plants at Upton and Lowell in Wyoming and at Belle Fourche, S.D., announced plans for a new 1-million-ton-per-year bentonite operation in Carter County, Mont.[10] In another bentonite-related move, Gulf Resources and Chemical Corp. acquired options to purchase Industrial Mineral Ventures, Inc. (IMV) of Golden, Colo. The options, at Gulf's discretion, were up to 2 years and included a credit agreement for IMV. IMV has large reserves of bentonite, sepiolite, saponite, calcium carbonate, and hectorite in a mixed deposit on the California-Nevada border. It presently is operating a sepiolite-processing plant in the area.

Industrywide improvements continued to be made in environmental controls systems and in automating, bagging, and handling procedures. Some experimental work was also underway exploring the practicality of switching from oil and gas firing in dryers to coal burning.

On December 26, 1977, Chemical Marketing Reporter quoted bentonite prices unchanged. Domestic material, 200-mesh, bags, carload lots, f.o.b. mines, was priced from $15.50 to $16.00 per ton; and imported Italian, white, high-gel material, bags, 5-ton lots, ex-warehouse at $337.60 per ton ($0.1688 per pound). The average unit value reported by domestic producers for bentonite sold or used in 1977 was $17.84, an increase of $1.23 from the $16.61 average of 1976. Per-ton values reported in the various producing States ranged from $4 to $41, but the average value reported by the larger producers was near the Montana average figure of $17.76.

Bentonite exports in 1977 increased from 787,000 tons in 1976 to 787,767 tons; value decreased from $50.4 million in 1976 to $45.8 million in 1977. Although the tonnage exported increased slightly above that shipped in 1976, the value decreased 9%. This decrease in value was the result of a decrease in the unit value of exported bentonite from $64.04 per ton in 1976 to $58.09 per ton in 1977. This decrease in per-ton value of exports was attributed to the return to a larger percentage of the lower cost pelletizing grades shipped. Exports in recent years included increasing percentages of higher cost drilling muds and foundry sands. Domestic bentonite producers were facing increased competition in foreign markets. Bentonite from the Greek Island of Milos was being blended with the U.S. clay for pelletizing Canadian taconite ores on a large scale.

Bentonite was exported to 84 countries. The major recipients were Canada, 48%; the United Kingdom, 12%; the Federal

Table 15.—Bentonite sold or used by producers in the United States, by type and State

State	Nonswelling		Swelling		Total	
	Short tons	Value	Short tons	Value	Short tons	Value
1976						
Arizona	W	W	W	W	27,921	$361,386
California	28,902	$747,032	58,822	$1,900,980	87,724	2,648,012
Colorado	1,200	12,000	W	W	W	W
Mississippi	373,457	6,739,559	--	--	373,457	6,739,559
Montana	--	--	158,695	2,304,871	158,695	2,304,871
Nevada	--	--	7,512	174,300	7,512	174,300
Oregon	--	--	1,814	29,024	1,814	29,024
Texas	39,414	850,344	--	--	39,414	850,344
Utah	--	--	2,000	8,000	2,000	8,000
Wyoming	--	--	2,495,797	39,514,743	2,495,797	39,514,743
Other States	[1]154,130	[1]2,254,203	[2]198,638	[2]3,929,505	[3]326,047	[3]5,834,322
Total	597,103	10,603,138	2,923,278	47,861,423	3,520,381	58,464,561
1977						
Arizona	W	W	W	W	33,322	443,524
California	33,545	461,290	61,724	2,220,692	95,269	2,681,982
Colorado	850	12,000	W	W	W	W
Mississippi	340,130	6,388,789	--	--	340,130	6,388,789
Montana	--	--	195,262	3,468,329	195,262	3,468,329
Nevada	--	--	9,635	157,950	9,635	157,950
Texas	39,592	973,981	--	--	39,592	973,981
Utah	880	12,320	6,000	24,000	6,880	36,320
Wyoming	--	--	2,761,838	47,762,228	2,761,838	47,762,228
Other States	[1]176,154	[1]3,044,380	[2]120,877	[2]2,306,415	[3]264,559	[3]4,919,271
Total	591,151	10,892,760	3,155,336	55,939,614	3,746,487	66,832,374

W Withheld to avoid disclosing company proprietary data; included with "Other States."
[1]Includes Alabama, Idaho (1977), and data indicated by symbol W.
[2]Includes Idaho, Kansas, South Dakota, Tennessee, and data indicated by symbol W.
[3]Incomplete total; remainder included with totals for specific States.

Republic of Germany, 6%; the Netherlands, 4%; and others, 30%. Domestic bentonite producers reported that the end uses of their exports were iron ore pelletizing, 36%; foundry sand, 33%; drilling mud, 27%; and others (including pet absorbent, waterproofing and sealing, and fertilizers), 4%.

Bentonite imports in 1977, including chemically activated material, totaled 2,514 tons valued at $362,000, compared with 2,945 tons valued at $466,000 in 1976. The 2,378 tons of chemically activated bentonite was imported from six countries, with Mexico supplying 49%; Canada, 38%; Japan, 11%; and the Federal Republic of Germany, France, Brazil, and the United Kingdom the remaining 2%.

Table 16.—Bentonite sold or used by producers in the United States, by type and use

(Short tons)

Use	1976			1977		
	Non-swelling	Swelling	Total	Non-swelling	Swelling	Total
Domestic:						
Adhesives	W	W	1,583	W	4,922	W
Animal feed	--	156,652	156,652	84,704	110,222	194,926
Brick, face	--	--	--	W	W	3,564
Catalysts (oil refining)	2,208	9	2,217	12,133	--	12,133
Cement, portland	--	250	250	--	450	450
Drilling mud	23,451	950,099	973,550	22,205	1,037,962	1,060,167
Fertilizers	9,160	--	9,160	2,380	30	2,410
Filtering, clarifying, decolorizing:						
Animal oils and mineral oils and greases	32,638	3,969	36,607	72,275	33,037	105,312
Vegetable oils	158,334	--	158,334	65,038	--	65,038
Foundry sand	288,769	357,704	646,473	289,559	577,746	867,305
Glazes, glass, enamels	--	W	W	--	120	120
Gypsum products	--	470	470	--	303	303
Medical, pharmaceutical, cosmetic	--	1,533	1,533	--	4,498	4,498
Paint	W	W	3,570	--	16,516	16,516
Pelletizing (iron ore)	--	868,947	868,947	--	629,353	629,353
Pesticides and related products	3,556	50	3,606	1,740	3,260	5,000
Pet absorbent	--	35,416	35,416	5	25,496	25,501
Tile:						
Floor and wall	477	--	477	--	--	--
Roofing	15,470	--	15,470	--	--	--
Other	31,052	1,925	32,977	91	--	91
Waterproofing and sealing	2,402	63,389	65,791	18,589	59,752	78,341
Miscellaneous	187	13,766	[1]8,800	5,510	103,795	[1]110,663
Total	567,704	2,454,179	3,021,883	574,229	2,607,462	3,181,691
Exports:						
Drilling mud	--	184,572	184,572	200	150,771	150,971
Foundry sand	16,331	153,749	170,080	16,538	168,683	185,221
Pelletizing (iron ore)	--	129,596	129,596	--	203,501	203,501
Other	13,068	1,182	14,250	184	24,919	25,103
Total	29,399	469,099	498,498	16,922	547,874	564,796
Grand total	597,103	2,923,278	3,520,381	591,151	3,155,336	3,746,487

W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous."
[1]Incomplete total; remainder included with total for each specific use.

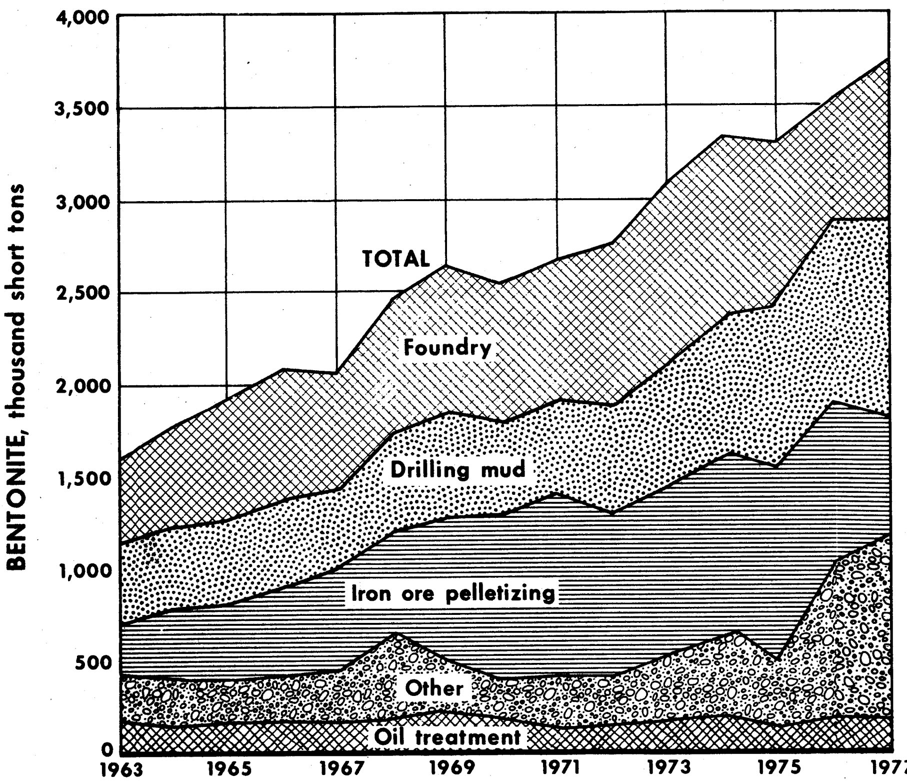


Figure 2.—Bentonite sold or used by domestic producers for specified uses.

FULLER'S EARTH

Production of fuller's earth in 1977 increased 6% in quantity and 13% in value. The unit value assigned by domestic producers increased $2.42 in 1977 to $41.51 per ton. This increase in value was due to large increases in unit value by Florida, Georgia, Illinois, Mississippi, and South Carolina producers.

Fuller's earth production was reported from operations in 10 States. The two top producing States, Georgia (40%) and Florida (30%), accounted for 70% of the domestic production. The other eight States accounted for the remaining 30%. All States except Illinois and Tennessee showed slight gains in production. Missouri reported production for 1977 but not 1976.

Fuller's earth is defined as a nonplastic clay or claylike material, usually high in magnesia, which has adequate decolorizing and purifying properties.

Production from the region that includes Attapulgus (Decatur County), Ga., and Quincy (Gadsden County), Fla., is composed predominantly of the lath-shaped amphibole clay mineral attapulgite. Most of the fuller's earth produced in other areas of the United States contains varieties of montmorillonite.

Prices for fuller's earth were not publicly quoted in 1977, but the value per ton for attapulgite reported by producers ranged from $25 to over $55; montmorillonite prices ranged from $24 to $46.

The tonnage of fuller's earth exported to 35 countries increased in 1976 from 42,274 to 45,135 tons. The unit value of exported fuller's earth declined $2.68 to $61.80 per ton. The major recipients were Canada, 27%; the Netherlands and the United Kingdom, each 24%; and other countries, the remaining 25%.

Imports of fuller's earth in 1977 were 68 tons valued at $5,684 from Canada and the United Kingdom.

Table 17.—Fuller's earth sold or used by producers in the United States, by type and State

Year and State	Attapulgite		Montmorillonite		Total	
	Short tons	Value	Short tons	Value	Short tons	Value
1976						
Florida	412,832	$19,006,753	--	--	412,832	$19,006,753
Georgia	345,249	14,159,671	176,037	$3,755,858	521,286	17,915,529
Nevada	W	W	--	--	W	W
Utah	--	--	2,238	55,950	2,238	55,950
Other States	[1]24,140	[1]1,184,481	[2]381,086	[2]14,276,302	405,226	15,460,783
Total	782,221	34,350,905	559,361	18,088,110	1,341,582	52,439,015
1977						
Florida	433,795	22,055,305	--	--	433,795	22,055,305
Georgia	397,948	17,051,255	178,783	4,500,344	576,731	21,551,599
Nevada	W	W	--	--	W	W
Utah	--	--	W	W	W	W
Other States	[1]26,719	[1]1,107,773	[2]391,081	[2]14,579,237	417,800	15,687,010
Total	858,462	40,214,333	569,864	19,079,581	1,428,326	59,293,914

W Withheld to avoid disclosing company proprietary data; included with "Other States."
[1]Includes Texas and data indicated by symbol W.
[2]Includes Illinois, Mississippi, Missouri (1977), South Carolina, Tennessee, and data indicated by symbol W.

Table 18.—Fuller's earth sold or used by producers in the United States, by type and use

(Short tons)

Use	1976			1977		
	Attapulgite	Montmorillonite	Total	Attapulgite	Montmorillonite	Total
Domestic:						
Adhesives	3,278	--	3,278	7,235	--	7,235
Animal feed	202	--	202	251	--	251
Cement, portland	W	W	50,244	--	--	--
Drilling mud	74,824	5,478	80,302	98,995	--	98,995
Fertilizers	35,652	9,309	44,961	45,600	10,857	56,457
Filtering, clarifying, and decolorizing mineral oils and greases	22,674	2,113	24,787	26,226	--	26,226
Medical, pharmaceutical, cosmetic	51	--	51	72	--	72
Oil and grease absorbents	270,222	120,954	391,176	271,745	168,352	440,097
Paint	2,791	--	2,791	7,656	--	7,656
Paper filling	150	--	150	3,527	--	3,527
Pesticides and related products	154,180	50,839	205,019	137,885	57,295	195,180
Pet absorbent	127,588	294,722	422,310	200,803	196,066	396,869
Rubber	5	--	5	53	--	53
Miscellaneous	26,510	44,978	[1]21,244	14,300	62,468	76,768
Total	718,127	528,393	1,246,520	814,348	495,038	1,309,386
Exports:						
Drilling mud	457	--	457	958	--	958
Fertilizers	--	--	--	3,135	--	3,135
Oil and grease absorbents	31,923	141	32,064	5,906	39,669	45,575
Pet absorbent	23,218	22,830	46,048	17,603	33,739	51,342
Miscellaneous	8,496	7,997	16,493	16,512	1,418	17,930
Total	64,094	30,968	95,062	44,114	74,826	118,940
Grand total	782,221	559,361	1,341,582	858,462	569,864	1,428,326

W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous."
[1]Incomplete total; remainder included with total for each specific use.

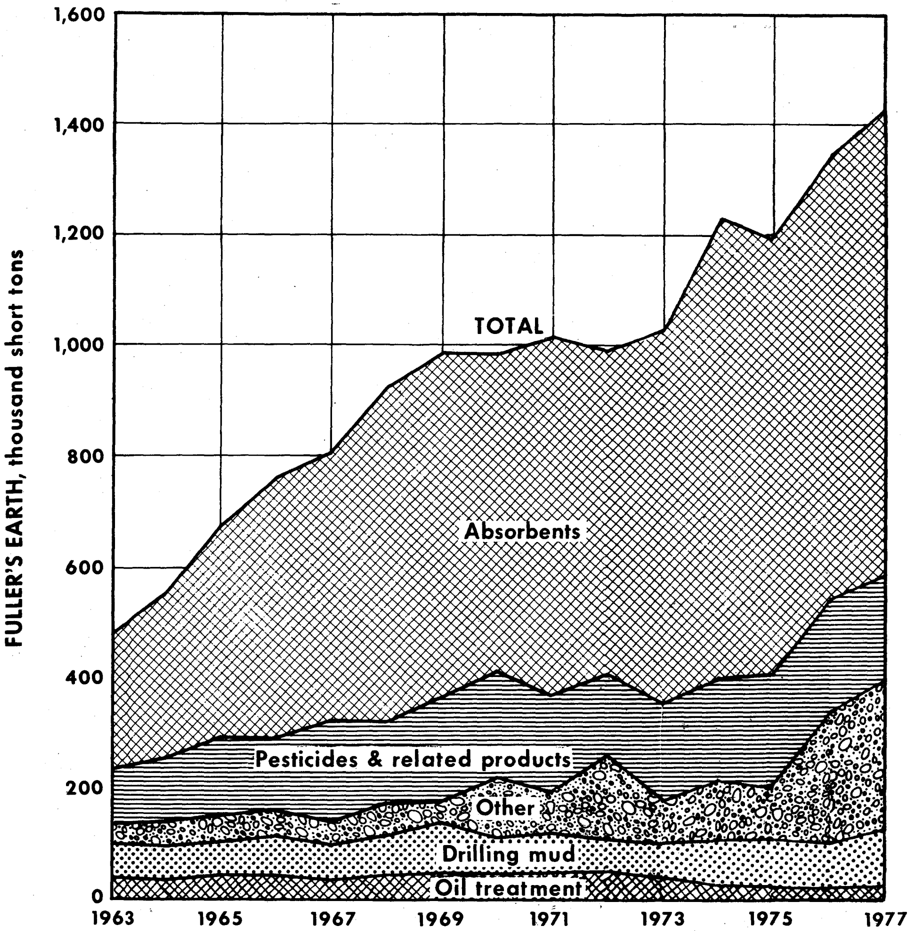


Figure 3.—Fuller's earth sold or used by domestic producers for specified uses.

COMMON CLAY

Domestic production of common clay and shale in 1977 totaled 37.9 million tons valued at $93.9 million. Common clay and shale represented 71% of the quantity and 16% of the value of the total clays in 1977. Domestic clays and shales are for the most part used by the producer in fabricating or manufacturing products. Less than 10% of the total clay and shale output was sold. The average unit value for all common clay and shale produced in the United States and Puerto Rico in 1977 was $2.48 per short ton, $0.36 more than in 1976. The range in unit value reported for the bulk of the output was from $1 to $6 per ton.

Common clay is defined as a clay or claylike material which is sufficiently plastic to permit ready mold and vitrification below 1,100°C. Shale is consolidated sedimentary rock composed chiefly of clay minerals that has been both laminated and indurated while buried under other sediments. These materials are used in the manufacture of structural clay products, such as brick and drain tile, portland cement clinker, and bloated lightweight aggregate.

In 1977, Susquehanna Brick Products, Inc., a manufacturer of face brick and other clay products in the New England area, was sold to K-F Brick Co. Inc. K-F is owned by the group that managed the Susquehanna brick business which included plants in Connecticut and Massachusetts. In another acquisition, Clayburn Ltd. of Canada purchased the manufacturing facilities of Lowell Brick Co., Everett, Wash., and will operate it as Clayburn, Inc.[11] The physical assets of the Major Brick Co., Henderson, Tex., were bought by Henderson Clay Products Inc., also in Henderson, and the Merry Companies Inc. expanded its Clay Division by acquiring Georgia-Carolina Brick and Tile Co., Augusta, Ga., and Guignard Brick Works, Lexington, S.C. Plans for new plants were announced by the Acme Brick Co. for Oklahoma City, Okla., and by Entrada Industries for its Interstate Brick Division.

Other expansions and/or modernizations were announced for 12 of Acme Brick's 14 plants; Jannock Corp.'s brickmaking subsidiary, Michigan Brick, Inc., at Corunna, Mich.; the Palmetto Brick Co. plant in Cheraw, S.C.; Wheeler Brick Co.'s first tunnel kiln in Jonesboro, Ark.; and the diversification of Humboldt Brick and Tile Co., Humboldt, Kans., into clay flower pot manufacturing.

The output of the energy-intensive common clay and shale industry was hindered again by shortages of fuel and labor. Construction rates increased in 1977. Industrywide attention was focusing on coal, sawdust, and woodchip firing, in the Northwest and Southeast, as a possible escape from the high cost and shortages of oil and gas.

Exports of common clay and shale are not collected by the U.S. Department of Commerce. Most countries have local deposits of either clays or shales that are adequate for manufacturing structural clay products, cement clinker, and lightweight aggregates, and thus have no need to import such materials.

Table 19.—Common clay and shale sold or used by producers in the United States, by State[1]

State	1976		1977	
	Short tons	Value	Short tons	Value
Alabama	1,731,341	$2,674,718	2,079,973	$5,566,910
Arkansas	998,033	1,235,755	908,413	1,192,165
California	1,992,487	4,928,352	2,411,653	8,138,769
Colorado	450,202	1,554,488	926,608	4,523,980
Connecticut	130,483	427,080	95,163	250,023
Delaware	11,241	7,900	10,935	6,561
Florida	242,638	632,326	119,411	257,682
Georgia	2,015,540	4,305,011	1,993,185	4,807,275
Illinois	1,258,136	2,889,933	913,837	4,790,446
Indiana	1,262,642	2,287,649	1,266,323	2,216,201
Iowa	1,016,772	2,244,873	882,505	2,460,989
Kansas	1,063,831	1,868,714	1,117,433	1,965,100
Kentucky	668,425	1,814,500	618,921	1,877,687
Louisiana	512,572	1,158,137	401,373	784,976
Maine	133,617	216,060	98,081	160,427
Maryland	702,361	1,816,949	892,859	2,343,614
Massachusetts	125,934	237,706	149,389	274,856
Michigan	1,934,334	4,741,192	2,007,391	5,125,835
Minnesota	W	W	162,637	276,483
Mississippi	1,113,723	2,109,552	1,142,869	2,451,899
Missouri	1,256,298	2,123,604	1,431,734	3,189,766
Montana	31,660	45,971	28,231	85,713
Nebraska	149,275	344,683	160,571	367,533
New Jersey	50,000	250,000	52,024	260,120
New Mexico	55,926	116,086	69,415	112,734
New York	649,543	2,089,523	564,369	1,728,329
North Carolina	2,750,011	4,677,254	3,022,055	4,989,585
Ohio	3,587,644	9,373,707	2,841,822	6,818,346
Oklahoma	1,154,656	1,678,247	1,015,891	1,686,862
Oregon	145,258	286,407	118,916	192,578
Pennsylvania	1,452,729	4,108,000	1,743,184	4,301,041
Puerto Rico	W	W	271,993	387,246
South Carolina	1,631,062	3,457,856	1,447,827	3,526,214
South Dakota	123,842	137,066	197,440	232,727
Tennessee	1,015,924	1,581,536	949,668	1,457,249
Texas	3,596,912	7,627,532	3,585,633	10,212,691
Utah	197,340	440,094	222,670	589,595
Virginia	862,036	1,210,199	889,812	1,293,836
Washington	380,856	1,140,537	309,346	1,091,008
West Virginia	275,138	463,583	389,041	599,333
Wyoming	201,440	500,460	203,871	606,343
Other States[2]	647,770	1,025,138	230,559	757,408
Total	37,579,632	79,828,378	37,945,031	93,958,135

W Withheld to avoid disclosing company proprietary data; included with "Other States."
[1]Includes Puerto Rico.
[2]Includes Arizona, Hawaii, Idaho, Nevada, New Hampshire, North Dakota, Wisconsin, and data indicated by symbol W.

CONSUMPTION AND USES

The manufacture of heavy clay products (building brick, sewer pipe, and drain, roofing, structural, terra cotta, and other tile), portland cement and clinker, and lightweight aggregate accounted for 39%, 19%, and 12%, respectively, of the total domestic consumption for 1977. In summary, 70% of all clay produced in 1977 was consumed in the manufacture of these clay- and shale-based construction materials. The foregoing clay tonnage relationships were similar to those reported for 1976. The utilization of clays in 1977 for heavy clay products and portland cement increased 16% and 5%, respectively, over that reported in 1976.

Heavy Clay Products.—The values reported for shipments of heavy clay products for 1977 increased 27% to $994 million from the 1976 value of $784 million. Trends in the various product categories were less consistent. Thousand-unit counts for building or common face brick increased 16% in 1977 from that shipped in 1976, shipments of glazed and unglazed ceramic tile and glazed brick increased 2%, and clay floor and wall tile increased 12%. The tonnage of unglazed structural tile decreased 30%, and vitrified clay sewer pipe and fittings shipped during the year increased 4%. The value of these shipments increased 32% for building brick and clay and 25% for floor and wall tile. The value increased 14% for clay sewer pipe and remained the same for the structural tiles.

Lightweight Aggregate.—Consumption of clay and shale in the making of lightweight aggregate increased in 1977 to 6,256,195 tons. This was a 1% increase from the 6.18 million tons used in 1976. This small rise was attributed to both an upturn in construction rates and growing uses in newer markets, such as running tracks, golf courses, potting, and a host of other horticultural applications.

The tonnage of raw material mentioned in tables 20 and 23 for lightweight aggregate production refers only to clay and shale and does not include the quantity of slate and blast furnace slag similarly used. In 1977, 491,603 tons of slate was expanded for lightweight aggregate, a 6% decrease from the 1976 figure of 523,000 tons. The amount of slag used for lightweight concrete aggregate and in block manufacture decreased 1% from 1,492,000 tons in 1976 to 1,475,345 tons in 1977.

Refractories.—All types of clay were used in manufacturing refractories. Fire clay, kaolin, and bentonites accounted for 51%, 18%, and 16%, respectively, of the total clays used for this purpose. Bentonite was used primarily as a bonding agent in proprietary foundry formulations. Minor tonnages of ball clay, fuller's earth, and common clay and shale (the remaining 15%) were also used, primarily as bonding agents.

The tonnage used for refractories in 1977 increased to 10% of the total clays produced. This slight increase in the use of clay-based refractories continued for a sixth year, a reversal in the downward pattern set for a number of years. The increase was due primarily to both the continued expansion in refractory aggregate production and an upsurge in the manufacturing of more conventional brick-type refractories. Refractory aggregates are used mostly in plastic, gunning, ramming, and castable mixes.

Filler.—All clays are used to some extent as fillers in one or more areas of use. Kaolin, fuller's earth, and bentonite are the principal filler clays. Kaolin was used in the manufacture of a large number of products, such as paper, rubber, paint, and adhesives. Fuller's earth was used primarily in pesticides and fertilizers. Clays in pesticides and fertilizers are used either as carriers, diluents, or prilling agents. Bentonites were used mainly in animal feed.

In 1977, 8% of the clay produced was used in filler applications. Of all the clay used for these purposes, kaolin accounted for 83%, fuller's earth 7%, and bentonite 5%. Ball clay and common clay and shale accounted for the remaining 5%. The total amount of kaolin consumed by this end use category increased 11%. In the individual kaolin categories, an increase of over 100% was recorded for linoleum. Other increases were gypsum products (86%), fertilizers (17%), paper coating (14%), plastics (13%), adhesives (11%), and rubber (8%). Total quantity of fuller's earth used in insecticides and fungicides decreased 5%.

Absorbent Uses.—Absorbent uses for clays, 960,623 tons, consumed 2% of the total 1977 clay production. Demand for absorbents in 1977 increased 3% over that reported for 1976. Fuller's earth was the principal clay used in absorbent applications; 87% of the entire output was consumed for this purpose. Bentonite was used to a lesser degree. Demand for clays in pet absorbent, representing 51% of the 1977 absorbent demand, decreased 7% from that reported for 1976. Demand for use in floor absorbents, chiefly to absorb hazardous oily substances, represented the remaining 49% of absorbent demand and increased 14% from the 1976 figure.

Drilling Mud.—Demand for clays in rotary-drilling muds increased 10% in 1977, from 1,055,113 tons in 1976 to 1,159,601 tons. This increase in demand, mostly in exploratory gas well drilling and to a lesser degree in oil well drilling, was spurred by the deregulation of "new" gas introduced into the interstate market after April 6, 1972. Drilling muds consumed 2% of the entire 1977 clay production. Swelling-type bentonite is the principal clay used in drilling mud mixes, although fuller's earth or nonswelling bentonite is also used to a limited extent. Bentonite and fuller's earth accounted for nearly 100% of the total amount of clay used for this purpose. Small amounts of ball clay and kaolin were used in specialized formulations.

Floor and Wall Tile.—Common clay and shale, ball clay, kaolin, and fire clay, in order of demand, were used in manufacturing floor, wall, and quarry tile. This tile end use category accounted for less than 1% of the total clay production in 1977. Demand in 1977, 395,042 tons, increased 4% from that shown in 1976.

Pelletizing Iron Ore.—Bentonite is used as a binder in forming hard iron ore pellets. Demand decreased in 1977 to 629,353 tons. This decrease in the use of bentonite for iron ore pelletizing, reflecting a downturn in taconite pellet production because of the iron ore strike, was compounded by inroads made by cheaper foreign bentonites into a traditional U.S. clay market and the coal strike at yearend. Of the total bentonite produced in 1977, about 22% of the swelling variety was consumed for this purpose. U.S. deposits continued to be the major source for swelling bentonites.

Ceramics.—The total demand for clays in the manufacture of pottery, sanitary ware, china and dinnerware, and related products (excluding clay flower pots) accounted for 2% of the total 1977 clay output. The total clay demand, principally ball and kaolin clays, increased from approximately 1,052,343 tons in 1976 to approximately 1,146,747 tons in 1977.

Table 20.—Clays sold or used by producers in the United States in 1977, including Puerto Rico, by kind and use

(Short tons)

Use	Ball clay	Bentonite	Common clay and shale	Fire clay (refractory only)	Fuller's earth	Kaolin	Undistributed[1]	Total
Adhesives	200	W	--	--	7,235	W	89,488	96,923
Alum (aluminum sulfate) and other chemicals	--	W	--	--	W	310,820	10,836	321,656
Animal feed	W	194,926	W	--	251	31,681	717	227,575
Asphalt emulsion and tiles	3,240	263	--	--	--	34,909	--	38,412
Building brick:								
Common	W	3,564	3,233,475	72,580	--	58,187	W	3,367,806
Face	W	--	15,533,404	41,425	--	281,973	W	15,856,802
Catalysts (oil refining)	W	12,133	--	--	W	89,531	38,417	140,081
Cement, portland	--	450	9,945,072	--	--	19,862	--	9,965,384
Ceramic (hobby and artware)	--	--	W	--	--	12,038	W	12,038
China and dinnerware	42,114	--	--	--	--	28,242	--	70,356
Crockery and other earthenware	6,665	W	4,261	--	--	36,864	W	47,790
Drilling mud	W	1,060,167	--	--	98,995	W	439	1,159,601
Electrical porcelain	19,270	--	--	--	--	33,064	--	52,334
Fertilizers	W	2,410	--	--	56,457	23,559	W	82,426
Fiberglass, mineral wool, other insulation	88,351	--	--	--	--	145,003	--	233,354
Filtering, clarifying, decolorizing:								
Animal oil	--	73,393	--	--	--	--	--	73,393
Mineral oils and greases	--	31,919	--	--	26,226	--	--	58,145
Vegetable oils	--	65,038	--	--	--	--	--	65,038
Firebrick, block, shapes	7,186	W	11,217	1,943,632	--	328,243	W	2,290,278
Flower pots	W	3	32,547	2,160	--	--	W	34,710
Flue linings and high-aluminum (minimum 50% Al_2O_3) refractories	16,450	--	165,946	225,600	--	132,888	--	540,884
Foundry sand	--	867,305	--	126,962	--	5,074	--	999,341
Glazes, glass, enamels	1,332	120	--	W	--	4,334	W	5,786
Grogs and crudes, refractory	W	--	--	98,723	--	302,938	W	401,661
Gypsum products	--	303	--	--	W	8,930	W	9,233
Ink	--	W	--	--	--	12,708	W	12,708
Kiln furniture	6,400	--	--	--	--	613	--	7,013
Lightweight aggregate:								
Concrete block	--	--	4,548,202	--	51	--	--	4,548,253
Structural concrete	--	--	1,168,064	--	--	--	--	1,168,064
Highway surfacing	--	--	407,527	--	--	--	--	407,527
Other	--	--	132,020	W	--	W	331	132,351
Linoleum and asphalt tile	--	--	--	--	--	36,128	--	36,128
Medical, pharmaceutical, cosmetic	--	4,498	--	W	72	1,842	W	6,412
Mortar and cement, refractory	54,951	W	271,284	337,400	W	35,136	59,827	758,598
Oil and grease absorbents	--	W	W	--	440,097	W	30,695	470,792
Paint	--	16,516	W	--	7,656	162,856	W	187,028
Paper coating	31,402	W	--	--	--	1,814,391	W	1,845,793
Paper filling	50,689	W	--	--	3,527	800,021	W	854,237
Pelletizing (iron ore)	--	629,353	--	--	--	W	W	629,353

Pelletizing (other)	--	--	--	20,100	--	--	--	20,100
Pesticides and related products	--	5,000	15,450	--	195,180	22,312	--	237,942
Pet absorbent	--	25,501	W	--	396,869	--	W	422,370
Plastics	--	W	W	--	W	69,922	1,676	71,598
Plug, tap and wad	--	W	--	7,180	--	--	W	7,180
Pottery	259,607	1	62,549	18,530	--	18,969	--	359,656
Roofing granules	--	--	W	--	W	20,590	54,181	74,771
Rubber	W	W	--	--	53	326,619	977	327,649
Sanitary ware	--	--	--	--	--	160,656	--	160,656
Sewer pipe, vitrified	--	W	1,376,950	38,951	W	--	163	1,416,064
Tamping dummies	--	--	W	--	--	--	--	W
Tile:								
Drain	--	--	280,010	--	--	--	--	280,010
Floor and wall	51,060	--	149,116	480	--	15,567	--	216,223
Quarry	--	--	177,967	W	--	W	852	178,819
Roofing	--	--	83,371	--	--	W	W	83,371
Structural	--	--	72,432	--	--	W	W	72,432
Terra cotta	--	--	W	--	--	--	--	W
Other	--	--	W	--	--	--	--	W
Waterproofing and sealing	W	78,341	--	--	W	130	932	79,403
Miscellaneous[2]	76,004	84,580	6,444	622	5,393	79,201	--	252,244
Undistributed	85,572	25,907	151,632	15,225	71,324	125,825	177,780	[3]185,954
Exports	93,734	564,796	116,091	16,037	118,940	896,932	--	1,806,530
Total	894,227	3,746,487	37,945,031	2,965,607	1,428,326	6,488,558	([4])	53,468,236

W Withheld to avoid disclosing company proprietary data; included with "Undistributed."
[1]Total of clays indicated by symbol W.
[2]Includes graphite anodes and unknown uses.
[3]Incomplete total; remainder included with "Miscellaneous."
[4]Included with total for each specific use.

Table 21.—Shipments of principal structural clay products in the United States

Products		1973	1974	1975	1976	1977
Unglazed common and face brick:						
Quantity	million standard brick	8,674	6,673	5,854	6,973	8,060
Value	million dollars	$451	$376	$358	$461	$607
Unglazed structural tile:						
Quantity	thousand short tons	94	100	88	71	50
Value	million dollars	$4	$4	$4	$3	$3
Vitrified clay and sewer pipe fittings:						
Quantity	thousand short tons	1,647	1,454	1,190	1,099	1,140
Value	million dollars	$138	$134	$124	$123	$140
Unglazed, salt-glazed, and ceramic-glazed structural facing tile, including glazed brick:						
Quantity	million equivalent	122	97	79	62	63
Value	million dollars	$13	$13	$11	$10	$11
Clay floor and wall tile, including quarry tile:						
Quantity	million square feet	301	273	236	259	291
Value	million dollars	$168	$168	$159	$186	$233
Total value[1]	do	$773	$695	$656	$784	$994

[1]Data may not add to totals shown because of independent rounding.

Table 22.—Common clay and shale used in building brick production in the United States in 1977, by State

State	Short tons	Value	State	Short tons	Value
Alabama	834,120	$1,268,615	Mississippi	830,263	$1,812,334
Arizona, Hawaii, New Mexico	120,106	210,932	Missouri	222,174	613,129
Arkansas	510,381	703,344	Nebraska and North Dakota	159,302	310,457
California	541,041	1,280,980	New Jersey	50,000	250,000
Colorado	899,518	4,422,689	New York	208,998	513,701
Connecticut	95,163	249,942	North Carolina	2,422,364	3,923,556
Delaware	10,935	6,561	Ohio	1,442,046	3,632,812
Florida	48	74	Oklahoma	432,412	768,286
Georgia	1,707,856	4,305,270	Oregon	42,360	60,467
Idaho, Montana, Utah	112,552	338,288	Pennsylvania	1,206,790	3,037,607
Illinois	350,008	1,121,122	South Carolina	1,037,727	2,502,595
Indiana and Iowa	751,022	1,321,526	South Dakota	16,760	19,641
Kansas	303,289	607,529	Tennessee	543,704	795,957
Kentucky	187,384	271,004	Texas	1,747,518	6,078,636
Louisiana	187,373	303,383	Virginia	782,004	1,136,654
Maryland and West Virginia	456,615	1,251,803	Washington	169,390	488,500
Maine, Massachusetts, New Hampshire	165,663	360,544	Wyoming	62,676	288,508
Michigan, Minnesota, Wisconsin	157,317	896,740	Total	18,766,879	45,153,186

Table 23.—Clay and shale used in lightweight aggregate production in the United States in 1977, by State and kind

State	Short tons					Total value
	Concrete block	Structural concrete	Highway surfacing	Other	Total	
Alabama and Arkansas	990,468	145,588	5,851	17,525	1,159,432	$3,819,967
California	362,096	228,012	--	--	590,108	3,513,830
Colorado, Florida, Georgia	30,600	20,400	--	351	51,351	86,700
Illinois, Indiana, Iowa	472,252	128,400	1,900	--	602,552	4,088,516
Kansas, Kentucky, Louisiana	404,390	103,614	73,845	23,287	605,136	1,230,649
Maryland, Massachusetts, Minnesota	664,243	12,970	--	35,955	713,168	1,524,953
Mississippi	116,200	26,700	166,100	--	309,000	632,000
Missouri, Nebraska, North Carolina	311,986	123,200	--	45,028	480,214	1,479,462
Montana	7,000	--	--	--	7,000	11,200
New York	144,600	67,400	--	2,500	214,500	992,200
North Dakota, Ohio, Pennsylvania	191,728	15,500	--	200	207,428	540,431
Oklahoma	140,883	80,424	--	--	221,307	376,222
South Dakota, Utah, Washington	135,972	60,763	--	--	196,735	386,305
Tennessee	205,728	3,000	--	--	208,728	434,959
Texas	271,067	150,238	159,831	2,672	583,808	1,189,003
Virginia	99,040	1,855	--	4,833	105,728	154,362
Total	4,548,253	1,168,064	407,527	132,351	6,256,195	20,460,759

Table 24.—Shipments of refractories in the United States, by kind

Product	Unit of quantity	1976 Quantity	1976 Value (thousands)	1977 Quantity	1977 Value (thousands)
CLAY REFRACTORIES					
Superduty fire clay brick and shapes	1,000 9-inch equivalent	57,053	$36,342	54,259	$38,863
Other fire clay, including semisilica, brick and shapes, glasshouse pots, tank blocks, feeder parts, and upper structure parts used only for glass tanks.	do	184,879	74,306	182,759	77,188
High-alumina (50% to 60% Al_2O_3) brick and shapes made of calcined diaspore or bauxite.[1]	do	63,337	78,588	68,002	90,168
Insulating firebrick and shapes	do	51,787	27,189	59,792	33,046
Ladle brick	do	197,075	43,668	195,893	46,793
Sleeves, nozzles, runner brick, tuyeres	do	36,209	21,837	35,690	21,704
Hot-top refractories	Short tons	22,940	2,645	22,865	3,144
Kiln furniture, radiant heater elements, potters' supplies, other miscellaneous-shaped refractory items.	do	NA	15,659	NA	17,406
Refractory bonding mortars	do	88,645	17,425	98,900	20,225
Plastic refractories and ramming mixes containing up to 87.5% Al_2O_3.[2]	do	238,917	47,632	148,845	24,457
Castable refractories	do	267,699	57,708	279,680	63,876
Gunning mixes	do	57,865	10,159	64,597	12,787
Other clay refractory materials sold in lump or ground form.[3] [4]	do	282,867	15,313	310,507	15,785
Total clay refractories		XX	448,471	XX	465,442
NONCLAY REFRACTORIES					
Silica brick and shapes	1,000 9-inch equivalent	38,669	35,721	29,126	28,254
Magnesite and magnesite-chrome brick and shapes.	do	85,106	187,135	89,248	212,611
Chrome and chrome-magnesite brick and shapes.	do	13,428	29,455	11,402	30,345
Shaped refractories containing natural graphite.	Short tons	19,852	24,236	20,449	26,835
Other carbon refractories: Forsterite, pyrophyllite, dolomite, dolomite-magnesite, molten-cast,[5] other brick and shapes.	1,000 9-inch equivalent	28,582	84,159	29,823	107,117
Other mullite, kyanite, sillimanite, or andalusite brick and shapes.	do	3,716	12,356	3,519	12,815
Other extra-high-alumina (over 60%) brick and fused bauxite, fused-alumina, and dense-sintered alumina shapes.[6]	do	4,205	23,797	6,622	26,543
Silicon carbide brick, shapes, and kiln furniture.	do	4,639	27,975	3,833	27,906
Zircon and zirconia brick and shapes	do	1,828	13,287	1,559	11,522
Refractory bonding mortar	Short tons	26,994	8,551	30,600	11,511
Hydraulic-setting nonclay refractory castables.	do	45,869	19,836	37,659	17,737
Plastic refractories and ramming mixes	do	172,510	50,085	172,739	56,802
Gunning mixes	do	325,160	62,237	376,619	73,845
Dead-burned magnesia or magnesite[3] [7]	do	526,542	78,137	412,719	71,384
Other nonclay refractory material sold in lump or ground form.[3]	do	491,326	25,661	499,727	33,984
Total nonclay refractories		XX	682,628	XX	749,211
Grand total refractories		XX	1,131,099	XX	1,214,653

NA Not available. XX Not applicable.

[1] Heated short of fusion; volatile materials are thus driven off in the presence of chemical changes, giving more stable material for refractory use.

[2] More or less plastic brick and materials which, after the addition of any water needed, are rammed into place.

[3] Materials for domestic use as finished refractories, and all exported material.

[4] Including calcined clay, ground brick, and siliceous and other gunning mixes.

[5] Molten cast refractories are made by fusing refractory oxides and pouring the molten material into molds to form finished shapes.

[6] Completely melted and cooled, then crushed and graded for use in a refractory.

[7] Includes shipments to refractory producers for reprocessing in the manufacture of other refractories.

Table 25.—U.S. exports of clay by country and class in 1977

(Thousand short tons and thousand dollars)

Country	Ball clay		Bentonite		Fire clay		Fuller's earth		Kaolin		Clays, n.e.c.		Total	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Argentina	--	--	(1)	228	(1)	3	--	--	14	1,278	7	709	21	2,218
Australia	--	--	17	1,320	8	421	1	65	25	1,585	6	429	57	3,820
Belgium-Luxembourg	--	--	(1)	120	(1)	5	2	145	4	387	6	514	12	1,171
Brazil	(1)	14	10	1,174	1	45	--	--	3	408	4	489	18	2,130
Brunei	--	--	5	342	--	--	--	--	--	--	1	40	6	382
Canada	41	999	380	14,442	111	2,649	12	710	150	7,653	88	4,712	782	31,165
Chile	--	--	3	357	--	--	(1)	2	1	151	(1)	39	4	549
Colombia	--	--	3	295	(1)	23	--	--	4	297	3	374	10	989
Finland	--	--	6	182	--	--	(1)	11	1	142	(1)	36	7	371
France	--	--	10	951	2	228	1	143	21	1,932	13	1,294	47	4,548
Germany, Federal Republic of	--	--	47	2,535	68	2,912	2	193	93	6,710	53	3,237	263	15,587
Guatemala	(1)	1	(1)	37	(1)	9	1	76	3	178	1	62	5	363
Italy	--	--	2	347	14	725	1	126	150	11,330	5	821	172	13,349
Japan	(1)	32	40	5,895	26	1,467	(1)	11	309	25,882	65	4,752	440	38,039
Korea, Republic of	(1)	(1)	(1)	194	2	115	(1)	4	8	1,062	3	419	13	1,794
Mexico	73	1,512	5	515	53	1,493	(1)	4	49	3,161	11	319	191	7,004
Netherlands	--	--	31	1,252	(1)	42	11	451	29	1,742	30	2,402	101	5,889
Philippines	1	31	2	412	3	174	--	--	2	331	3	388	11	1,336
Saudi Arabia	--	--	28	1,516	--	--	--	--	(1)	1	(1)	26	28	1,543
Singapore	--	--	14	672	--	--	--	--	(1)	21	--	--	14	693
South Africa, Republic of	--	--	2	490	(1)	3	(1)	9	6	818	5	407	13	1,727
Spain	--	--	7	342	(1)	8	(1)	44	10	866	1	141	18	1,401
Sweden	(1)	4	(1)	61	4	209	(1)	3	9	659	5	370	18	1,306
Switzerland	--	--	(1)	31	(1)	10	(1)	4	4	322	1	48	5	415
Taiwan	--	--	3	377	1	92	--	--	9	733	17	1,461	30	2,663
Thailand	--	--	2	161	--	--	--	--	1	145	1	191	4	497
United Arab Emirates	--	--	9	1,338	--	--	1	115	--	--	--	--	10	1,453
United Kingdom	(1)	1	97	5,060	7	408	11	541	4	427	9	744	128	7,181
Venezuela	2	100	30	1,828	2	181	(1)	4	16	1,412	2	210	52	3,735
Other	(1)	8	34	3,302	5	409	1	119	26	2,272	12	1,358	78	7,468
Total[2]	117	2,702	788	45,775	307	11,632	45	2,781	952	71,907	352	25,993	2,561	160,790

[1]Less than 1/2 unit.
[2]Data may not add to totals shown because of independent rounding.

Table 26.—U.S. imports for consumption of clay in 1977

Kind	Quantity (short tons)	Value (thousands)
China clay or kaolin, whether or not beneficiated:		
Canada	740	$55
Germany, Federal Republic of	3	2
Japan	3	1
Netherlands	232	13
United Kingdom	18,684	804
Total[2]	19,663	875
Fuller's earth, not beneficiated: United Kingdom	22	2
Fuller's earth, wholly or partly beneficiated:		
Canada	45	3
United Kingdom	1	(1)
Total	46	3
Bentonite:		
Brazil	11	(1)
Canada	36	11
Germany, Federal Republic of	88	8
Total[2]	136	19
Common blue and other ball clay, not beneficiated:		
Canada	551	51
United Kingdom	5,634	225
Total	6,185	276
Common blue and other ball clay, wholly or partly beneficiated: United Kingdom	5,153	156
Clays, n.e.c., not beneficiated:		
Germany, Federal Republic of	3	1
Italy	1	2
United Kingdom	2	(1)
Total[2]	7	4
Clays, n.e.c., wholly or partly beneficiated:		
Belgium-Luxembourg	44	6
Canada	321	13
Germany, Federal Republic of	265	51
Spain	27	1
United Kingdom	1,752	167
Total[2]	2,409	239
Clays artificially activated with acid:		
Canada	903	73
France	(1)	1
Germany, Federal Republic of	57	39
Japan	251	98
Mexico	1,164	129
United Kingdom	2	3
Total[2]	2,378	343
Grand total	35,999	1,917

[1]Less than 1/2 unit.
[2]Data may not add to totals shown because of independent rounding.

WORLD REVIEW

Argentina.—The Instituto Tecnologico de Mineria y Aquas Subterraneas reported the discovery of kaolin deposits at Los Alamos.[12] The kaolin reserves and quality were not included in the announcement.

Australia.—A semicommercial pilot plant for recovering paper-quality kaolin was scheduled to be operational in 1978.[13] The new plant, owned equally by Western Australian Kaolin Co. Pty., Ltd., and Consolidated Goldfields of Australia, is near the Gabbin kaolin deposit.

Brazil.—A second paper-grade kaolin project using J. M. Huber Corp. technology was announced.[14] The first project at Morro do Felipe in the Territory of Amapá in northern Brazil, operated by Caulim Da Amazonia (a subsidiary of National Bulk Carriers and a member of The Ludwig Group), is now producing normally and is expected to be approaching its design capacity of over 200,000 short tons per year. The second project, also in the north, is near the Capim River, some 170 miles up the Amazon from Bélem, the capital of Pará State. This project, operated by Caulim Da Para, a joint venture between Huber and Construtora Mendes Junior, was to have a capacity of 280,000 tons per year, of which 200,000 tons is coating quality and the remainder is filler grade. Because of a limited domestic market, the bulk of this production is targeted for export to Japan and Europe.

Canada.—A 60,000-short-ton-per-year bentonite-processing plant is to be built by Avonlea Mineral Industries Ltd., of Wilcox, Saskatchewan.[15] A portion of the $1.4 million required for the planned construction was to be supplied by the Government.

Chad.—The economic reserves of undisclosed-quality kaolin were announced as 500,000 tons by the Director of Mines and Geology.

France.—The new chamotte facility, to produce refractory calcined kaolin and/or kaolin-bauxite mixtures, at Oriolles was reported to be fully operational at midyear.[17] The new plant is operated by SARCA, a joint subsidiary of the French MOKTA group and the Italian SIRMA group. In a kaolin transaction, the Berrien deposit in Brittany was acquired by ECC in association with some of the existing area producers.[18] A subsidiary company, Kaolins du Finistere S.A., was formed to operate the deposit and recover a high-quality ceramic-grade kaolin. The deposit was operated formerly by a group which included Engelhard Minerals and Chemicals Corp. and marketed mostly a paper-quality clay.

Guyana.—Laboratory tests of cores, on unknown centers, from several kaolin deposits have reportedly proved out "many millions of tons" of top-quality paper grades beneath the bauxite deposits.[19] Plans included converting the mined-out bauxite areas into potential kaolin mines.

Italy.—The Italian bentonite producer, S.A. Mineraria Isole Pontine (SAMIP), forced to cease mining on the holiday island of Ponza, was actively investigating a number of bentonite and other smectitic clay deposits in Italy.[20] The investigation was particularly centered in the Nuoro region of Sardinia.

India.—An extensive kaolin deposit of unreported quality was discovered in Assam State.[21] The area is also rich in sillimanite and glass sands. The Industrial Promotion and Investment Corp. of Orissa Ltd. (IPICOL), with an eye towards an unnamed potential export market, was attempting to induce the private sector to construct a central washing plant for improving the recovery and quality of local kaolins.[22] Reserves in Orissa State were estimated at 35 million metric tons (38 million short tons), and the fire clay reserves at 62 million metric tons (68 million short tons).

Japan.—A wholly owned subsidiary of ITC Enterprises Ltd., Baltimore, Md., ITC-Japan Ltd., has taken over Fuji Kaolin Co., Ltd.,[23] a competing supplier of paper-grade kaolins. ITC, one of the largest exporters of U.S. paper-quality kaolins, was also the Japanese representative for Georgia Kaolin Co. and the ECC U.S. subsidiary, Anglo-American Clays Corp.

Nigeria.—High-quality kaolin deposits in commercial quantities were discovered in Kaduna State by the Nigerian Mining Corp. in conjunction with the Federal Institute of Industrial Research of Oshodi, Japan.[24]

Pakistan.—The Azad Kashmir State Government approved a 5-million-rupee expenditure on mineral surveys and exploration in two districts of Poonch and Katli.[25] The areas are believed to contain clays and bauxite.

South Africa, Republic of.—The Otavi Mining Co. was awarded a contract to supply a wide range of refractory materials, including clays and chamottes, to Japan.[26]

Sudan.—The Government of the Southern Region retained Hunting Geology and Geophysics Ltd. of the United Kingdom to undertake mineral surveys of 30,000 square kilometers (18,642 square miles) of the region.[27] This survey follows up an earlier reconnaissance. Kaolin and other clays were of primary interest in order to permit local industrial development.

United Kingdom.—The English China Clays Group changed the name of its marketing arm from English China Clay Sales to ECC International.[28] In another move ECC set up its own sales unit in Helsinki, Finland-ECC International Oy. This was to permit a closer working relationship with the Finnish paper industry.

Permission was granted to ECC Ball Clays, after an appeal, by the Dorset County Council to mine on the Arne Peninsula of Dorset.[29] The appeal was granted subject to the company meeting stringent environmental conditions on the methods of work-

Table 27.—Kaolin: World production, by country

(Thousand short tons)

Country[1]	1975	1976	1977[p]
North America:			
Mexico	133	79	97
United States[2]	5,334	6,115	6,469
South America:			
Argentina	104	92	98
Brazil (beneficiated)	191	231	[e]230
Chile	66	74	55
Colombia[e]	138	165	165
Ecuador	3	[e]3	2
Paraguay	13	15	24
Peru	[e]6	10	12
Venezuela	17	11	[e]11
Europe:			
Austria (marketable)	83	79	82
Belgium[e]	110	110	220
Bulgaria[e]	165	165	165
Czechoslovakia	580	601	[e]610
Denmark[e]	20	20	22
France[e 3]	[r]830	830	850
Germany, Federal Republic of (marketable)	462	487	[e]500
Greece	80	78	72
Hungary	98	79	[e]77
Italy:			
Crude	86	90	90
Kaolinitic earth	31	29	23
Poland	92	105	[e]100
Portugal	57	56	60
Romania[e]	96	100	100
Spain (marketable)[4]	229	228	[e]230
U.S.S.R.[e]	2,400	2,400	2,500
United Kingdom	3,549	4,241	[e]4,245
Africa:			
Algeria	12	9	13
Angola	([5])	--	1
Burundi	--	3	[e]3
Egypt	37	31	54
Ethiopia (including Eritrea)	55	50	[e]45
Kenya	--	--	1
Madagascar	5	28	2
Mozambique[e]	[r]1	1	1
Nigeria[e]	1	1	1
South Africa, Republic of	63	66	98
Swaziland	3	1	--
Tanzania	1	[e]1	[e]1
Asia:			
Bangladesh	4	2	[e]1
Hong Kong	2	1	3
India:			
Salable	259	328	[e]240
Processed	[r]107	114	98
Indonesia	28	32	40
Iran	[e]110	[e]140	[e]145
Israel	13	11	6
Japan	227	249	250
Korea, Republic of	[r]421	418	393
Malaysia	19	29	35
Pakistan	[r] ([5])	1	([5])
Sri Lanka	4	5	[e]5
Taiwan[e 6]	23	23	23
Thailand	17	18	27
Turkey	38	72	[e]80
Oceania:			
Australia	89	[r e]90	[e]90
New Zealand	30	[e]30	[e]30
Total	[r]16,542	18,247	18,795

[e]Estimate. [p]Preliminary. [r]Revised.

[1]In addition to the countries listed, the People's Republic of China, the German Democratic Republic, Lebanon, Nigeria, Vietnam, Southern Rhodesia and Yugoslavia also produced kaolin, but information is inadequate to make reliable estimates of output levels. Costa Rica, Guatemala, and Morocco each produced less than 500 tons in each of the years covered by this table.

[2]Kaolin sold or used by producers.

[3]Includes kaolinitic clay.

[4]Excludes unwashed kaolin as follows, in thousand short tons: 1975—187; 1976—150 (estimated); 1977—Not available.

[5]Less than 1/2 unit.

[6]Data given are for ceramic and pottery clays.

Table 28.—Bentonite: World production, by country

(Short tons)

Country[1]	1975	1976	1977[p]
North America:			
Guatemala	[e]10	[e]10	--
Mexico	35,833	61,270	65,223
United States	3,229,267	3,520,381	3,746,487
South America:			
Argentina	127,870	145,850	160,318
Brazil	128,733	157,871	[e]165,000
Colombia[e]	1,100	1,100	1,100
Peru	[e]28,000	43,591	45,795
Europe:			
France[e]	[r]22,000	[r]22,000	24,000
Greece	476,165	345,538	462,363
Hungary	96,890	134,590	[e]143,300
Italy	308,691	258,648	309,011
Poland[e]	55,000	55,000	55,000
Romania[e]	69,200	70,000	70,000
Spain	83,060	119,213	[e]120,000
Africa:			
Algeria (bentonite clay)[e]	39,000	43,000	27,000
Morocco	3,363	4,430	5,299
Mozambique	1,983	2,533	[e]4,000
South Africa, Republic of	41,391	43,654	41,029
Asia:			
Burma	1,008	1,053	1,075
Cyprus (bentonite clay)[2]	12,690	3,123	14,558
Iran	55,000	[e]55,000	[e]55,000
Israel (metabentonite)	3,300	16,500	8,800
Japan	444,965	[e]440,000	[e]440,000
Pakistan	[r]744	823	[e]720
Philippines	729	2,334	2,512
Turkey	[r]35,997	23,287	[e]28,000
Oceania:			
Australia[3]	[r]3,693	[e]3,300	[e]3,300
New Zealand (processed)	[4]5,783	1,149	1,100
Total	[r]5,311,465	5,575,248	5,999,990

[e]Estimate. [p]Preliminary. [r]Revised.

[1]In addition to the countries listed, Austria, Canada, the People's Republic of China, the Federal Republic of Germany, and the U.S.S.R. are believed to have produced bentonite, but output is not reported and available information is inadequate to make reliable estimates of output levels.

[2]Exports.

[3]Including bentonite clay.

[4]Includes unprocessed bentonite.

Table 29.—Fuller's earth: World production, by country[1]

(Short tons)

Country[2]	1975	1976	1977[p]
Algeria	24,250	[e]24,300	[e]27,600
Argentina	260	3,454	3,406
Australia	20	[e]22	[e]22
Italy	77,700	27,402	6,993
Mexico	42,105	22,165	67,648
Morocco (smectite)	26,147	40,530	23,176
Pakistan	[r]13,382	17,637	[e]16,500
Senegal (attapulgite)	18,407	5,100	3,089
United Kingdom	180,779	179,677	178,574
United States	1,189,064	1,341,582	1,428,326
Total	[r]1,572,114	1,661,869	1,755,334

[e]Estimate. [p]Preliminary. [r]Revised.

[1]Excludes centrally planned economy countries, some of which presumably produce fuller's earth, but for which no information is available.

[2]In addition to the countries listed, France, Iran, Japan, and Turkey have reportedly produced fuller's earth in the past and may continue to do so, but output is not reported, and available information is inadequate to make reliable estimates of output levels.

ing and restoration. The original ruling was overturned in part because the whiteware ceramic industry was deemed important to the national economy, and the manufacture of its products, in particular wall and floor tiles, depends on continuing supplies of Dorset whiteware ball clay.

TECHNOLOGY

The Federal Bureau of Mines and six aluminum producers (three fewer than in 1976) continued cosponsoring research on extracting alumina from domestic materials that are plentiful, which could ease our dependence on imported metallurgical- and refractory-grade bauxite. Using miniplant facilities at the Boulder City (Nev.) Metallurgy Engineering Laboratory, and with support from the eight other Bureau research centers, researchers were investigating several methods for extracting alumina from clays, anorthosite, alunite, and dawsonite-bearing oil shales. Each participating company was contributing $50,000 annually, with the cost to the Bureau averaging $700,000 annually.

The clay-nitric acid miniplant, the first acid process studied, using calcined kaolin was successfully completed. The miniplant study showed that with four stages of countercurrent decantation (CCD), over 90% of the alumina was recoverable. A patent was granted describing a solvent extraction process for removing iron from a concentrated aqueous solution, containing about 50 to 56.8 weight-percent of the nitrate.[30] Current work was being devoted to the design, construction, and operation of a kaolin clay-hydrochloric acid miniplant. This miniplant has already been operated for several continuous campaigns of the leaching, solvent extraction, and solids-liquid separation sections, mainly to optimize alumina recovery from the leach solutions. Preliminary data show that recovering over 95% of the acid-soluble alumina during leaching is possible with a CCD circuit.

Emphasis was also given during the year to the gas-sparging crystallization step in order to optimize recovery of the $AlCl_3.6H_2O$ crystals in a suitable size range for subsequent thermal decomposition in a fluidized bed to alumina. To date, specially built rubber-lined equipment has been operated successfully in the crystallizer. Miniplant problems, investigated at the other centers in support, were in the areas of determining the best materials for construction (emphasizing corrosion), fluidized-bed decomposition of the hexahydrate, tests on the sulfurous acid leaching of clays, lime sinter processing of anorthosites, reduction roasting of alunite, and disposal of processing wastes. In addition, three contracts of particular interest were granted. Two contracts were for delineating the environmental factors in recovering alumina from domestic ores.[31] The other contract provided for a study comparing six nonbauxitic alumina processes with the objective of selecting the two most promising candidate processes for further study.[32] The comparisons covered both technical and economic aspects of alumina process plants of commercial size in the United States. The processes considered were hydrochloric acid-clay (evaporative and gas-induced crystallization), nitric acid-clay, sulfurous acid-clay, anorthosite-lime sinter, and alunite. This was the first study of a three-part program. The clay-hydrochloric acid (gas-sparging crystallization) and clay-nitric acid processes were selected by the Bureau of Mines for more detailed evaluation. Some factors affecting the chlorination of kaolin were discussed.[33]

In other clay work, the Bureau continued to aid State geological surveys and other Federal agencies in delineating undeveloped deposits of ceramic raw materials by clay testing and evaluation, and by devising flowsheets to upgrade marginal materials. Also included within the scope of this program was research to develop wear- and polish-resistant aggregates from materials such as expanded clays, shales, and slates. This test program for clay and ceramic raw materials was described in a Bureau publication.[34]

The outlook for an integrated aluminum-from-kaolin industry in the Southeast, principally from Georgia kaolins was discussed.[35] Another method of producing aluminum from clays was patented during the year.[36] In this process the aluminiferous clay, either kaolin or bauxite, is mixed with byproduct kaolin-containing sludge from papermaking and then calcined to both carbonize the cellulose fraction and dehydrate the clay. The solids are separated by filtration and chlorinated, and the chloride is eventually converted to aluminum metal.

A two-part treatise covered the industrial minerals of Japan. The first part dealt with the production, reserves, imports, and geological distribution of the industrial minerals by Prefectures, along with a special section on raw materials that could be logically grouped as ceramics and/or refractories.[37] Of particular interest in this section was a description of the unique Japanese clay nomenclature and classification scheme. The major clay-producing areas in northern Honshu, Gifu, Mitsuishi, and the Kyushu and Sikoku Islands, along with selected operations, were also covered. The high-alumina materials, such as bauxite, sillimanite, and synthetic mullites, basic refractory materials, pottery, whiteware, and the glass industries, were afforded similar treatment. The second part detailed construction and chemically oriented materials.[38] The wide range of lightweight aggregates including expanded clays and shales were included in the construction section. The section on chemically oriented materials emphasized the paper and pulp and paint industries, which are large consumers of high-cost kaolin fillers and extenders. The industrial minerals of the Republic of South Africa and Thailand were covered in other articles. The South African article began with a general introduction and then profiled some of the major industrial mineral deposits and operations.[39] The fire clay, bentonite, and kaolin deposits were detailed in a special clay section. The Thailand article discussed its geology and enormous potential for producing a wide variety of industrial minerals including kaolin.[40]

The properties and uses of sillimanite-type refractories and their alternatives, synthetic mullites produced from kaolin and/or bauxitic mixtures, were discussed in great detail.[41] The discussion included the principal worldwide producers of natural and synthetic mullitic materials, their processes, and typical chemical analyses of these high-alumina refractories. A special section elaborated on the factors to consider before selecting a high-alumina refractory for a particular job. In another refractory paper, the present and future worldwide supply of the major refractory raw materials, including fire clays and kaolin-based grog, was correlated with both the technology of refractories and the consuming industries.[42] The work maintained that as supplies are exhausted, time, favorable economic factors, and new technologies, using presently uneconomic sources or for synthesizing substitutes, must be forthcoming to assure adequate supplies for the refractories industry in the future.

The geology of Georgia kaolin deposits and problems associated with their use was published.[43] This excellent effort consisted of two sections, a deposit section and a problem section. The deposit discussion defined the general types of kaolin found—soft and hard—their occurrences, and their geological age. The problem section discussed the lack of convincing proof on the mode of deposit formation, conflicting interpretations of the stratigraphy, the reasons for the beneficial low iron content, and finally why the anatase (TiO_2) contaminant is more abundant in Tertiary than in Cretaceous kaolin. A map of the kaolin and bauxite districts in the Coastal Plain of the Southeastern United States and electron micrographs of typical Tertiary and Cretaceous kaolins were also included. In an analogous paper, scanning electron micrographs (SEM) were shown for three representative types of Georgia kaolin: "Soft" Cretaceous-age clay, "hard" fine-grained clay, and "flint kaolin."[44] Evidence was cited claiming the Sparta Granite and a thick deposit of its overlying saprolite as the probable rock sources for these kaolins. The proof consisted of correlating micrographs, morphology, chemical analyses, and X-ray difraction data with similar data from the three distinct kaolin types.

The international pulp and paper industries, as markets for a wide variety of industrial minerals, were treated in detail, in an article highlighting paper development, paper properties, and paper manufacturing processes along with chemical and mechanical pulping and pulping technology.[45] The chemical and industrial minerals used in both pulping and manufacturing were treated in depth separately. The entire spectrum of kaolin grades for filler and coating, their consumption levels, and use of other mineral pigments, such as TiO_2 and talc, were correlated with the future outlook for paper.

The dehydroxylation phases of kaolinite from Zettlitz, Czechoslovakia, were investigated by radial electron density distribution (RED) and X-ray spectroscopy.[46] Special emphasis was devoted to two amorphous or poorly crystallized transition phases-metakaolinite (600° to 800° C) and spinel structure (900° C). This detailed structural analysis of these transition phases in the kaolinite-mullite thermal sequence, or any mullite research, could affect the commercial production of calcined and sintered kaolins. The calcined grades are used largely as fillers and extenders, whereas the sintered kaolins are used in refractories. The paragenesis, composition, and unit cell dimensions of analyzed mullites either crystallized from a melt or formed by solid state reaction were researched.[47] The research revealed that the arc-melted mullites contain between 67 to 68 mole-percent Al_2O_3, whereas solid-state varieties were all under 63 mole-percent Al_2O_3. In addition, it was found that the composition was controlled by many factors, the most important being firing time, initial bulk composition, the nature, grain size, and efficiency of mixing of starting materials, and finally, whether or not corundum or free Al_2O_3 nucleated.

The phosphate-bonded mullitic or aluminosilicate plastic refractories (monolithics), which have captured a large share of the refractory markets since the early 1950's because of their ease in installation and extraordinary mechanical strength in service, were covered in two papers. The first paper, on refractory plastics containing P_2O_5 with hot modulus-of-rupture (MOR) at temperatures between 1,500° and 2,500° F, dealt with only three types of aggregates-calcined flint clay, calcined bauxite, and tabular alumina.[48] It was determined that the conventional phosphate binders-phosphoric acid, liquid aluminum phosphates, and/or their mixtures-did not play an important role in hot MOR's. The second paper summarized the progress made since an earlier classic study in 1950, in which the alteration of the bond thermally and applications of phosphate-bonded refractories were treated.[49] This present work, unlike the earlier study, covered both the acid and basic refractories-bricks, mortars, ramming mixes, plastics, and cold-setting castables.[50] The mechanisms of bonding and uses for these refractories were treated, and selected properties were compared with those of refractories containing nonphosphatic bonds. In addition, new and novel phosphate-bonding chemicals were discussed. Clay and nonclay binders used in foundry sands were evaluated in another report, which attempted to identify defect characteristics for the different classes of binders and to evaluate emission problems.[51] The western or swelling bentonites, fine clay binders, and other competing inorganic and organic materials were investigated.

Environmental research on heavy metals indicated that pH has a pronounced effect on the amounts adsorbed from landfill leachates by kaolinite and montmorillonite clay minerals.[52] It was concluded that the principal adsorption mechanism was cation and anion exchange, and that the monovalent species of each element that was principally adsorbed by anion exchange.

---

[1]Physical scientist, Division of Nonmetallic Minerals.

[2]Murray, H. H. Kaolin 1977. Min. Eng., v. 30, No. 5, May 1978, pp. 532-533.

[3]Iannicelli, J. Kaolin: Production Reaches New High in 1977. Eng. and Min. J., v. 178, No. 3, March 1978, pp. 139-140.

[4]Chemical Marketing Reporter. Kaolin Operations Sold to Nord By Cyprus Mines. V. 212, No. 16, Oct. 17, 1977, pp. 5, 47.

[5]Mining Journal (London). Industry In Action. Exploration-Georgia: Kaolin Interest. V. 289, No. 7417, Oct. 14, 1977, p. 315.

[6]Albany slip clay is included with ball clay solely for statistical convenience.

[7]Bulletin of the American Ceramic Society. News Notes: K-T Purchases Bell Clay. V. 56, No. 2, February 1977, p. 231.

[8]Transferred in mid-1976 within the Panhandle and Eastern Co. from the Youghiogheny and Ohio Coal Co. to the Aurora Metal Co.

[9]Pit and Quarry. Industry News: Bentonite Production Facilities Under Construction in Montana. V. 170, No. 6, December 1970, p. 40.

[10]Industrial Minerals. Company News and Mineral Notes. No. 115, April 1977, p. 47.

[11]Brick and Clay Record. Industry Newsfront. V. 169, No. 4, September 1977, p. 13.

[12]Page 49 of work cited in footnote 10.

[13]Engineering and Mining Journal. This Month In Mining: In the Pacific-Australia. V. 178, No. 9, September 1977, p. 358.

[14]Industrial Minerals. World of Minerals: Brazil-Kaolin Project No. 2. Uses Huber Technology. No. 121, October 1977, pp. 10-11.

[15]Industrial Minerals. Company News and Mineral Notes. No. 121, October 1977, p. 48.

[16]Page 49 of work cited in footnote 10.

[17]Industrial Minerals. Company News and Mineral Notes. No. 123, December 1977, p. 69.

[18]Industrial Minerals. World of Minerals: France-ECC Takes Over Berrien Kaolin. No. 115, April 1977, p. 13.

[19]Industrial Minerals. Company News and Mineral Notes. No. 120, September 1977, p. 69.

[20]Industrial Minerals. Company News and Mineral Notes. No. 117, June 1977, p. 66.

[21]Industrial Minerals. Company News and Mineral Notes. No. 114, March 1977, p. 44.

[22]U.S. Embassy, New Delhi, India. State Department Airgram A-225, Dec. 6, 1977, 9 pp.

[23]Industrial Minerals. World of Minerals: Japan-Kaolin Takeover. No. 120, September 1977, p. 11.

[24]Page 67 of work cited in footnote 19.

[25]Mining Journal (London). Industry In Action: Exploration-Pakistan Mineral Survey. V. 289, No. 7404, July 15, 1977, p. 49.

[26]Industrial Minerals. Company News and Mineral Notes. No. 122, November 1977, p. 78.

[27]Industrial Minerals. Company Notes and Mineral Notes. No. 116, May 1977, p. 58.

[28]Page 65 of work cited in footnote 15.

[29]Industrial Minerals. World of Minerals: U.K.-Greenlight For Arne Ball Clays. No. 115, April 1977, p. 14.

[30]Schultze, L. E., D. J. Bauer, and J. A. Eisele (assigned to U.S. Department of the Interior). Removal of Iron From Aluminum Nitrate. U.S. Pat. 4,032,613, June 18, 1977.

[31]Colorado School of Mines Research Institute (Golden, Colo.). Evaluation of The Environmental Factors Involved in Metallurgical Processes To Utilize Domestic Resources for Production of Alumina. BuMines Contract JO 275040, Sept. 30, 1977; available for consultation in Division of Metallurgy, Washington, D.C.

PEDCO Environmental, Inc. (Cincinnati, Ohio). Evaluation of the Environmental Factors Involved in Metallurgical Processes To Utilize Domestic Resources for Production of Alumina. BuMines Contract JO 275047, Sept. 30, 1977; available for consultation in Division of Metallurgy, Washington, D.C.

[32]Bengtson, K. B., P. Chuberka, L. E. Malm, A. E. McLaughlin, R. F. Nunn, and D. L. Stein. Alumina Process Feasibility Study and Preliminary Pilot Plant Design. Task I Final Report. Comparison of Six Processes (research done under Contract No. JO 265048 by Kaiser Engineers, Oakland, Calif.) BuMines Open File Report 18-78, 1978, 256 pp.; available for reference at Bureau of Mines facilities in Tuscaloosa, Ala., Avondale, Md., Twin Cities, Minn., Rolla, Mo., Boulder City and Reno, Nev., Albany, Oreg., and Salt Lake City, Utah, and at the National Library of Natural Resources, U.S. Department of the Interior, Washington, D.C.

[33]Landsberg, A. Some Factors Affecting the Chlorination of Kaolinitic Clay. Metall. Trans., v. 8B, September 1977, pp. 435-441.

[34]Liles, K. J., and H. Heystek. The Bureau of Mines Test Program for Clay and Ceramic Raw Materials. BuMines IC 8729, 1977, 28 pp.

[35]Husted, J. E. An Integrated Aluminum Industry for the Southeast-Concerns and Outlook. Min. Cong. J., v. 63, No. 9, September 1977, pp. 28-33.

[36]Willhoft, E.M.A. Recovering Aluminum Values From Aluminum-Containing Materials. Brit. Pat. 1,472,683, May 4, 1977.

[37]Harbin, P. The Industrial Minerals of Japan, Part 1. Industrial Minerals, No. 118, July 1977, pp. 17-49.

[38]Harbin, P. The Industrial Minerals of Japan, Part 2. Industrial Minerals, No. 119, August 1977, pp. 15-39.

[39]Manos, A. The Industrial Minerals of South Africa. Industrial Minerals, No. 122, November 1977, pp. 16-65.

[40]Industrial Minerals. The Industrial Minerals of Thailand. No. 117, June 1977, pp. 19-37.

[41]Industrial Minerals. Sillimanite Minerals: Synthetics Encroaching on Markets. No. 117, June 1977, pp. 41-59.

[42]Hicks, J.C. Refractory Raw Materials: Status of Supply. Bull. Am. Ceram. Soc., v. 56, No. 9, September 1977, pp. 774-776, 780.

[43]Patterson, S. H. The Geology of Georgia Kaolin Deposits-Progress and Problems. Pres. at Ann. Meeting, Soc. Min. Eng., AIME, Atlanta, Ga., Mar. 6-10, 1977, SME Preprint 77-H-16, 8 pp.

[44]Keller, W. D. Scan Electron Micographs of Kaolins Collected From Diverse Environments of Origin-IV. Georgia Kaolin and Kaolinizing Source Rocks. Clays and Clay Minerals, v. 25, No. 5, October 1977, pp. 311-346.

[45]Industrial Minerals. Pulp and Paper as a Market for Industrial Minerals. No. 123, November 1977, pp. 17-49.

[46]Leonard, A. J. Structural Analysis of the Transition Phases in the Kaolinite-Mullite Thermal Sequence. J. Am. Ceram. Soc., v. 60, No. 1-2, January-February 1977, pp. 37-43.

[47]Cameron, W. E. Compositions and Cell Dimension of Mullite. Bull. Am. Ceram. Soc., v. 56, No. 11, November 1977, pp. 1003-1007, 1011.

[48]Fisher, R. E. Hot Strength of Phosphate-Bonded Refractory Plastics. Bull. Am. Ceram. Soc., v. 56, No. 7, July 1977, pp. 637-639.

[49]Kingery, W. D. Fundamental Study of Phosphate Bonding in Refractories: I-III. J. Am. Ceram. Soc., v. 33, No. 8, August 1950, pp. 239-250.

[50]Cassidy, J. E. Phosphate Bonding Then and Now. Bull. Am. Ceram. Soc., v. 56, No. 7, July 1977, pp. 640-643.

[51]Heine, H. J. Steel Founder's T and O Conference Scores Again. Foundry Management and Technical, v. 105, No. 2, February 1977, pp. 82-91.

[52]Griffin, R. A., R. R. Frost, A. K. Au, G. D. Robinson, and N. F. Shimp. Attenuation of Pollutants in Municipal Landfill Leachate by Clay Minerals. Part 2—Heavy-Metal Adsorption. Ill. State Geol. Survey (Urbana, Ill.), Environmental Geol. Notes, No. 79, April 1977, 47 pp.

Cobalt

By Scott F. Sibley[1]

There was a moderate increase in demand for cobalt in 1977 compared with that of 1976. Total reported consumption of cobalt in the United States was 16,577,000 pounds, a small increase over that of 1976. An increase in commercial aircraft engine production accounted for the significant recovery in consumption of superalloys from the relatively low levels of 1976. Consumer stocks reached a record monthly high of 3.1 million pounds in August but declined in the last quarter.

Zaire reportedly made increased use of the Tazara rail line linking Zambia, Zaire's southern neighbor, with the port of Dar es Salaam in Tanzania to the east. However, the principal shipment route for Zairian copper, of which cobalt is a byproduct, was southerly, via Zambia, Southern Rhodesia, and Botswana to the Republic of South Africa's port of East London. Much of Zaire's cobalt production was also shipped to Zaire's own port of Matadi on the Atlantic, a route that is much less vulnerable to disruption than the southern route.

The cobalt stockpile goal of 85.4 million pounds announced by the General Services Administration (GSA) in October 1976 was reaffirmed in October 1977, subject to annual review. The actual stockpile inventory at yearend totaled 40.9 million pounds. Legislation regarding purchases or sales of critical commodities for the stockpile was pending in Congress at yearend.

Table 1.—Salient cobalt statistics

(Thousand pounds of contained cobalt)

	1973	1974	1975	1976	1977
United States:					
Consumption	18,741	18,861	12,787	16,482	16,577
Imports for consumption	19,238	16,122	6,608	16,487	17,548
Stocks, Dec. 31: Consumer	2,451	2,047	1,801	3,180	3,738
Price: Metal, per pound	\$2.45-\$3.10	\$3.10-\$3.75	\$3.75-\$4.00	\$4.00-\$5.40	\$5.20-\$6.40
World production, mine	64,856	68,090	[r]68,000	[r]62,394	65,222

[r]Revised.

DOMESTIC PRODUCTION

Although no cobalt was produced from domestic mining operations in 1977, AMAX Inc., recovered significant quantities from imported matte at its Port Nickel refinery in Braithwaite, La. AMAX announced in October that production at the refinery would be held to 75% of capacity. Nickel and cobalt production were expected to be maintained at the reduced rate until mid-1978, at which time a review of the market situation was to be made to set production levels for the rest of 1978. The move reportedly was made to avoid excessive inventories. Consequently, shipment levels were expected to match production levels closely in 1977 and 1978. According to AMAX's annual report, 487,000 pounds of cobalt were produced at the facility in 1977.

AMAX Exploration, Inc., conducted the preliminary development phase of its Minnamax copper-nickel-cobalt project in northwestern Minnesota. The purpose of the activity at the site was to (1) determine the continuity of mineralization through diamond drilling; (2) determine the mining and environmental parameters; and (3) excavate bulk samples for concentrating tests. About 25,000 tons of ore per day could eventually be produced from the ore body, which grades about 0.01% cobalt. A shaft was sunk to a depth of 1,728 feet, and by yearend 3,600 feet of drifting was to have been completed. Baseline environmental studies were also conducted in cooperation with the Minnesota Department of Natural Resources. The mine evaluation was scheduled for completion by the end of 1981, at which time a decision on whether to proceed would be made. If results are favorable, mining would not begin until the mid-1980's.

Metallurgie Hoboken-Overpelt, S.A., of Belgium, early in the year announced that it would undertake detailed studies on the construction of a plant in the United States to produce extra-fine cobalt powder. Tentative plans called for construction of a plant with an annual capacity of about 1 million pounds per year of extra-fine cobalt metal powder, to be in operation by 1980. By yearend, no announcement had been made on selection of a plant site. In a related significant development, GTE Sylvania Corp. announced that it planned to produce extra-fine cobalt powder, using secondary material as feedstock (See section on Technology).

CONSUMPTION AND USES

Consumption of cobalt in the United States remained strong throughout 1977, rising 0.6% over that reported in 1976. Of the cobalt consumed, 70% was as metal, 23% as salts and driers, 3% as oxide, 3% as purchased scrap, and 1% in other forms. Consumer stocks at yearend remained at a relatively high level, reflecting a continuing concern over the possibility of disruption of supply from southern Africa.

Major uses in 1977 were transportation (aircraft) (24%), electrical (magnets) (25%), machinery (principally cutting tools) (16%), paints (mainly driers) (15%), ceramics (11%), chemicals (8%), and other (1%).

A conference on the market for cobalt-rare earth magnets, sponsored by Gorham International, Inc., was held in late September near Chicago, Ill. Reportedly, the market for these magnets could expand from $6 million per year to $100 million per year in 1987. The magnets are especially useful because of their greater energy product compared with other types of magnets of the same size. The automotive industry was especially interested in cobalt-rare earth magnets because of the possibilities for weight reduction in such devices as wiper motors, electric fuel pumps, fan motors, distributors, and other uses. The ultimate potential for use of cobalt-rare earth magnets was estimated at 2.2 pounds per car. These magnets were too expensive for automotive use in 1977, but the mischmetal-cobalt (a combination of rare-earth metals and cobalt) magnet cost was entering the price range where it would be attractive to the automotive industry. If the auto indus-

Table 2.—Comparison of selected end uses, 1976-77

Use	Percent of total 1976	Percent of total 1977
Steel:		
Stainless and heat resisting	0.3	0.5
Full alloy	1	2
Tool	1	2
Superalloys	17	22
Alloys (excludes alloy steels and superalloys):		
Cutting and wear-resistant materials	10	9
Welding and alloy hard-facing rods and materials	3	3
Magnetic alloys	21	21
Nonferrous alloys	5	4
Chemical and ceramic uses:		
Pigments	1	1
Catalysts	9	8
Ground coat frit	.5	.5
Glass decolorizer	.2	.2
Salts and driers	24	23

Table 3.—Cobalt materials consumed by refiners or processors in the United States

(Thousand pounds of contained cobalt)

Form[1]	1973	1974	1975	1976	1977
Alloy and concentrate[2]	14	245	340	1,186	266
Metal	4,028	4,754	3,162	5,001	4,772
Hydrate	60	46	41	47	40
Other	26	153	110	130	77

[1]Total consumption is not shown because some metal and hydrate originated from alloy and concentrate, and a total would involve duplication.
[2]For 1974-77, quantity given is cobalt content of imported matte (general imports).

Table 4.—Cobalt products[1] produced and shipped by refiners and processors in the United States

(Thousand pounds)

	1976				1977			
	Production		Shipments		Production		Shipments	
	Gross weight	Cobalt content	Gross weight	Cobalt content	Gross weight	Cobalt content	Gross weight	Cobalt content
Metal	363	363	NA	NA	487	487	NA	NA
Hydrate	952	588	730	451	1,046	647	950	588
Salts[2]	10,876	2,545	10,888	2,444	9,929	2,334	9,324	2,161
Driers	12,783	1,112	12,551	1,089	12,972	1,095	11,897	1,029
Total	24,974	4,608	24,169	3,984	24,434	4,563	22,171	3,778

NA Not available.
[1]Figures on oxide withheld to avoid disclosing company proprietary data.
[2]Various salts combined to avoid disclosing company proprietary data.

Table 5.—U.S. consumption of cobalt in 1977, by end use

(Thousand pounds of contained cobalt)

Use	Quantity
Steel:	
Carbon	[1]
Stainless and heat resisting	75
Full alloy	359
High strength, low alloy	W
Electric	W
Tool	307
Cast irons	W
Superalloys	3,712
Alloys (excludes alloy steels and superalloys):	
Cutting and wear-resistant materials[2]	1,428
Welding and alloy hard-facing rods and materials	442
Magnetic alloys	3,478
Nonferrous alloys	650
Other alloys	276
Mill products made from metal powder	W
Chemical and ceramic uses:	
Pigments	187
Catalysts	1,285
Ground coat frit	78
Glass decolorizer	27
Other	6
Miscellaneous and unspecified	489
Total	12,799
Salts and driers: Lacquers, varnishes, paints, ink, pigments, enamels, glazes, feed, electroplating, etc	3,778
Grand total	16,577

W Withheld to avoid disclosing company proprietary data; included in "Miscellaneous and unspecified."
[1]Less than 1/2 unit.
[2]Includes cemented and sintered carbides and cast carbide dies or parts.

Table 6.—U.S. consumption of cobalt, by year and form

(Thousand pounds of contained cobalt)

Form	1973	1974	1975	1976	1977
Metal	14,240	14,420	9,202	11,706	11,547
Oxide	668	536	372	462	426
Purchased scrap	264	270	342	329	507
Other	(1)	(1)	(1)	(1)	319
Salts and driers	3,569	3,635	2,871	3,985	3,778
Total	18,741	18,861	12,787	16,482	16,577

[1]Included in purchased scrap.

try should decide to make greater use of cobalt, production of cobalt might increase by 20% to 40% in response to this new demand.

A special technical problem of the energy industry resulted in expanded usage of cobalt-containing alloys. Gas wells drilled to depths of about 20,000 feet may encounter severe operating conditions. These conditions include (1) high corrosion because of the presence of up to 40% hydrogen sulfide (sour gas), (2) bottom hole pressures of about 20,000 pounds per square inch; and (3) temperatures of about 380° F. To avoid frequent replacement of well tubing, the petroleum industry reportedly turned to special alloys, one of which was MP35N, containing 34.4% cobalt. Using this alloy, lifetime of tubing could be multiplied at least tenfold. Moreover, because a constant tubing diameter could be maintained, gas production per well could be doubled. This alloy was used in such parts as logging tools, valve stems on wellheads, springs, and safety valve systems.[2]

PRICES

The producer cobalt price of $5.40 per pound at the beginning of the year was lowered to $5.20 per pound in January. In July, the price was raised to $6.00 per pound. The last increase in price occurred in December, when the price was raised to $6.40 per pound. The first price change reportedly was the result of a currency realinement of the U.S. dollar versus the Belgian franc; the second was brought about by increased mining costs. The December increase was brought about by weakening of the U.S. dollar versus the Belgian franc. The weighted average price of cobalt for the year was $5.58 per pound for specification-grade material. All dealer prices were quoted f.o.b. New York or Chicago and applied to granules (shot) or broken cathodes in 551-pound (250-kilogram) drums. From December 1972 to December 1977, the price of cobalt rose at an annual rate of 20%, not adjusted for inflation. In terms of 1977 dollars, the price increase averaged 13% per year over the same 5-year period. These price increases may be compared with average annual increases for a 20-year period (1957-77) of 5% and 1% for actual and adjusted prices, respectively.

FOREIGN TRADE

Exports of unwrought cobalt metal and waste and scrap totaled 1,842,877 pounds, gross weight, valued at $4,974,026, and were shipped to 20 countries. The Federal Republic of Germany and Japan received the largest quantity—476,804 pounds (gross weight) valued at $621,906 and 466,700 pounds (gross weight) valued at $883,799, respectively. Exports of wrought cobalt metal and alloys—741,839 pounds gross weight valued at $6,175,305—were shipped to 27 countries.

Total imports of cobalt (17,548,000 pounds, contained weight) were up 6% over those of 1976. The top five sources of cobalt imports to the United States in 1977 were Zaire (43%), Belgium-Luxembourg (22%), Zambia (14%), Finland (7%), and Norway (5%). Material originating in southern Africa (that imported from Zaire, Zambia, Belgium-Luxembourg, and Botswana) accounted for 79% of total imports. The reported figure for imports from Botswana was the estimated cobalt content of the material received for processing.

Table 7.—U.S. imports for consumption of cobalt, by country

(Thousand pounds and thousand dollars)

Country	Metal[1]				Oxide				Other forms[2]				Total content[3]	
	1976		1977		1976		1977		1976		1977		1976	1977
	Gross weight	Value	Gross weight	Value	Gross weight	Value	Gross weight	Value	Content	Value	Content	Value[4]		
Australia	3	10	12	34	(5)	2	--	--	(5)	(5)	--	--	3	12
Belgium-Luxembourg	2,420	12,882	3,398	21,607	138	569	495	2,305	19	81	r59	303	2,541	3,824
Botswana	--	--	--	--	--	--	--	--	1,049	r2,795	71	r237	1,049	71
Canada	738	3,142	657	3,600	--	--	11	41	(5)	1	--	--	738	665
Finland	844	3,810	1,282	7,311	--	--	--	--	--	--	--	--	844	1,282
France	291	869	436	1,822	--	--	--	--	--	--	--	--	291	436
Germany, Federal Republic of	660	2,733	118	638	(5)	1	--	--	(5)	(5)	--	--	660	118
Ireland	--	--	--	--	(5)	1	--	--	--	--	--	--	(5)	--
Japan	178	839	55	239	--	--	--	--	--	--	r3	18	178	58
Mexico	--	--	1	(5)	--	--	--	--	--	--	--	--	--	1
Netherlands	87	170	16	51	--	--	--	--	--	--	--	--	87	16
New Caledonia	--	--	--	--	--	--	--	--	137	r365	196	r655	137	196
Norway	1,130	4,674	799	4,048	--	--	--	--	--	--	--	--	1,130	799
Singapore	--	--	--	--	--	--	--	--	--	--	r1	9	--	1
South Africa, Republic of	--	--	--	--	--	--	--	--	--	--	(5)	(5)	--	(5)
Spain	--	--	44	232	--	--	--	--	--	--	--	--	--	44
Sweden	--	--	--	--	--	--	--	--	--	--	r1	6	--	1
Switzerland	(5)	3	1	4	--	--	--	--	--	--	--	--	(5)	1
Tanzania	--	--	21	100	--	--	--	--	--	--	--	--	--	21
United Kingdom	259	594	110	261	(5)	(5)	--	--	51	283	r10	45	310	119
U.S.S.R	10	42	--	--	--	--	--	--	--	--	--	--	10	--
Zaire	6,781	29,038	7,498	39,206	--	--	--	--	--	--	--	--	6,781	7,498
Zambia	1,728	7,493	2,385	12,228	--	--	--	--	--	--	--	--	1,728	2,385
Total	15,129	66,299	16,833	91,381	138	573	506	2,346	1,256	r3,525	r341	r1,273	16,487	17,548

rRevised.
[1]Includes unwrought metal and waste and scrap.
[2]Contained cobalt in nickel-copper and nickel matte for Botswana, New Caledonia, and the Republic of South Africa. Salts and compounds were imported from remaining countries.
[3]Estimated contained cobalt.
[4]Based on weighted average price for 1977, $5.58 per pound contained metal times 0.6, for imports from Botswana, New Caledonia, and the Republic of South Africa.
[5]Less than 1/2 unit, contained metal.

Table 8.—U.S. imports for consumption of cobalt, by class

(Thousand pounds and thousand dollars)

Class	1975	1976	1977
Metal:[1]			
Gross weight	6,092	15,129	16,833
Cobalt content[e]	6,092	15,129	16,833
Value	$25,611	$66,299	$91,381
Oxide:			
Gross weight	233	138	506
Cobalt content[e]	168	102	374
Value	$779	$573	$2,346
Salts and compounds:			
Gross weight	41	235	246
Cobalt content[e]	8	70	74
Value	$73	$365	$381
Other forms:[2]			
Gross weight	25,931	39,426	21,954
Cobalt content[e]	340	1,186	267
Value	$39,397	$70,293	$24,557
Total:			
Gross weight	32,297	54,928	39,539
Cobalt content[e]	6,608	16,487	17,548

[e]Estimate.
[1]Includes unwrought metal and waste and scrap.
[2]Contained cobalt in nickel-copper and nickel matte.

WORLD REVIEW

Ocean Mining.—The sixth session of the Third United Nations Conference on the Law of the Sea (LOS) began May 23 in New York and ended in late July. The composite negotiating text that emerged from the meetings was considered unacceptable by several principal participants. Another session was scheduled for March 1978 in Geneva, Switzerland. Failure of the international meetings to produce any acceptable results provided impetus to passage of domestic legislation to enable seabed mining.

Two bills dealing with seabed mining were debated in Congress. One bill was the Deep Seabed Hard Minerals Act (H.R.3350), introduced by Representative John B. Breaux of Louisiana and Representative John M. Murphy of New York. The second, the Deep Seabed Mineral Resources Act (S.2053), was introduced by Senator Lee Metcalf of Montana. One of the principal points of contention in domestic legislation was the issue of investment guarantees. Under this provision, companies would receive a monetary guarantee against investment losses that resulted from any treaty the United States might sign. A related controversial point was the question of whether or not an ocean mining fund should be established. Companies would pay into this fund an annual fee, and if an international law of the sea treaty eventually prohibited mining by private consortia, each consortium would be compensated from the fund up to a maximum of $350 million. Even in the absence of an investment guarantee, most proposals would require U.S. companies to obtain licenses from the U.S. Government. However, many observers agreed that an individual consortium already had the legal right to mine the ocean floor under existing international statutes. At yearend, chances for passage of an international treaty appeared remote, while passage of domestic legislation seemed imminent.

A leading ocean mining consortium, Ocean Mining Associates, reportedly began tests in March on recovering of manganese nodules from 15,000 feet of water in the Pacific Ocean. The tests were to last 6 to 8 months. The test system was approximately one-fifth scale. In 1970, the same organization demonstrated a nodule mining system in about 3,000 feet of water on the Blake Plateau off the coast of Florida. According to the group, these tests proved that nodules could be collected and airlifted to the surface. The consortium's oceanographic vessel, the *R/V Prospector*, conducted extensive exploration in the Pacific nodule area, where a mining claim was staked. The location for prospective mining operations was in the middle of a triangle formed by Hawaii, the Marquesas Islands, and Baja California. A converted, diesel-driven, 560-

foot ore carrier, renamed the *Deepsea Miner II*, was to be used for the mining platform. If the nodule lifting phase proved successful, a 10-ton-per-day pilot plant was to be constructed and operated.

Sumitomo Metal Mining Co., a major participant in the Ocean Management, Inc. (OMI), consortium, reportedly planned to begin construction of a seabed nodule testing plant at its Niihama smelter in Ehime Prefecture, Japan, late in 1977. The OMI consortium was composed of INCO, Ltd., of Canada (25%); West German interests, Arbeitsgemeinschaft Meerestechnische-gewinnbare Rohstoffe (AMR group) (25%); Deep Ocean Mining Co. (23 Japanese companies, including Sumitomo) (25%); and Sedco, Inc., of the United States (25%). Prior to plant construction, OMI planned to begin major mining equipment trials in the Pacific Ocean in October. As with the Ocean Mining Associates consortium, which began such tests in March of 1977, OMI scheduled a 6-month mining test phase during which about 3,306 short tons of nodules were to be lifted several thousand meters from the sea floor to the surface.

Australia.—As of the third quarter 1977, the Greenvale nickel-cobalt project continued to encounter financial difficulties. The laterite project, located in Queensland, is a joint venture of Freeport Queensland Nickel, Inc., and Metals Exploration Queensland, Pty, Ltd. The financial losses were attributed to a deterioration of the nickel market during the year, while costs of fuel, labor, and materials continued to rise. Nevertheless, output improved modestly in the third quarter and signs pointed toward improvement in 1978.

Because of these financial problems, operators of the Greenvale project reportedly canceled plans for a $17.6 million installation of two new roasters, which would have raised productive capacity substantially. In the first quarter of 1977, byproduct cobalt production at the Greenvale site was only 45% of capacity. About 438,000 pounds of cobalt in mixed sulfides were produced in the first quarter. In 1976, cobalt production reached 57% of capacity. Although the outlook brightened somewhat at yearend, operation of the Greenvale plant had been continuously impaired by technical difficulties since operations were begun in 1974.

The Electrolytic Zinc Co. of Australia Ltd. continued to produce byproduct cobalt oxide at its Risdon Works in Tasmania. About 40,000 pounds of cobalt oxide are produced at the plant annually.

Botswana.—The operations of the Selebi-Pikwe nickel-copper-cobalt project in Botswana were investigated in October by a team from AMAX Inc., and Anglo American Corp., two principal shareholders. The Selebi-Pikwe project, which is operated by Bamangwato Concessions, Ltd., and financed by Botswana RST Ltd., reportedly showed a $17.8 million loss in the first half of 1977. This brought total indebtedness to $301 million. The team attempted to find ways to increase production to yield a positive cash flow in the shortest possible time. High capital and operating costs, and numerous technical problems, combined to produce continual losses.

Production of matte at Selebi-Pikwe in the 6 months to June was about 12,500 tons, versus about 16,800 short tons produced during the same period of 1976. The decrease partially resulted from a 6-week smelter shutdown in April and May to modify equipment. However, production capacity reportedly was reached at least once at the project, in June. According to officials of Bamangwato Concessions, Ltd., the project achieved significant production improvements after installation or modification of major pieces of equipment, particularly at the smelter. Production first began in late 1973, and subsequently many problems, including lack of skilled labor and shortage of trained supervisors, were overcome. Situated 35 miles east of the main rail link connecting the Republic of South Africa with Southern Rhodesia, Zambia, and Zaire, the mining complex produced high-grade copper-nickel-cobalt matte (78% Ni plus Cu, and 1.25% Co) for shipment by rail to the Indian Ocean port of Maputo in Mozambique. From there, the material was shipped to the Braithwaite, La. refinery of AMAX Inc. Some of the refined metal was sold in the Federal Republic of Germany under contract. Production during the last quarter of 1977 was about 3,300 short tons of matte per month, an amount significantly less than capacity.

In November, officials of AMAX Inc., stated that a study of its Botswana interests was being initiated. AMAX holds a 29.8% interest in Botswana RST Ltd. The study followed the continuing deterioration of the copper market, as well as the aforementioned problems. It was expected to be completed by yearend.

Canada.—Cobalt production at the Fort Saskatchewan refinery of Sherritt Gordon Mines, Ltd., reached a record level of 1,012,000 pounds during the year. Feed material purchased for the plant during the first quarter allowed it to operate at increased capacity for the balance of the year. More than 1 million pounds of cobalt was also expected to be produced in 1978.

Falconbridge Nickel Mines Ltd. and INCO, Ltd. of Canada cut back nickel production during the year because of a relatively low demand for nickel. This was expected to reduce production of byproduct cobalt.

Indonesia.—According to reports at yearend, plans were still being made to go ahead with construction of the $900 million nickel-cobalt smelting project of P.T. Pacific Nikkel Indonesia, Ltd., (PNI). PNI is owned by United States Steel Corp. and Hoogovens Ijmuiden BV of the Netherlands. In early 1977, these were the only companies that remained of the original six American and European partners, including Sherritt Gordon Mines, Ltd., and Newmont Mining Corp. However, at midyear, Amoco Minerals Co., a subsidiary of Standard Oil Co. of Indiana, tentatively agreed to equity participation in the project.

In 1969, the Indonesian Government reportedly granted the original consortium the right to evaluate the Gag Island deposit, located near Irian Java. After extensive drilling, Pacific Nikkel outlined minable deposits in excess of 90 million tons of laterite ore. There was a possibility that the Indonesian Government would purchase 20% equity in the project. The company planned to produce about 55,000 short tons of nickel per year using Sherritt Gordon Mines, Ltd.'s, hydrometallurgical process.

Japan.—The Japanese Ministry of International Trade and Industry estimated that because of price increases in 1976, demand in 1977 would decline by 5% to 6 million pounds, a decrease from the 6.3 million pounds consumed in 1976. Magnetic materials were expected to account for about 47% of demand, and superalloys, about 12%. No further breakdown was available. Production of refined metal was expected to reach 3.3 million pounds, or about one-half of capacity. Because of reduced demand, imports were also expected to decline to about one-half that of 1976, or about 4.2 million pounds.

A manganese nodule processing plant was planned by Sumitomo Metal Mining Co. at its Niihama smelter, with construction to begin late in 1977. Sumitomo is a partner in the Deep Ocean Mining Co., which includes 23 Japanese companies that joined together in 1975. Deep Ocean Mining Co. in turn became a partner with other foreign interests in the OMI consortium.

Sumitomo Metal Mining Co. produced cobalt at the rate of about 80 short tons per month by midyear, while Nippon Mining Co. produced at only about 50 short tons per month. The latter rate was about 50% of capacity. Demand for cobalt in Japan reportedly was 200 to 250 short tons per month.

Philippines.—Mechanical problems at the Nonoc Island refinery of Marinduque Mining & Industrial Corp. in Surigao Province, reportedly continued to hold down production, but the situation improved in late 1977. The refinery was shut down for annual maintenance and installation of a new boiler late in 1976. Operation at about 55% of design capacity of 3.3 million pounds per year of cobalt was reached during January and February 1977. According to company officials, the mechanical difficulties were being resolved but were taking longer than anticipated to overcome. The operation experienced considerable financial difficulty during the year, partly because of strong downward pressure on world nickel prices. As a result, the firm fell into technical noncompliance with terms of a 1975 loan agreement that refinanced the project. This meant that under certain circumstances creditors could begin to insist on accelerated payment of debt. The underlying financial problem was the maintenance of certain working capital and stockholders' equity levels. At midyear, it was announced that the Development Bank of the Philippines had agreed to provide assistance in meeting debt service and working capital requirements. By yearend, the project was expected to reach at least 60% of capacity. Operations were begun at the Surigao facility in October of 1974.

Marinduque reportedly planned to construct a cobalt refinery in the Philippines to refine 7 million pounds per year of cobalt contained in mixed sulfide concentrates. The $16 million project was expected to be financed by the Asian Development Bank. Concentrates currently produced are sent to Japan for refining. If a capacity production of 7 million pounds per year of cobalt metal were reached, the Philippines would be among the top five producers of refined cobalt in the world. Company officials planned to increase capacity to improve the profitability of existing operations at the Nonoc Island nickel-cobalt processing facility. Marinduque expected to maintain the 1977 nickel production level in 1978, thereby limiting cobalt production.

Zaire.—The invasion of Shaba Province in early 1977 by troops based in Angola apparently had little effect on cobalt production in, or shipments from, Zaire. However, the Benguela Railroad through Angola remained closed during the year. The major portion of Zaire's cobalt production was shipped out of the country via rail and barge to the Atlantic port of Matadi at the mouth of the Congo River.

Construction of the 1,200-mile Inga-Shaba high-tension transmission line was halted early in the year. Morrison-Knudson Corp., the U.S. contractor, withdrew its engineering team from Kolwezi, delaying further the startup of new expansion projects. One of these expansions was the Tenke Fungurume copper-cobalt project, which was to be postponed and scaled down because of cost escalation and civil disturbances. Two principal partners in the project were Charter Consolidated, Ltd., and Amoco Minerals Co., along with Japanese and French interests. Cobalt content of the resource was estimated at 0.45% Co or about 250,000 short tons of cobalt metal. At yearend, various foreign partners of the Zaire Government in the consortium, Société Minière de Tenke Fungurume (SMTF), proposed a scaled down project, in which 10,000 short tons of copper-cobalt concentrates would be delivered to the Zairian state company Générale des Carrière et des Mines (GECAMINES) for refining. The new project would cost $14 million in comparison with the original project cost estimate of $800 million. Target capacities of the aborted project were 130,000 short tons of refined copper and 6,500 tons of cobalt. However, promoters of the smaller project reportedly were having difficulty obtaining loans. By yearend, $280 million had been spent on the original project to build the basic infrastructure.

According to reports, Zaire made increasing use of the Tazara rail line linking Zambia with Tanzania's port of Dar es Salaam. However, the principal shipment route for Zairian copper and minor amounts of cobalt was through Zambia, Southern Rhodesia, and Botswana to the Republic of South Africa's port of East London. These shipments amounted to about 24,000 short tons of metal per year. In March, April, May, and June, Zaire shipped 836, 1,320, 1,540, and 1,540 short tons of metal, respectively, on the Tazara line. Transportation costs for the Tazara route reportedly were about $13 per ton cheaper than those of the longer southern route. Zambia made greater use of the Tazara line, since it was for Zambian metal that the rail line was originally built under contract with the People's Republic of China. Although the capacities of both the rail line and the port of Dar es Salaam were limited, Zaire was expected to make greater use of the rail line in the future because of the greater vulnerability to disruption of the southern route.

An official of Société Générale des Minerais (SGM) of Belgium, in remarks prepared for a meeting of the National Association of Recycling Industries in Pittsburgh, stated that expanded production of cobalt in Zaire and Zambia should provide a supply of cobalt sufficient to enable projected world demand through 1985 to be met. The expansion of the Chambishi plant of Roan Consolidated Mines, Ltd., in Zambia was to add 4 million pounds to its production by the end of 1978. Moreover, GECAMINES in Zaire was expected to raise its production by 12 million pounds per year to 42 million pounds per year by mid-1978. The latter expansion was part of a major investment program already financed and underway. In addition, GECAMINES was studying the possibility of recovering significant quantities of cobalt from residues accumulated in stockpiled tailings. If these programs come onstream as scheduled, cobalt production in Zaire could reach 40 to 50 million pounds per year by about 1980.

Zambia.—Zambia relied principally on the Tazara railway to transport copper and cobalt out of the country. Although transportation was not as serious a problem as it was in former years, loss of expatriate personnel and low copper prices continued to plague the mining operations. Production was not seriously impeded and expansions were planned. According to reports, Zambia planned to double its cobalt production in 1979 to about 8 million pounds per year. This was to be accomplished by expansion of the Chambishi facility, Roan Consolidated Mines, Ltd., on the Copperbelt.

Zambia and Angola reportedly planned a rail link with Zambia's Copperbelt, thereby bypassing Zaire. The line would run from Mwinilungo in Zambia to the town of Luena in Mexico Province, Angola, where it would connect with the Benguela railway. Although Zambia did not rely on Southern Rhodesia's transport system, its common border with Southern Rhodesia resulted in numerous conflicts.

Table 9.—Cobalt: World production, by country

(Short tons)

Country	Mine output, metal content[1]			Metal[2]		
	1975	1976	1977[p]	1975	1976	1977[p]
Australia	2,986	3,741	3,759	--	--	--
Botswana	89	165	182	[e]9	[3]78	[e]90
Canada[4]	[r]1,492	1,494	1,662	[r]280	328	506
Cuba[e]	1,800	1,800	1,800	--	--	--
Finland	1,545	1,410	1,462	[r]904	983	1,086
France	--	--	--	[r]848	874	[e]940
Germany, Federal Republic of	--	--	--	375	[e]385	[e]385
Japan	--	--	--	53	568	1,205
Morocco	2,162	950	1,721	--	--	--
New Caledonia[e 5]	[r]3,770	4,570	4,630	--	--	--
Norway[6]	NA	NA	NA	852	635	777
Philippines	[r]129	567	1,195	--	--	--
U.S.S.R.[e]	[r]2,000	2,000	2,100	[r]2,000	2,000	2,100
United Kingdom[e 7]	--	--	--	510	760	890
United States	--	--	--	33	182	244
Zaire	[e]15,400	[e]12,100	[e]11,600	15,033	11,779	11,260
Zambia	[r]2,627	[e]2,400	[e]2,500	[r]2,032	1,786	1,877
Total	[r]34,000	31,197	32,611	22,929	20,358	21,360

[e]Estimate. [p]Preliminary. [r]Revised. NA Not available.

[1]In addition to the countries listed, Bulgaria, Cyprus, the German Democratic Republic, Greece, Poland, the Republic of South Africa, Spain, Sweden, and Uganda are known to produce nonferrous ores that contain recoverable amounts of cobalt, but recovery, if any, from ore produced in these countries is not reported, and available general information is inadequate to permit formulation of reliable estimates of output levels. Other copper and/or nickel producing nations neither listed in the body of the table nor in the preceeding part of this note also may produce ores containing cobalt as a byproduct component.

[2]Czechoslovakia presumably recovers cobalt from materials from Cuba. Belgium continues to refine cobalt but output is not reported and available general information is inadequate for the formulation of reliable estimates of output levels.

[3]Sales.

[4]Actual output is not reported. Data presented for mine output are total cobalt content of all products derived from ores of Canadian origin, including nickel oxide sinter shipped to the United Kingdom for further processing, and nickel-copper-cobalt matte shipped to Norway for further processing. Data presented for metal output represent the output within Canada of metallic cobalt from ores of both Canadian and non-Canadian origin.

[5]Series revised to reflect estimated total cobalt contained in all ores mined, rather than only the cobalt content of ferronickel and nickel matte produced in New Caledonia. Corresponding figures for other recent years are as follows in short tons: 1972—3,110; 1973—3,300; 1974—3,930. The estimated cobalt content of metallurgical products produced in New Caledonia (nickel matte and ferronickel) for recent years is as follows, in short tons: 1972—1,870; 1973—1,920; 1974—2,120; 1975—2,260; 1976—2,040; 1977–1,720. The user of this data is cautioned that not all of the cobalt contained in either the total ore production or in the intermediate metallurgical products is recovered as cobalt or cobalt chemicals; a significant part of the total output remains in nickel products.

[6]Data on domestic mine production, if any, are not available, but if output has continued, a small part of the recorded metal output may be from domestic raw materials, rather than from imported Canadian nickel-copper-cobalt matte.

[7]Estimated recovery of elemental cobalt and cobalt in compounds from intermediate metallurgical products from Canada.

TECHNOLOGY

The Bureau of Mines conducted research during the year on four separate projects dealing with cobalt. Researchers at the Albany Metallurgy Research Center, Albany, Oreg., continued to develop a process for recovering nickel, cobalt, and copper from the laterites of northern California and southern Oregon. Research on the process was initiated in 1971 and progressed from batch tests to tests of 20 pounds per hour of laterites in semicontinuous processing circuits in 1974. After a technical study showed the feasibility of the process, a development unit was constructed and completed in September 1977. The continuous circuit unit processes 1 ton per day of laterite material. As part of the process being used, a procedure was developed for recovery of cobalt from ammoniacal nickel raffinate solutions by solvent extraction-electrowinning. Cobalt was extracted in one stage with an experimental reagent supplied by industry. Ammonia was removed from the loaded reagent in two water-ammonium sulfate wash stages and one dilute acid wash. Cobalt was then stripped from the organic extractant in one stage with the cobalt electrolyte and electrowon in a nondiaphragm cell.

At the Rolla Metallurgy Research Center, a froth flotation technique that isolated the cobalt and nickel fractions in a flotation residue was under development. Success in laboratory-scale tests led to a cooperative agreement with Cominco American Corp. to install a 60-kilogram-per-hour demonstration unit in its Magmont mill near Bixby, Mo. A small fraction of the Magmont circuit was diverted to the demonstration plant. Composition of the diverted stream ranged from 0.3% to 1.3% cobalt. Over 60% of the contained nickel and cobalt was recovered in the flotation residue, which graded higher than 5% cobalt. Ongoing research was directed toward recovery of the upgraded product by various hydrometallurgical techniques. On an annual basis, the unprocessed concentrates in the Missouri region contained about 650,000 pounds of cobalt.

Work continued at the Twin Cities (Minn.) Metallurgy Research Center on recovery of nickel, cobalt, and platinum-group metals from the Duluth Gabbro, located near Ely, Minn. Pyrometallurgical procedures were used to produce low-iron mattes from bulk sulfide concentrates. Cobalt recovery in this stage was 80%. A two-stage sulfuric acid leach was used to extract and separate the copper and nickel values from the matte. Efforts of the researchers were directed toward development of techniques for optimum recovery of cobalt.

The Caron process, which consists of a reductive roast and ammonia leach treatment, was used to obtain favorable metal recoveries from Pacific Ocean nodules at the Salt Lake City Metallurgy Research Center. Various hydrometallurgical techniques to recover manganese, copper, nickel, and cobalt from the nodules were tested.

Kennecott Copper Corp. developed a new hydrometallurgical process for extracting nickel, copper, cobalt, and molybdenum from manganese nodules. The process (termed the Cuprion Process) involved reduction leaching at atmospheric pressure in the temperature range of 45° C to 50° C. A pilot plant that continuously processed 800 pounds of nodule ore per day reportedly was successful. In the process, an ammonium carbonate solution, containing cuprous ions, is contacted with the nodules in order to leach the metal content. Cobalt is recovered along with molybdenum by chemical means after nickel and copper are recovered by liquid ion exchange and electrowinning. The leaching reagents are recyclable. However, carbon monoxide is consumed for reduction and is one of the major cost items. Manganese is rejected to the tailings. Incremental quantities of manganese can be recovered, depending on market conditions.[3]

Improvements in corrosion-resistant, nickel-based, superalloys reportedly were made by a leading British research company. The firm's efforts were concentrated on overcoming the deleterious effects of the prime corrosive agents, sodium sulfate and sodium chloride. Marketed under the trade names NIMONIC and NIMOCAST, the alloys contain about 20% cobalt. The corrosion resistance of the alloys was significantly increased through addition of 20% to 30% chromium, and a former tendency toward decreased creep resistance and formation of an embrittling phase after addition of chromium was largely overcome. The alloys were particularly well suited to marine environments but could also be used in other applications, such as for valves in automobiles and diesel engines. Moreover, with respect to the alloy itself, the fuel or incoming air used in gas turbines would require less purification.[4]

Several leading superalloy manufacturers reportedly were active in research to develop directionally solidified (d/s) eutectic alloys. One promising series of nickel-based alloys are the "nitacs" - an acronym for nickel, tantalum, and carbide. These alloys contain 50% to 55% nickel, with lesser amounts of cobalt, chromium, rhenium, and hafnium. Tantalum carbides in the alloy form rods about 25 microns in diameter in a conventional superalloy matrix. The objective of the research was to develop an alloy that could be used for airfoils in jet engines at temperatures up to 2,000° F, or about 250° F higher than temperatures that superalloys marketed in 1977 could withstand.

According to one company official, an alloy of this type might be ready for engine tests in 1980 and be in use by 1982. Stress-rupture properties have been tested, and work was to focus next on fabrication of hollow airfoils. Two principal disadvantages of the alloys were (1) melting for casting takes place at over 3,000° F, too high for conventional molds in investment casting; and (2) excessive time is required for grain growth in the d/s process. Alternative materials and techniques were being tried in order to correct these problems.

According to reports, a principal maker of superalloys developed a powder metal alloy for valve seat inserts. The alloy could double the life of rebuilt diesel truck engines. Reportedly, the inserts have twice the wear resistance and 65% higher transverse rupture strength than the cast insert they were designed to replace. The alloy contained 31% chromium, 12.5% tungsten, and 2.3% carbon, with residuals of nickel, iron, and manganese; the balance was cobalt. Because of the homogeneous microstructure and the fine grain size inherent in powder metal materials, the alloy can withstand temperatures to about 900° C. The inserts were also proposed as original equipment in the manufacture of diesel engines. [5]

Increased recycling of cobalt contained in cemented carbides resulted from development work performed by a leading alloy manufacturer, Metallurgical International, Inc. New equipment designed to process cemented carbide scrap reportedly increased the company's productive capacity of carbide powders by 50% and permitted production of high-purity, coarse-grained material. Residual titanium and tantalum contents of the carbide powders were reported to be virtually undetectable, and depletion of the original carbon was almost nonexistent. The powders were suited for production of cemented carbide used for metal cutting tools, mining drill bits, steel mill rolls, and drawing and forming dies.

A significant related development was announced by the major cemented carbide producer, GTE Sylvania Corp. The company announced plans to produce extra-fine cobalt powder suitable for use in cemented carbide cutting tools, using secondary material as feedstock; future plans included sale of the powder as well as its use in the firm's operations. Until this development, this special powder had been produced for U.S. consumption mainly by Metallurgie Hoboken Overpelt in Belgium. Officials stated that the process was proprietary and that the new operation would be housed in a 25,000-square-foot addition to the company's existing plant in Towanda, Pa. The plant was scheduled to be completed by yearend and the product was to be placed on the market during the first quarter of 1978.[6] In a related development, according to the annual report of Sherritt Gordon Mines, Ltd., a new extra-fine grade of cobalt powder suitable for maufacture of carbide parts, and an improved cobalt-tungsten carbide composite powder to be used for wear-resistant coatings, were produced in development quantities.

Japanese researchers at the Research Institute of Metals at Tokhoku University reportedly developed an amorphous magnet alloy of cobalt, iron, and boron, with silicon or nickel, that was superior to molybdenum-permalloy or ferrite magnets. Applications for the magnet included magnetic devices in TV sets, power transformers, and magnetic heads in tape recorders. In Japan, most cobalt is used in magnetic materials. Significant developments in this field were also made in the United States. Bureau of Mines research to evaluate metal substitution in praeseodymium-cobalt-copper alloys continued. The objective was to develop a low-cost permanent magnet with superior strength properties to replace platinum-cobalt alloys and to supplement samarium-cobalt magnets.

A leading aerospace contractor suggested that the manufacture of cobalt-rare earth magnets in the future might occur in space. An earth-orbiting factory would consist of a habitation module and a general-purpose laboratory module with manufacturing equipment capable of producing 20,000 pounds of magnets per year. With the use of such magnets, of higher strength than could be produced on earth, the weight of small motors in automobiles and a number of appliances might be reduced.

A new cobalt-iron alloy with exceptional noise damping properties reportedly was developed. The alloy combined a high noise-loss factor with good strength, low cost, and corrosion resistance. Development researchers claimed that it would absorb vibration over a wide temperature range and would be easily and economically fabricated. The damping effects were related to the microstructure of the material. Methods of forming the alloy included casting, forging, and cold working and the alloy could be cold rolled into foil. The cost of making the cobalt-iron alloy was estimated at $3 per pound. Although the material was designed for military use, commercial applications could be feasible. For example, machinery might be made quieter by using the super-damping alloy in noncritical parts, such as washers, that do not require high strength. One military application was the torpedo propeller, in which a significant 10-decibel noise reduction was achieved. [7]

A number of patents were issued during the year, many dealing with extraction of cobalt from manganese nodules. Other patents issued included those related to extraction of cobalt values from cobalt-nickel ore; recovery of nickel, cobalt and other metals from a solution produced by leaching a silicate ore with sulfuric acid; and liquid-

liquid solvent extraction of cobalt from an acidic sulfate ore leach solution containing both cobalt and nickel.

---

[1]Physical scientist, Division of Ferrous Metals.

[2]Irving, R. V. Exotic Metals Prove Out for Sour Gas Tubing. Iron Age, v. 218, No. 21, Nov. 22, 1976, pp. 59-61.

[3]Agarwal, J. C., H. E. Barner, N. Beecher, D. S. Davies, and R. N. Kust. Kennecott Process for Recovery of Copper, Nickel, Cobalt, and Molybdenum From Ocean Nodules. Pres. at AIME Ann. Meeting, Denver, Colo., Feb. 28 to Mar. 2, 1978, Preprint No. 78-b-89, 6 pp.

[4]Wallis, P. B. High Temperature Corrosion Resistant Alloys. Turbomachinery Internat., v. 18, No. 6, November-December 1977, pp. 52-54.

[5]Trainor, T. Cobalt P/M Insert Resists Wear. Am. Metal Market, v. 86, No. 35, Feb. 20, 1978, p. 18.

[6]American Metal Market. GTE Expects To Be Nation's First Major Producer of Cobalt Powder. V. 85, No. 123, June 27, 1977, p. 24.

[7]Van Cleave, D. A. Alloy Synthesis Creates a Noise Damping Material. Iron Age, v. 219, No. 13, Apr. 4, 1977, pp. 34-35.

Columbium and Tantalum

By Thomas S. Jones[1]

All columbium and tantalum raw materials were imported in 1977; there was no U.S. mine production and there were no stockpile releases of any consequence. Compared with the 1976 figures, imports of mineral concentrates, tin slags, and other raw material forms were, on the basis of content, 8% less for columbium and 42% greater for tantalum. Receipts of raw materials of such byproduct origin as tin slags were a particularly large part of tantalum raw material imports. Consumption of raw materials decreased 9% for columbium and 2% for tantalum, both again on a content basis. Tin slag constituted the majority of raw materials inventories.

Increases in raw materials prices for both columbium and tantalum helped lead to higher prices for most primary and intermediate products. For columbium, raw materials prices rose about 13%. For tantalum, ore and concentrate prices increased about 40%, and product price advances made more probable the substitution of alternate materials in tantalum end uses.

Consumption of ferrocolumbium was at the second highest level on record. The amount consumed was 29% greater than in 1976, as nearly twice as much was used in superalloys and higher amounts were used in all main steelmaking categories. Imports provided the greater part of ferrocolumbium supply and were about twice the quantity produced domestically.

At about $24 million, the value of columbium and tantalum exports was a record amount. Tantalum in various forms made up much more of the total than did columbium. Tantalum also constituted a greater share of the combined metal, alloy, and scrap imports, which were over 100% greater than those of 1976.

Legislation and Government Programs.—Changes in U.S. Government inventories of columbium and tantalum materials were insignificant in 1977, and there were no sales of stockpile excesses. Stocks of columbium concentrates declined by 32 pounds of contained columbium, while those of tantalum minerals increased by 3,513 pounds of contained tantalum.

In February 1977 the U.S. Government imposed a moratorium on requests for new stockpile acquisitions and disposals, pending review of stockpile policy and of goals established on October 1, 1976. On October 7, 1977, the moratorium was lifted when President Carter reaffirmed major elements of the strategic and critical materials stockpile policy developed in 1976. Long-range stockpile goals were not changed by this action. However, progress towards the goals was to be achieved through an Annual Materials Plan as developed by an Interagency Annual Materials Plan Steering Committee chaired by the Federal Preparedness Agency (FPA) of the General Services Administration. Subsequently, FPA announced a policy whereby shortages of a given material would be offset by surplus inventories of a related material.

As of yearend 1977, under the offset concept 94% of the goal for columbium concentrates was met. However, goals for all three tantalum stockpile items were far greater than inventories, and no offsets could be applied. The inventory of tantalum minerals was about one-half of the goal. For tantalum carbide powder and tantalum metal, inventories represented only 3% and 12% of the respective goals.

Table 1.—Salient columbium statistics

(Thousand pounds)

	1973	1974	1975	1976	1977
United States:					
Mine production of columbium-tantalum concentrates	--	--	--	--	--
Releases from Government excesses (Cb content)[1]	2,344	2,739	463	70	--
Consumption of raw materials (Cb content)	2,806	3,250	2,137	3,379	3,080
Production of primary products:					
Columbium metal (Cb content)	W	W	W	W	W
Ferrocolumbium (Cb content)	1,496	1,917	e985	1,565	1,455
Consumption of primary products:					
Columbium metal (Cb content)	254	221	130	291	W
Ferrocolumbium, ferrotantalum-columbium, and other columbium and tantalum materials (Cb and Ta content)	4,056	4,626	3,348	3,389	4,389
Exports: Columbium metal, compounds, and alloys (gross weight)	96	33	53	67	75
Imports for consumption:					
Mineral concentrate (Cb content)e	1,314	1,583	845	2,201	1,551
Columbium metal and columbium-bearing alloys (Cb content)	4	1	3	(2)	2
Ferrocolumbium (Cb content)e	r2,748	r3,030	r1,947	2,221	2,676
Tin slags (Cb content)[3]	603	460	144	296	880
World: Production of columbium-tantalum concentrates (Cb content)e	32,452	20,597	r17,324	r20,862	22,719

eEstimate. rRevised. W Withheld to avoid disclosing individual company confidential data.
[1]Includes columbium content in raw materials from which columbium is not recovered and material released as payment-in-kind for upgrading.
[2]Less than 1/2 unit.
[3]Receipts reported by consumers; includes other low-grade materials and synthetic concentrates in 1977.

Table 2.—Salient tantalum statistics

(Thousand pounds)

	1973	1974	1975	1976	1977
United States:					
Mine production of columbium-tantalum concentrates	--	--	--	--	--
Releases from Government excesses (Ta content)[1]	266	884	87	8	[2](4)
Consumption of raw materials (Ta content)	2,221	2,425	1,077	2,005	1,958
Production of primary metal (Ta content)	1,619	1,849	844	1,873	1,390
Consumption of primary products:					
Tantalum metal (Ta content)	1,096	1,159	450	1,098	732
Ferrocolumbium, ferrotantalum-columbium, and other columbium and tantalum materials (Cb and Ta content)	4,056	4,626	3,348	3,389	4,389
Exports:					
Tantalum ore and concentrate (gross weight)	16	201	60	59	118
Tantalum metal, compounds, and alloys (gross weight)	344	503	471	367	470
Tantalum and tantalum alloy powder (Ta content)	202	233	161	219	234
Imports for consumption:					
Mineral concentrate (Ta content)e	428	786	631	827	657
Tantalum metal and tantalum-bearing alloys (Ta content)	101	184	66	52	226
Tin slags (Ta content)[3]	719	760	236	431	1,275
World: Production of columbium-tantalum concentrates (Ta content)e	847	962	r906	r756	861

eEstimate. rRevised.
[1]Includes material released as payment-in-kind for upgrading.
[2]Net change in inventory report.
[3]Receipts reported by consumers; includes other low-grade materials and synthetic concentrates in 1977.

Table 3.—Columbium and tantalum materials in Government inventories as of Dec. 31, 1977

(Thousand pounds of columbium or tantalum content)

Material	Stockpile goals	National (strategic) stockpile	Defense Production Act (DPA) inventory	Supplemental stockpile	Total
Columbium:					
Concentrates	3,131	[1]1,781	(2)	--	[3]1,781
Carbide powder	--	21	--	--	[3]21
Ferrocolumbium	--	[4]931	--	--	[3]931
Metal	--	45	--	--	[3]45
Tantalum:					
Minerals	5,452	[5]2,552	(2)	--	2,552
Carbide powder	889	29	--	--	29
Metal	1,650	[6]201	--	--	201

[1]Includes 869,000 pounds of non-stockpile-grade material.
[2]Less than 1/2 unit.
[3]All surplus columbium carbide powder, ferrocolumbium, and columbium metal were used to offset columbium concentrates shortfall. Total offset = 1,173,000 pounds.
[4]Includes 333,000 pounds of non-stockpile-grade material.
[5]Includes 1,152,000 pounds of non-stockpile-grade material.
[6]Includes negligible quantity of non-stockpile-grade material.

DOMESTIC PRODUCTION

All columbium and tantalum source materials continued to be imported in 1977, as there was again no reported domestic mineral production of either columbium or tantalum.

Columbium metal and ingot were produced by too few companies to permit disclosure of production data. According to reports from five firms, production of ferrocolumbium, expressed as contained columbium, was 1,455,000 pounds, a 7% decrease from that of 1976. Value of ferrocolumbium production rose to an estimated $10.8 million, the rise reflecting both higher unit value and an increased proportion of high-purity ferrocolumbium in the total.

Tantalum metal powder production in 1977 of 1,390,000 pounds was a decrease of 26%. Production of tantalum ingots was 578,000 pounds, virtually unchanged from 1976. Domestic producers reported strong demand for tantalum, particularly by the electronic industry. For Fansteel, Inc., this caused facilities for producing tantalum wire to be operated nearly at capacity. Consequently, the company undertook a major expansion of wire drawing and spooling facilities that was to be completed early in 1978.

Kawecki Berylco Industries, Inc., (KBI) and Kennametal, Inc., were both involved in changes of ownership. The approximately 49% ownership of KBI held by Molycorp, Inc., passed to Union Oil of California when Molycorp was merged into Union Oil late in July. Litigation over a loan by KBI to International Chemalloy Corp., the owner of Tantalum Mining Corp. of Canada Ltd. (Tanco), was settled; KBI continued to own just under 25% of Tanco stock. Early in the year Kennametal made its first public offering of stock, sales of which raised a net $10 million.

In November, Foote Mineral Co. announced its appointment as sales agent in North America for standard ferrocolumbium produced in Brazil. This arrangement was made between Foote and Mineração Catalão de Goías S.A., which began production of ferrocolumbium in 1977.

Table 4.—Major domestic columbium and tantalum processing and producing companies in 1977

Company	Location	Columbium	Tantalum	Tantalum carbide	Ferro-columbium
Fansteel, Inc	Chicago, Ill	X	X	X	--
	Muskogee, Okla	X	X	X	--
General Electric Co	Warren, Mich	--	--	X	--
Kawecki Div., Kawecki-Berylco Industries, Inc.	Boyertown, Pa	X	X	X	X
Kennametal, Inc	Latrobe, Pa	X	X	X	--
Mallinckrodt, Inc	St. Louis, Mo	X	X	--	--
NRC Inc	Newton, Mass	X	X	X	--
Newcomer Products, Inc	Latrobe, Pa	--	--	X	--
The Pesses Co	Pulaski, Pa	X	--	--	X
Reading Alloys Co., Inc	Robesonia, Pa	X	--	--	X
Shieldalloy Corp	Newfield, N.J	X	--	--	X
Teledyne Wah Chang Albany	Albany, Oreg	X	X	X	X

CONSUMPTION AND USES

Major end uses other than in steelmaking continued to be in aerospace for columbium and in electronics for tantalum, according to data of the Tantalum Producers Association. In each case, these end uses accounted for over 60% of total consumption aside from steelmaking. Electronics uses again were a small but growing share of overall columbium consumption.

Reported consumption of ferrocolumbium, ferrotantalum-columbium, and other columbium and tantalum materials increased 29% over that of 1976 to the second highest total on record. Usage in superalloys nearly doubled and accounted for more growth in consumption than any steel category. Consumption in steel, which continued to amount to four-fifths of total consumption, was higher for all main categories and was up by 21% overall in spite of a slight decline in steel production. For carbon steel the consumption increase approached one-third, while average consumption per ton of carbon steel produced rose even more.

In high-strength, low-alloy (HSLA) steel, consumption of columbium units was higher by one-fifth. Additional applications of HSLA steel were developed in such transportation end uses as truck side rails, truck trailer frames, one-piece bumpers, and bumper backup systems. Trends in specifications for pipeline steels also added to the demand for columbium, more so worldwide than in the United States. Not including countries with centrally planned economies, pipeline mileage laid in 1977 was reported to have established a record, at more than a third above that in 1976. For the United States the increase was 4%.

Consumption in stainless and heat-resisting steel increased and was in proportion to a greater production of columbium-bearing type 347. Because of its stabilizing capability, potential future uses of columbium in stainless steel included heat-exchanger tubes of austenitic grades for fluidized-bed units for coal combustion and sheet and plate forms of molybdenum-bearing ferritic grades.

Expanding demand for tantalum capacitors, in such applications as automotive electronic ignition systems, tended to be offset by a trend toward powders with higher capacitance. Union Carbide Corp. formed an Electronics Division that includes manufacture of tantalum capacitors. Union Carbide significantly increased domestic productive capacity for capacitors just prior to 1977 by beginning operations at a new plant at Columbus, Ga. Sprague Electric Co. also enlarged its capabilities for manufacture of tantalum capacitors through an expansion in 1977 of facilities at Sanford, Maine.

Table 5.—Reported shipments of columbium and tantalum materials

(Pounds of metal content)

Material	1976	1977	Change (percent)
Columbium products:			
Compounds, including alloys	791,300	889,000	+12
Metal, including worked products	101,600	178,900	+76
Other	41,000	10,700	-74
Total columbium	933,900	1,078,600	+15
Tantalum products:			
Oxides and salts	55,400	62,800	+13
Alloy additive	13,200	12,200	-8
Carbide	93,300	118,500	+27
Powder and anodes	759,000	759,200	--
Ingot (unworked consolidated metal)	7,700	8,000	+4
Mill products	238,500	292,400	+23
Scrap	130,700	168,300	+29
Other	--	2,300	--
Total tantalum	1,297,800	1,423,700	+10

Source: Tantalum Producers Association.

Table 6.—Consumption of ferrocolumbium, ferrotantalum-columbium, and other columbium and tantalum materials in the United States in 1977, by end use

(Pounds)

End use	Contained columbium and tantalum
Steel:	
Carbon	1,169,023
Stainless and heat-resisting	567,588
Full alloy	583,001
High-strength, low-alloy	1,188,363
Electric	--
Tool	W
Unspecified	13,688
Total steel	3,521,663
Superalloys	796,488
Alloys (excluding alloy steels and superalloys)	64,937
Miscellaneous and unspecified	5,544
Total	4,388,632

W Withheld to avoid disclosing individual company confidential data; included with "Steel: Unspecified."

STOCKS

Aggregate stocks of columbium and tantalum raw materials reported by processors and dealers for yearend 1977 contained 3,272,000 pounds of columbium and 3,367,000 pounds of tantalum, which were increases of 17% and 1%, respectively, over yearend 1976 inventories. Tin slag constituted the majority of the inventories.

Processor and dealer inventories of other columbium and tantalum materials at yearend follow, in pounds of contained columbium and tantalum:

Material	Dec. 31, 1976	Dec. 31, 1977
COLUMBIUM		
Primary metal and ingot	147,308	262,245
Scrap	106,958	119,764
Oxide and other compounds	539,094	639,435
TANTALUM		
Primary metal	302,274	218,274
Capacitor-grade powder	94,088	97,246
Ingot	114,349	111,628
Scrap	174,457	138,181
Oxide	49,174	30,287
Potassium tantalum fluoride	88,572	94,959
Other compounds	45,028	38,225

Producer stocks of ferrocolumbium at yearend 1977 were 655,000 pounds of contained columbium, an 18% decline from the 794,000 pounds in stock at the end of 1976. Consumer stocks of predominantly ferroalloy forms of columbium and tantalum decreased by nearly 30% overall, in pounds of contained columbium and tantalum:

Material	Dec. 31, 1976	Dec. 31, 1977
Ferrocolumbium[1]	932,244	637,058
Other columbium and tantalum materials	30,361	53,704

[1]Including ferrotantalum-columbium.

PRICES

Price increases in 1977 for pyrochlore and columbium oxide led to higher prices for most commonly used forms of columbium. The price of pyrochlore rose 13% in May, from $2.25 to $2.55 per pound of Cb_2O_5. Price listings had been based on Canadian pyrochlore but were discontinued in March and replaced by a listing for Brazilian pyrochlore on the basis of the approximate official Brazilian export price, f.o.b. shipping point, 50% to 55% Cb_2O_5. The price of purified columbium oxide, calcined grade, went from $4.90 to $5.60 per pound at the end of March, a 14% increase. Higher raw material and labor costs were said to have necessitated the increase. On the other hand, the price of spot columbite concentrates was relatively stable, the range of $3.00 to $3.50 broadening in March and holding thereafter at $2.85 to $3.50 per pound of combined columbium and tantalum pentoxides, c.i.f. U.S. ports.

Prices of both steelmaking and high-purity grades of ferrocolumbium responded to the price increases for raw materials. The spot, regular grade of ferroalloy with 63% to 68% columbium, formerly listed as the spot, low-alloy grade, went up 8% in price in July, from $4.73 to $5.12 per pound of contained columbium, f.o.b. shipping point. The price of high-purity ferrocolumbium rose 14% during May, the same percentage increase as for the purified oxide from which it is made; the change was from $11.80 to $13.45 per pound of contained columbium. The price of nickel columbium, also in high-purity form, increased 15% at the same time, going from $14.30 to $16.47 per pound of contained columbium.

The price range for U.S. reactor-grade columbium metal ingot advanced from $18 to $25 per pound at the end of 1976, to $26 to $33 at the end of 1977, a 37% increase for the middle of the range. The price changed in April and again in July, with most of the increase coming in April. Prices for U.S. reactor-grade columbium metal powder changed at the same times, declining from $30 to $45 per pound at the end of 1976 to $29 to $37 at the end of 1977, an average 12% decrease.

Prices for tantalum raw materials increased sharply because of continual upward pressure throughout the year. For spot tantalite ore, 60% basis c.i.f. U.S. ports, the price range moved from $17.25 to $18.00 per pound of contained Ta_2O_5 at the beginning of the year to $22.75 to $26.50 by yearend, an average 40% increase mostly taking place in August. The list price of Tanco tantalite, which went up 11% on January 1, 1977, from $16 to $17.75 per pound of contained Ta_2O_5, jumped 35% to $24 late in September and remained at that level the rest of the year.

The cost of tantalum was a factor in raising the price of U.S. grade tantalum metal powder. Per pound of tantalum, the price range rose in May to $40 to $58.25, an average 18% above the $35.40 to $48 range that prevailed throughout 1976. However, the price quotation for U.S. grade tantalum metal rod stayed as in 1976 at $52 to $80 per pound. The quoted price range for U.S. tantalum metal sheet, which in 1976 had ranged from $48 to $118 per pound, was revised in March to $72 to $82, a level which applied for the rest of 1977.

The price per pound of tantalum carbide rose by about the same proportion as that of tantalum metal powder, advancing from about $33.50 at the beginning of the year to $40 in September.

FOREIGN TRADE

Exports of columbium and tantalum metals, alloys, powder, scrap, ores, and concentrates increased compared with those of 1976 by 26% in quantity to 896,000 pounds overall and by 53% in value to a record $23.7 million. Half the increase in value was because of greater exports of tantalum metals and alloys in crude form and as scrap. This class of tantalum exports also rose in unit value by 65%, and together with powder continued to be the most significant part of columbium and tantalum exports.

Countries accounting for 99% of both quantity and value of all columbium and tantalum exports were Austria, Belgium, Canada, France, the Federal Republic of Germany, Israel, Italy, Japan, Poland, Spain, the United Kingdom, and the U.S.S.R. Of these 12, the Federal Republic of Germany, Japan, and the United Kingdom were the chief recipients, together accounting for 87% of quantity and 83% of value. At least one-fifth of every export class went to the Federal Republic of Germany, which took all shipments of tantalum ores and concentrates. Countries receiving sizable portions of the various other export classes were, in thousand pounds and thousand dollars, Belgium (19, $72) and the Federal Republic of Germany (16, $174) for unwrought columbium and columbium alloys, including waste and scrap; the United Kingdom (10, $503), the Federal Republic of Germany (8, $186), and the U.S.S.R. (8, $113) for wrought columbium and columbium alloys; the Federal Republic of Germany (340, $6,661), Japan (31, $1,015), and the United Kingdom (29, $233) for unwrought tantalum and tantalum alloys, including waste and scrap; the United Kingdom (17, $1,038), the Federal Republic of Germany (17, $1,000), and Japan (14, $853) for wrought tantalum and tantalum alloys; and the Federal Republic of Germany (76, $2,652), Japan (54, $2,542) and the United Kingdom (38, $1,725) for tantalum and tantalum alloy powder.

Imports for consumption of columbium and tantalum metal, alloys, waste, and scrap totaled 228,000 pounds at a value of $4.4 million. This was more than twice the 1976 quantity at not quite double the value. Imports were received from 11 countries, of which especially the Federal Republic of Germany followed by Mexico, the United Kingdom, the Netherlands, and Belgium were the source of all but a few percent of total quantity and value. Imports of columbium metal and alloys continued to be relatively insignificant, amounting to 120 pounds of unwrought columbium, waste, and scrap at a value of $4,982 from the Federal Republic of Germany and 2,000 pounds of unwrought columbium alloys at a value of $7,075 from Brazil. Chief sources of tantalum metal and alloys were the Federal Republic of Germany (84,813 pounds, $2,625,393), Mexico (59,215 pounds, $431,555), and the United Kingdom (28,803 pounds, $180,946) out of a total of 200,460 pounds of unwrought tantalum metal, waste, and scrap at a value of $3,389,686; the Federal Republic of Germany (19,842 pounds, $658,001) out of a total of 19,942 pounds of unwrought tantalum alloys at a value of $661,701; and the Federal Republic of Germany (4,487 pounds, $152,516), Belgium (1,121 pounds, $71,014), and Austria (321 pounds, $62,201) out of a total of 5,990 pounds of wrought tantalum metal at a value of $291,047.

Imports for consumption of columbium mineral concentrates were 15% less than in 1976 but at 22% greater value, as average unit value rose 43%. Average grade was estimated as 56% Cb_2O_5, 6% Ta_2O_5, compared with 58% Cb_2O_5, 4% Ta_2O_5 in 1976. The 3,364,000 pounds of imports were estimated to contain 1,322,000 pounds of columbium and 171,000 pounds of tantalum. Canada accounted for about half of both total quantity and value of imports and displaced Brazil as the leading source. Nigeria, Malaysia, and the People's Republic of China remained the next most important supplying countries.

Imports of tantalum mineral concentrates amounted to 1,524,000 pounds and contained an estimated 486,000 pounds of tantalum and 229,000 pounds of columbium. Average grade was estimated as 39% Ta_2O_5 and 29% Cb_2O_5. Tantalum concentrates were received in greatest amount from Canada, which provided about one-third of both total quantity and value.

Receipts of tin slags, other low-grade materials, and synthetic concentrates were substantially greater than in 1976. Such materials accounted for about one-third of the columbium units and two-thirds of the tantalum units in all nonmetallic raw materials received. Receipts of tin slags were again reported to be predominantly from Thailand and Malaysia. On November 8, 1977, the duty on synthetic tantalum-columbium concentrates was suspended until July 1, 1980, through enactment of Public Law 95-161.

Table 7.—U.S. exports of columbium and tantalum, by class

(Thousand pounds, gross weight, and thousand dollars)

Class	1976		1977	
	Quantity	Value	Quantity	Value
Columbium and columbium alloys, unwrought, and waste and scrap	24	175	42	349
Columbium and columbium alloys, wrought	43	604	33	1,059
Tantalum ores and concentrates	59	317	118	944
Tantalum and tantalum alloys, wrought	45	2,571	63	3,957
Tantalum metals and alloys, in crude form and scrap	322	3,823	406	7,973
Tantalum and tantalum alloy powder	219	7,982	234	9,380

Table 8.—U.S. imports for consumption of columbium-mineral concentrates, by country

(Thousand pounds and thousand dollars)

	1976		1977	
	Gross weight	Value[r]	Gross weight	Value
Brazil	1,868	2,197	566	1,107
Canada	1,196	1,792	1,669	3,042
China, People's Republic of	179	224	154	387
Germany, Federal Republic of	23	65	68	81
Japan	--	--	22	47
Malaysia	[r]156	351	153	418
Netherlands	--	--	100	188
Nigeria	477	763	506	1,071
Rwanda	--	--	15	61
Spain	11	54	--	--
Taiwan	40	51	27	37
Thailand	5	19	33	100
United Kingdom	--	--	11	26
Zaire	13	51	40	206
Total	3,968	5,567	3,364	6,771

[r]Revised.

Table 9.—U.S. imports for consumption of tantalum-mineral concentrates, by country

(Thousand pounds and thousand dollars)

	1976		1977	
	Gross weight	Value[r]	Gross weight	Value
Australia	229	1,655	61	428
Belgium-Luxembourg[1]	1	6	17	85
Brazil	148	677	145	1,244
Canada	[r]498	2,534	491	2,909
China, People's Republic of	5	3	--	--
France	2	31	1	16
Germany, Federal Republic of[2]	1,067	7,678	91	901
Malaysia	22	48	50	25
Mozambique	53	474	18	128
Netherlands	22	114	16	76
Nigeria	--	--	56	160
Portugal	--	--	17	87
Rwanda	99	250	85	339
South Africa, Republic of	9	39	--	--
Spain	40	185	40	266
Tanzania	7	24	--	--
Thailand	199	709	217	882
United Kingdom	--	--	44	378
Zaire	156	598	175	1,017
Total	2,557	15,025	1,524	8,941

[r]Revised.
[1]Presumably country of transshipment rather than original source.
[2]Includes synthetic concentrates for 1976.

WORLD REVIEW

Australia.—Goldrim Mining Australia Ltd., late in the year, reportedly started mining tin and tantalite from the Wodgina deposit in the Pilbara region of Western Australia. Alluvium with a tantalite content of 0.56% or greater was to be mined at the rate of about 25,000 tons per year. This export-oriented operation, which could be hampered in the future by water shortages, was anticipated to last for approximately 5 years.

Another tin-tantalite mining operation in Western Australia appeared to be heading for a change in ownership, from Vultan Minerals to Greenbushes Tin N.L. Greenbushes has been mining leases under license from Vultan, but reportedly was enlarging its shares in Vultan, to a 44% interest before the year was over.

Brazil.—Production and exports of ferrocolumbium were both reduced from the record quantities of 1976. Production was 32% less at 7,500 tons; the new producer, Mineração Catalão de Goías S.A., accounted for 14% of the total, and the established producer, Companhía Brasileira de Metalurgia e Mineração (CBMM), for the balance. Exports of ferrocolumbium were 7,700 tons, the third highest annual total and 22% less than in 1976.

Eventual extraction of columbium as a byproduct of phosphate mining was being planned by Mineração Vale do Paranaiba S.A. (Valep), which is 99% owned by Companhía Vale do Rio Doce (CVRD). Operations at the Tapira minesite in western Minas Gerais were to begin in 1978, the initial product being phosphate concentrate. Future projects to recover columbium and minerals other than phosphate in the deposit were being formulated. Columbium reserves were stated to be among the largest in the world.

Canada.—The first full year of production from the Niobec Inc. mine at St. Honore, Quebec, yielded 5,342,000 pounds of Cb_2O_5. A total of 584,000 tons of ore grading 0.71% Cb_2O_5 was milled in 1977 at an average rate of 1,600 tons per day; recovery was 64%. Niobec, jointly held by Teck Corp. Ltd. and Société Québécoise d'Exploration Minière (SOQUEM), an exploration company owned by the Government of Quebec, became associated with German interests in the latter part of the year when Metallgesellschaft A.G. purchased through its Canadian subsidiary a 10% equity in Teck.

Operations of Tanco at Bernic Lake, Manitoba, were reported to have continued satisfactorily, and the company was able to carry out further underground exploration. This was achieved even though International Chemalloy Corp., owner of just over 50% of Tanco's shares, was in receivership status. On the other hand, efforts to solve the financial problems of St. Lawrence Columbium and Metals Corp. did not succeed. Consequently, some of the company's assets were sold, but not the mine and mill at Oka, Quebec, and other properties. Negotiations underway prior to the sale could have culminated in a conversion from underground to open pit mining. Proven reserves were judged sufficient to support open pit operations for 17 years.

New Insco Mines explored for uranium and columbium at the company's Prairie Lake property in northern Ontario. Test drillings of a carbonatite complex indicated an average Cb_2O_5 content of 0.25%.

Malaysia.—The Malaysian Government took steps to increase tin output even as production by the world's largest tin producer was falling by nearly 10% from the 1976 level. Mining and export taxes were reduced, and exploration was encouraged for both hard rock and offshore deposits. The Governments of Malaysia, Indonesia, and Thailand were arranging joint financing of a mining and refining technology center to be located in Malaysia, possibly with cooperation from other Asian producers.

Nigeria.—Sales of byproduct columbite by Amalgamated Tin Mines of Nigeria (Holdings) Ltd. in the fiscal year ending March 31, 1977, decreased by a third from those of the previous year to 165 tons. However, revenues from sales of this relatively high-tantalum-content columbite were nearly the same in a strong market. Congestion at the port of Apapa and delays in issuance of export licenses contributed to interruptions in shipments in 1977.

Thailand.—Although apparently favoring increased production, the Government raised the royalty on mined tin. The state-controlled Offshore Mining Organization signed a 5-year contract with Billiton Thailand Ltd. for dredging for tin in Phangnga Bay off Phuket Island, in the same area as the former Thai Exploration and Mining Co. (Temco) concession. Also, the Government invited bids for a new smelter with a minimum capacity of 3,300 tons per year to provide competition with the much larger and dominant Billiton Thaisarco smelter.

Table 10.— Columbium and tantalum: World production of mineral concentrates by country[1]

(Thousand pounds)

Country[2]	Gross weight[3]			Columbium content[4]			Tantalum content[4]		
	1975	1976	1977[p]	1975	1976	1977[p]	1975	1976	1977[p]
Argentina:									
Columbite	2	([5])	([5])	1	([5])	([5])	1	([5])	([5])
Tantalite	1	([5])	([5])	([5])	([5])	([5])	1	([5])	([5])
Australia: Columbite-tantalite[6]	291	273	348	29	69	62	95	87	118
Brazil:									
Columbite-tantalite	220	436	[e]440	42	98	[e]80	65	128	[e]140
Pyrochlore	[r]32,198	41,894	[e]44,000	[7]13,504	[7]17,571	[e]17,800	--	--	--
Burundi: Columbite-tantalite	--	9	[e]10	--	2	[e]2	--	2	[e]2
Canada:									
Pyrochlore	[e]7,500	[r] [e]6,600	[e]11,000	[7]2,560	[7]2,300	[7]3,900	--	--	--
Tantalite	[e]740	[e]520	[e]500	[r] [e]20	[r] [e]15	[e]14	[7] [r]324	[7]230	[e]220
Malaysia: Columbite-tantalite	110	101	99	39	43	39	17	12	15
Mozambique:									
Columbite	--	[e]4	--	--	[e]1	--	--	[e]2	--
Microlite	97	123	[e]95	4	5	[e]4	53	68	[e]52
Tantalite	101	[r] [e]62	[e]82	13	[r] [e]8	[e]14	45	[r] [e]27	[e]33
Nigeria:									
Columbite	2,183	1,433	1,698	960	631	691	144	82	156
Tantalite	3	[e]2	1	1	[e]1	([5])	1	[e]1	1
Portugal: Tantalite	24	11	5	6	3	2	6	3	2
Rhodesia, Southern: Columbite-tantalite[e]	90	90	90	10	10	10	25	25	25
Rwanda: Columbite-tantalite	103	100	[e]100	29	29	[e]31	23	24	[e]21
Thailand:									
Columbite	15	88	[e]88	4	23	[e]24	3	14	[e]15
Tantalite	227	15	[e]15	54	4	[e]4	54	4	4
Uganda: Columbite-tantalite[e]	5	5	5	1	1	1	1	1	1
Zaire: Columbite-tantalite	176	174	183	47	48	41	48	46	56
Total	[e]44,086	51,940	58,759	[r]17,324	20,862	22,719	[r]906	756	861

[e]Estimate. [p]Preliminary. [r]Revised.

[1]Excludes columbium and tantalum-bearing tin concentrates and slag.

[2]In addition to the countries listed, Spain, the Territory of South-West Africa, the U.S.S.R., and Zambia also produced or are believed to produce columbium and tantalum mineral concentrates, but information is unavailable to make adequate estimates of output levels.

[3]Data on gross weight generally has been presented as reported in sources, divided into concentrates of columbite, tantalite, pyrochlore, and microlite where information is available to do so, and reported in groups such as columbite-tantalite where it is not.

[4]Unless otherwise specified, metal content is based on U.S. Bureau of Mines estimates. Figures specifically listed as estimates are derived from an estimated gross weight.

[5]Less than 1/2 unit.

[6]Exports.

[7]Reported in official country sources.

TECHNOLOGY

High-temperature reaction between pyrochlore samples from the St. Honore deposit in Canada and chlorine gas was studied in the laboratory. Formation of volatile compounds was observed at all three reaction temperatures investigated, 1,000° C, 1,400° C, and 1,800° C. Under the 1,800° C test conditions, 84% of the columbium content of the original pyrochlore sample was recovered in a condensate.[2]

Studies on the metallurgy of HSLA steels, also known as microalloyed steels, continued to provide information on steels containing small contents of such alloying elements as columbium, vanadium, molybdenum, and titanium. The proceedings of an international symposium held in Washington, D.C., in 1975 on the effects of compositional and processing variations on such steels were published.[3] In 1976 an international conference on weldability of HSLA steels was held in Rome; among papers presented was a review of steel production routes. The three alternatives of normalizing, controlled rolling, and quenching and tempering were compared, and interrelationships between end use application, production facilities, and alloying costs were pointed out.[4] An HSLA steel composition that has been developed with arctic pipelines in mind as a prime application was reported to have sufficient fabricability to compete against quenched and tempered carbon steels; the composition included microalloying amounts of columbium and molybdenum in addition to low alloy contents of copper, nickel, and chromium.[5] Another high-strength steel composition developed for structural and line pipe uses was a low-carbon, high-manganese control-rolled ferrite-pearlite steel microalloyed with about 0.1% vanadium and 0.02% columbium.[6]

Application of superconducting columbium materials in generation and transmission of electrical power and in electric motors remained in the research and development stage. Various columbium materials were being explored, but attention was focused on those already commercially available: Columbium-titanium, a ductile alloy, and columbium-tin, a brittle intermetallic compound. Both materials were to be used to construct experimental superconducting magnet coils for the energy-from-fusion program at the Oak Ridge National Laboratory.[7] Columbium-tin was being used to make a prototype ship engine rated at 3,000 horsepower.[8] Laboratory and design studies were being performed on manufacture of columbium-tin tapes and incorporation of these tapes into coaxial cables for alternating current power transmission.[9] Powder metallurgy methods were being investigated for preparation of columbium-tin wires, with encouraging results.[10] Manufacture of superconducting materials was discussed at an international conference held in Port Chester, N.Y., in 1976, the proceedings of which were published in 1977.[11]

In aerospace applications, a nickel-base Ni-Cb-Cr-Al alloy with 20-1/2% columbium was being tested in a program on use of directionally-solidified eutectic superalloys for jet engine blades.[12] Improved high-temperature creep resistance was a goal of the program. Columbium- and tantalum-base alloys were being considered for uses in space power systems. One of the prime candidates for a structural application involving long-term service at elevated temperatures in a high-vacuum space environment, a Cb-Hf-Ti alloy, was shown not to be susceptible to aging embrittlement.[13] However, the Ta-W-Hf alloy T-111, with potential for nuclear fuel-element cladding and liquid alkali-metal containment uses in space, was found to contain critical tungsten and hafnium contents leading to aging embrittlement.[14] A process was developed for producing a tantalum carbide-graphite composite thought to have space vehicle and tooling applications because of resistance to thermal shock and high melting point. Steps in manufacturing the composite included vapor deposition and hot pressing.[15]

In a review of technical advances in electrolytic capacitors, the advantages of solid electrolyte tantalum capacitors were cited to explain why this type of capacitor has assumed a dominant position in the domestic industry during the past 20 years.[16]

---

[1]Physical scientist, Division of Ferrous Metals.

[2]Berjoan, R., and P. Meubus. High Temperature Chlorination Reaction of a Pyrochlore Mineral. Metallurgical Trans. B, v. 8B, No. 3, September 1977, pp. 461-466.

[3]Union Carbide Corp. Microalloying '75. 1977, 748 pp.; available from American Society for Metals, Metals Park, Ohio.

[4]Preston, R. R. HSLA Metallurgy in Europe. J. Metals, v. 29, January 1977, pp. 9-16.

[5]Irving, R. R. Will a New HSLA Steel Make the Grade? Iron Age, v. 220, No. 24, Dec. 19, 1977, pp. 51-53.

[6]Goetz, G. J. New X70-X80 HSLA Steels for Structural and Line Pipe Use. J. Metals, v. 29, August 1977, pp. 12-18.

[7]Mari, A. ERDA Awards Subcontracts To Develop Superconducting Electromagnetic Coils. Am. Metal Market, v. 85, No. 147, Aug. 1, 1977, p. 20.

[8]Miska, K. H. Superconductors Improve Magnets, Motors and Power Transmission. Materials Eng., v. 85, June 1977, pp. 64-67.

[9]Bussiere, J. F. The Development of Low-Loss Nb_3Sn for AC Power Transmission: A Review. IEEE Trans. Magnetics, v. MAG-13, January 1977, pp. 131-137.

[10]Pickus, M. R., and J. L-F. Wang. Superconductors by Powder Metallurgy Techniques. Ch. in Modern Developments in Powder Metallurgy, ed. by H. H. Hausner and P. W. Taubenblat. Metal Powder Industries Federation, Princeton, N. J., v. 11, 1977, pp. 315-329.

[11]Meyerhoff, R. W. (ed.). Manufacture of Superconducting Materials. American Society for Metals, Metals Park, Ohio, 1977, 231 pp.

[12]Larsen, R. Single-Crystal Castings Studied. Am. Metal Market, v. 85, No. 234, Dec. 5, 1977, p. 13.

[13]Stephens, J. R. Effects of Long-Term Aging on Ductility and Microstructure of Cb and Mo Alloys. Metallography, v. 10, 1977, pp. 1-25.

[14]——. Effects of Alloy Composition in Alleviating Embrittlement Problems Associated With the Tantalum Alloy T-111. J. Less-Common Metals, v. 51, 1977, pp. 93-111.

[15]Chemical Week. Los Alamos Develops 6,760 F Compound. V. 121, No. 2, July 13, 1977, p. 55.

[16]Bernard, W. J. Developments in Electrolytic Capacitors. J. Electrochem. Soc., v. 124, December 1977, pp. 403C-409C.

Copper

By Harold J. Schroeder[1] and James H. Jolly[1]

In 1977 world mine production of copper was a record 8.50 million tons. The United States, despite reduced production, continued to lead the world in mine output with 18% of the total, followed by Chile, the U.S.S.R., Canada, Zambia, Zaire, Peru, Poland, and the Philippines. Despite the highest recorded world consumption stocks of refined copper continued to rise, keeping a downward pressure on London Metal Exchange prices, which trended down from an average 63 cents per pound for January to

Table 1.—Salient copper statistics

	1973	1974	1975	1976	1977
United States:					
Ore produced ______ thousand short tons__	289,998	293,443	263,003	283,736	259,974
Average yield of copper ________percent__	0.53	0.49	0.47	0.51	0.52
Primary (new) copper produced—					
From domestic ores, as reported by—					
Mines ______________short tons__	1,717,940	1,597,002	1,413,366	1,605,586	1,503,966
Value ______________thousands__	$2,044,349	$2,468,964	$1,814,763	$2,234,975	$2,009,297
Smelters ____________short tons__	1,705,065	1,532,066	1,374,324	1,461,256	1,394,432
Percent of world total __________	22	19	18	18	17
Refineries____________short tons__	1,698,337	1,420,905	1,286,189	1,422,723	1,410,997
From foreign ores, matte, etc., as reported by refineries _________do____	170,151	233,753	157,189	116,585	85,187
Total new refined, domestic and foreign ________do____	1,868,488	1,654,658	1,443,378	1,539,308	1,496,184
Secondary copper recovered from old scrap only _____________do____	486,214	483,432	369,173	419,126	451,868
Exports:					
Metallic copper ______________do____	292,504	246,205	304,712	r217,063	192,200
Refined ___________________do____	189,396	126,526	172,426	r111,887	51,528
Imports, general:					
Unmanufactured _____________do____	420,513	608,602	324,126	534,713	516,729
Refined ___________________do____	202,955	313,569	146,805	381,524	390,776
Stocks Dec. 31: Producers:					
Refined ___________________do____	37,000	101,000	207,000	190,000	234,000
Blister and materials in solution____do____	265,000	324,000	312,000	321,000	346,000
Total ___________________do____	302,000	425,000	519,000	511,000	580,000
Consumption:					
Refined copper ______________do____	2,437,048	2,194,168	1,534,508	1,991,885	2,184,959
Apparent consumption, primary copper ______________do____	1,902,000	1,778,000	1,312,000	r1,826,000	1,791,000
Apparent consumption, primary and old copper (old scrap only)____do____	2,388,000	2,261,000	1,681,000	r2,245,000	2,243,000
Price: Weighted average, cents per pound ____	59.5	77.3	64.2	69.6	66.8
World:					
Production:					
Mine _________________short tons__	7,844,901	8,047,959	r7,725,676	r8,272,228	8,503,477
Smelter ___________________do____	7,878,480	8,067,651	r7,684,297	r8,038,574	8,268,030
Price: London, average cents per pound______	80.86	93.13	56.08	63.92	59.44

r Revised.

57 cents for December. Meetings held during the year by the Intergovernmental Council of Copper Exporting Nations (CIPEC) and by copper producer and consumer nations under United Nations sponsorship failed to agree on ways to reduce copper market instability.

In the United States, consumption of refined copper increased for the second year of recovery from the severe slump in 1975 and was only slightly below the 1974 level of consumption. Mine production of recoverable copper, affected by strikes and production cutbacks, declined significantly. Strikes by copper workers at many producing units, starting June 30, were of much shorter duration than was generally anticipated and did not result in a material reduction of the prestrike buildup of inventories. The buildup of inventories along with reduced consumption in the latter half of the year led to production curtailments, some mine closures, and a serious unemployment situation in the domestic copper mining industry. Various market factors resulted in domestic producer prices for refined cathode copper increasing in three steps, from 65 cents per pound at the start of the year to 74 cents in mid-March, then decreasing in four steps between May and August to 60 cents, and followed by an advance to 63 cents in mid-December.

Legislation and Government Programs.—The stockpile goal of 1,299,000 tons of copper, established by the Federal Preparedness Agency (FPA) in 1976, remained in effect. No program has been announced for purchases against the new goal. However, 20,261 tons from the previous stockpile that remained unused from transfers to other Government agencies were transferred back into the new stockpile.

The U.S. Department of Commerce amended Schedule A of Defense Materials System Order 4 to revise the base period and the set-aside percentages for copper-controlled materials. The amendment changes the base period from calendar year 1975 to calendar year 1976, and the set-aside percentages from 7% to 4% on unalloyed rod, bar, shapes, and wire; from 10% to 6% on alloy seamless tube and pipes; and from 3% to 2% on copper foundry products.

Import duties on copper ores, concentrates, blister, and refined copper remained at 0.8 cent per pound. The duty remained suspended on copper and copper-base scrap through June 1981.

The Generalized System of Tariff Preferences (GSP), which was implemented in 1976, in accordance with Title V of the Trade Act of 1974, remained in effect. The system consists of duty-free treatment for a period up to 10 years, on a wide range of designated articles imported directly from any developing country designated as a beneficiary developing country (BDC). All copper items imported from BDC's have been granted GSP status. There are a number of limitations to the program such as the provision that a country does not receive GSP coverage if the imports of a particular article from that country exceeded $25 million during the previous calendar year. This provision is reviewed every year for possible changes. The review for 1977, with respect to copper, resulted in denial of duty-free treatment for refined copper from Peru, Yugoslavia, Zambia, and Chile; black and blister copper from Chile; copper matte from Botswana; and copper wire from Chile. Duty-free status will be restored for cement and blister copper from Peru, and for cupronickel plates from Mexico.

DOMESTIC PRODUCTION

PRIMARY COPPER

Mine Production.—Domestic mine production of recoverable copper was 1.5 million tons, a 6% decrease from 1976. Principal copper producing States were Arizona, with 61.4% of the total, Utah (12.9%), New Mexico (11%), Montana (5.7%), Nevada (4.5%), and Michigan (2.8%). These States accounted for 98.3% of total production. The decrease in production was the result of a copper worker's strike in midyear at most of the major operations lasting for periods of a few days to 10 weeks, post-strike shutdowns, reduced work schedules and some mine closings.

Open pit mines accounted for 83% of mine output and underground mines accounted for 17%. The production of copper from dump and in-place leaching, mainly recovered by precipitaion with iron, was 134,215 tons or 9% of mine output. Total mine production of copper recovered by leaching methods was 264,962 tons.

The Anaconda Company mine production of copper decreased approximately 5% from

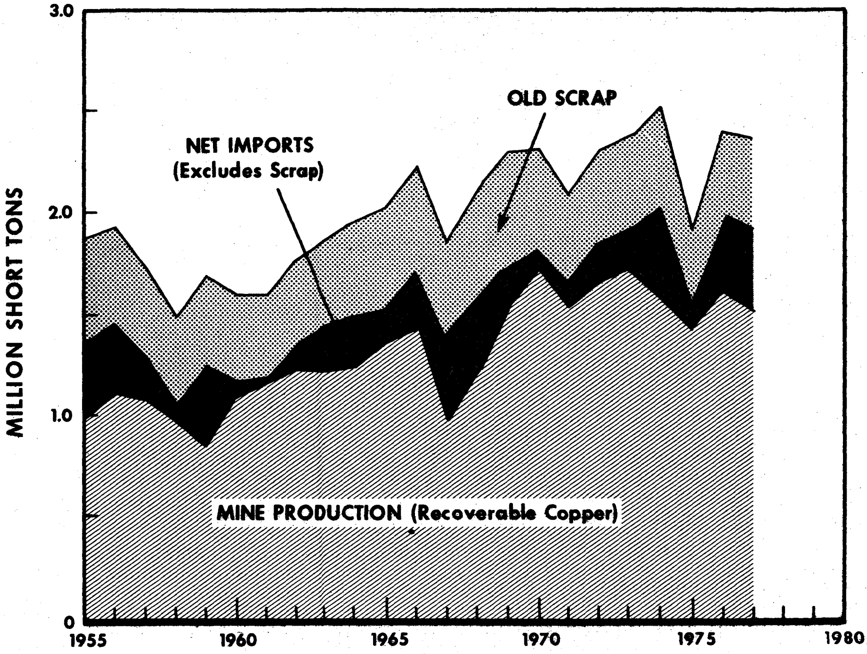


Figure 1.—Sources of copper supply for United States copper consumption.

that of 1976. The Berkeley pit at Butte, Mont., accounted for approximately 73% of the total and the remainder was from the Yerington mine at Weed Heights, Nev., and the Victoria mine near Ely, Nev. Because of the depressed conditions in the copper industry, the Victoria mine and mill were closed in September and operations were curtailed at the Yerington mine in October. Development of the underground mine and concentrator at Carr Fork, Utah, about 25 miles west of Salt Lake City, continued with production scheduled to start in late 1979 and building to a production level of 60,000 short tons of copper per year as market conditions warrant.

Anamax Mining Co., a joint venture of The Anaconda Company and AMAX Inc., operated the Twin Buttes, Ariz., open pit mine and produced 335,975 tons of copper concentrates from processing sulfide ore and 34,387 tons of electrowon refined copper from processing oxide ores. Copper concentrating operations were held to about 60% of capacity, as in 1976, because of the depressed copper market but improved metallurgical recoveries resulted in a 36% increase in copper production over that of 1976. Production also improved at the oxide ore electrowinning plant where output was 19% over that of 1976.

Anamax and ASARCO Incorporated, partners in the Eisenhower Mining Co., continued to develop the Palo Verde copper deposit, located 6 miles from the Twin Buttes operation and between two ASARCO operations. The Palo Verde ore body contains an estimated 125 million tons of ore averaging 0.6% copper. Stripping of overburden was in progress and mining of the underlying ore was expected to start early in 1979.

ASARCO operated three copper mines in the vicinity of Tucson, Ariz., the Mission, Silver Bell, and San Xavier units. The mines were not operated during July through October, due to a copper worker's strike from June 30 to September 8, and a shutdown until November 1 when production was resumed on a curtailed basis. The Mission and Silver Bell units produced 23,300 tons and 15,500 tons of copper in concentrates and precipitates compared with 35,200 tons and 22,300 tons in 1976. Output from the San Xavier mine and leach plant was 10,600 tons of copper in precipitates compared with 11,400 tons in 1976. The Sacaton open pit mine near Casa

Grande, Ariz., produced 19,900 tons of copper in concentrates compared with 22,000 tons in 1976. The Sacaton unit was not affected by the copper strike and operated at full production except for a 7-week shutdown in September and October because of the depressed copper market. Development of an underground ore body was resumed in July when sinking of the main shaft commenced. By yearend the shaft had reached a depth of about 1,200 feet.

Cities Service Co. operated mines in Arizona and Tennessee that produced 71,500 tons of copper compared with 86,600 tons in 1976. A strike and shutdown from July 1 through September 11, at the Pinto Valley mine in Miami, Ariz., and a strike at the Copperhill mine in Tennessee from mid-April to mid-August were contributing factors in the decreased production. Expansion plans at the Pinto Valley property were suspended pending improvement in the copper market. The Miami East underground mine development program in Arizona was also on a standby basis.

The Cyprus Pima Mining Co. operated the open pit Pima mine near Tucson, Ariz., milling 14.1 million tons of ore averaging 0.48% copper. Output of copper in concentrates was 53,255 tons. Proven ore reserves at yearend was estimated to be 146 million tons averaging 0.48% copper, sufficient to sustain the operation for at least 8 more years at past production levels. The mine was shutdown in September for an indefinite period primarily because of low copper prices. Cyprus Bagdad Copper Co., at its Bagdad, Ariz. property, mined 3.6 million tons of sulfide ore averaging 0.59% copper, yielding concentrates containing 15,640 tons of copper. In addition, 7,500 tons of cathode copper recovered by a leach-electrowinning process were produced. The expansion program, begun in 1974, to enlarge the open pit mine and the construction of a 40,000-ton-per-day concentrator, was completed as scheduled in late 1977. Ore reserves at yearend were approximately 290 million tons of proven ore averaging 0.49% copper. Sufficient exploration work was completed to establish additional mineralization, although further exploratory and development work and economic analysis must be completed to determine if mining will be profitable.

Duval Corp., a subsidiary of Pennzoil Co., operated the Sierrita, the Esperanza, and the Mineral Park copper-molybdenum open pit mines in Arizona and the Copper Canyon open pit copper mine in Nevada. Output from these mines accounted for approximately 9% of the total U.S. production. Operations ceased for 6 weeks in late summer at all four mines as a result of low copper prices. The Esperanza property remained closed except for the waste dump leaching operation.

Hecla Mining Co., in a joint venture with El Paso Natural Gas Co., operated the Lakeshore underground copper mine until early September when activity was suspended because of losses incurred from low copper prices. The closure of the mine was also due to an inventory buildup of cement copper precipitates resulting from strikes at receiving smelters. The suspension of operations continued through yearend. Copper production from both oxide and sulfide ores during the year was 20,410 tons of copper. An additional 15,410 tons of copper in purchased concentrates was recovered by processing in the electrowinining plant.

Inspiration Consolidated Copper Co. operated the Thornton, Red Hill, and Joe Bush open pit copper mines in the vicinity of Inspiration, Ariz.; 6.1 million tons of waste and 2.5 million tons of ore were mined for a combined 8.6 million tons of material handled. The combined production from in-plant processed ore in the form of concentrates, precipitates, and electrowon cathodes was 14,561 tons of copper. Waste dump leaching of mined material, too low in copper content for in-plant treatment, yielded an additional 5,325 tons of copper. At the Ox Hide mine, 1.5 million tons of ore was mined for heap leaching dumps and 2,320 tons of copper was recovered in the form of precipitates. At the Christmas open pit mine, southeast of Miami, Ariz., output was 5,194 tons from processing slightly less than 1 million tons of ore and removal of 4.2 million tons of waste. Total mine production from all operating mines was 27,400 tons of copper compared with 48,864 tons in 1976. All of Inspiration's Arizona operations were shutdown by a strike from July 1 through August 26. Following the strike, operations resumed at the smelter, refinery, and rod fabricating and sulfuric acid plants. Recovery of copper by leaching at the Ox Hide mine resumed in October. The mines and other treatment plants remained shutdown for the remainder of the year.

Kennecott Copper Corp. operated mines in Arizona, Nevada, New Mexico, and Utah; these mines produced a combined total of 358,150 tons of copper, a 3% increase from the 1976 output. The Utah Copper Div. accounted for 195,353 tons of the total followed by the Ray Mines Div. (Arizona) with 80,326 tons, Chino Mines Div. (New Mexico) with 57,263 tons, and the Nevada Mines Div. with 25,208 tons. Better equipment and facilities and more effective methods enabled the Utah Copper Div. to improve production. The Chino Mines Div. brought a precipitate plant on line at the new Lampbright waste dump to take advantage of low cost copper found in waste dump material. The increase in production at the Ruth pit, Nevada Mines Div., was the result of resumption of mining and milling operations following a 10-month suspension in the previous year. Development projects at the potential copper ore deposit beneath the perimeter of the Utah Copper Div., Bingham Canyon mine and at Flambeau, Wis., were temporarily suspended.

Magma Copper Co. operated two underground copper mines in Arizona with a combined output of 163,000 tons of copper compared with 145,000 tons in 1976, an increase of 12%. The San Manuel mine continued to operate at curtailed levels throughout the year. However, at the smaller Superior mine, production was maintained at full capacity. A limited development program continued to gain access for underground drilling in the adjoining Kalamazoo ore body at San Manuel. The mills at Superior and San Manuel continued to re-treat copper-bearing smelter slag accumulated in previous years.

Mines of the Phelps Dodge Corp., produced 276,700 tons of copper in concentrates, ores, and precipitates compared with 331,000 tons in 1976, a decrease of 16.4%. Output at Morenci, Ariz., Tyrone, N. Mex., Metcalf, Ariz., and Ajo, Ariz., was 100,700 tons, 84,700 tons, 50,500 tons, and 36,000 tons, respectively. The Bisbie, Ariz., operation contributed 4,300 tons and miscellaneous sources contributed 500 tons. The decrease was due to the strikes which closed the Arizona operations from July 1 to August 12, the post-strike shutdown of the Ajo mine until October 2, and reduced work schedules at the mines during the balance of the year. Development work continued at the deep ore body at Safford, Ariz. However, no further development work was done on the Copper Basin property southwest of Prescott, Ariz.

Ranchers Exploration and Development Corp. produced slightly less than 9,000 tons of copper cathodes - a record high - by a leaching-solvent extraction-electrowinning process at its Bluebird mine near Miami, Ariz. The in situ leaching operation at the Old Reliable deposit near San Manuel, Ariz., remained on standby throughout 1977, awaiting more favorable marketing conditions. Almost 400 tons of copper was produced from the leaching operations at the Big Mike mine near Winnemucca, Nev.

UV Industries, Inc., operated the Continental mine near Bayard, N. Mex., mining 664,000 tons of ore with an average copper assay of 1.66% from underground operations and 1,687,000 tons of ore with an average copper assay of 0.82% from open pit operations. Concentrates produced from milling the ore totaled 86,000 tons with an average copper content of 25%. Estimated reserves at yearend were 18.1 million tons averaging 0.86% copper suitable for open pit mining and 16.4 million tons averaging 2.06% copper suitable for underground mining. An exploration program at Bayard was reported to be highly successful and initial indications were that a second open pit may be a possibility. Present estimates indicated ore reserves in excess of 10 million tons of copper ore averaging approximately 0.6% copper.

The White Pine, Mich., operations of Copper Range Co., milled 3.5 million tons of copper ore yielding 46,060 tons of copper in concentrate compared with 3.7 million tons of ore which yielded 44,380 tons of copper in concentate in 1976. The mine was closed during August by a strike from August 1 through August 15, followed by a 2-week shutdown.

Smelter Production.—Output of copper at primary smelters in the United States was 1.48 million tons, a 6% decrease from production of the preceding year.

ASARCO completed the first phase of a major comprehensive modernization and air quality control program late in the year at its El Paso, Tex., copper and lead smelters. The program was expected to reduce substantially the need for curtailment to meet Governmental air quality standards. Construction began on the second phase of the program scheduled for completion in 1978 which includes construction of an enclosed ore handling system to minimize dust from incoming ore shipments, and an 800-ton-per-day sulfuric acid plant to capture sulfur dioxide emissions during the roasting of copper and lead ores. The program at the Tacoma, Wash., smelter to improve the capture of solid-particle emissions proceeded on schedule. In addition to the strike-caused loss of production at ASARCO's three copper smelters, there was also curtailments in production during adverse weather conditions to remain in compliance with environmental control requirements.

Kennecott commenced the phaseout of the old Utah copper smelter and the new smelter modification project began to come on line in September. The transition was being made with insignificant loss of production. The changeover was to be completed by mid-1978. The McGill, Nev., smelter reopened in January, following a 5-month closure in the previous year, and continued full scale operation throughout the year.

The Phelps Dodge Hidalgo smelter operated for the first full year and produced 82,500 tons of copper anodes, mainly from the Tyrone, N. Mex., concentrator, compared with 37,900 tons in 1976, when it operated for only half of the year. Installation of a second acid plant and other facilities was completed in November on schedule.

San Manuel smelter operations of Magma Copper Co., were adversely affected during the fourth quarter of 1976 and the first quarter of 1977 by an unusually high number of intermittent curtailments required for air pollution control during atmospheric inversions. The problems were corrected by the end of the first quarter of 1977, and production returned to normal by the end of April. Periodic curtailments of smelter production during the year to stay within sulfur dioxide emission limits during unfavorable atmospheric conditions resulted in some loss of production. In mid-year, Magma undertook conversion of its reverbertory furnaces to burn coal as a primary fuel. The conversion was expected to be completed in 1979.

Refined Production.—In 1977 production of refined copper from primary materials decreased 3% to 1.50 million tons. Refined copper produced from scrap was 385,418 tons compared with 375,155 tons in 1976. Total production of refined copper in the United States was 1.88 million tons, 80% derived from primary and 20% from scrap sources.

The Anaconda Company closed the Arbiter plant, a hydrometallurgical refinery at Anaconda, Mont., for an indeterminate period. The feed that had been designated for treatment at the Arbiter plant was processed at the company's nearby conventional smelter.

Duval Corp., continued testing of its new CLEAR process (an acronym for copper, leach, electrolysis, and regeneration) plant for the electrolytic production of copper crystals. The patented CLEAR process creates no solid, liquid, or gaseous pollution. The plant, designed to produce 44,000 short tons of copper crystals annually, was running at about 85% of design capacity.

Copper Sulfate.—Copper sulfate was produced from electrolytic tankhouse solutions, blister copper, and secondary metal by companies with plants located as follows:

Company	Plant location
The Anaconda Company	Great Falls, Mont.
Chevron Chemical Co	Richmond, Calif.
Cities Service Co	Copperhill, Tenn.
Phelps Dodge Refining Corp	Laurel Hill, N.Y., El Paso, Tex.
Van Waters & Rogers Inc	Wallace, Idaho.

Copper sulfate production decreased for the fourth consecutive year to 30,100 tons, the smallest quantity since 1934. Shipments including consumption by producing companies increased 2% over those of 1976 and exceeded production by 857 tons, drawing down stocks from the relatively high level of 8,557 tons at yearend 1976 to 7,700 tons at yearend 1977. Of the total shipments of 30,957 tons, reports indicated that 16,487 tons was for agricultural uses, 12,799 tons was for industrial uses, and 1,671 tons was for other uses.

Byproduct Sulfuric Acid.—Sulfuric acid was produced at 14 copper smelters from the sulfur contained in offgases, and output increased for the 10th consecutive year from 2,281,600 tons to a record 2,357,400 tons on a 100% acid basis.

SECONDARY COPPER AND BRASS

Domestic recovery of copper in all forms from all classes of purchased scrap totaled 1.20 million tons in 1977, a 4% increase over the 1976 total. Recovery from copper-base scrap advanced from 1.11 million tons to 1.16 million tons. Brass mills accounted for

46% of the recovered copper, secondary smelters for 26%, and primary producers for 23%. The remaining 5% was reclaimed at chemical plants, foundries, and manufacturers.

Consumption of purchased copper-base scrap in 1977 was 1.57 million tons consisting of 61% new scrap and 39% old scrap. Of the major categories of copper and copper-alloy products derived from scrap, the output of unalloyed copper, brass mill products, and brass and bronze ingots was 402,000 tons, 664,000 tons, and 244,200 tons, increases of 3%, 2%, and 7%, respectively.

CONSUMPTION

Consumption of refined copper in the first half of 1977 was 17% above the comparable period for 1976, but this rate of consumption was not sustained in the second half. Consumption for the year advanced 10% to 2.2 million tons, the second year of recovery from the drastic slump in 1975, and approximately the same as consumption in 1974. Wire mills accounted for 69% of refined copper consumption, brass mills accounted for 29%, and all other categories accounted for the remaining 2%.

Apparent withdrawals of primary refined copper on domestic account was 1.79 million tons compared with 1.83 million tons in 1976.

STOCKS

Stocks of refined copper at primary producers were drawn down from 190,000 tons at the start of the year to 79,000 tons by the end of June, then moved up to 234,000 tons by yearend. At wire rod and brass mills, the stocks of refined copper increased from 150,000 tons at the start of the year to 213,000 tons at the end of July, then declined to 123,000 tons by the end of November and ended the year where they began at 150,000 tons. Stocks of refined copper in Commodity Exchange, Inc., warehouses increased from 201,000 tons at the start of the year to 213,000 tons at the end of March, then declined to 184,000 tons by yearend.

PRICES

Prices of copper on the London Metal Exchange (LME) increased from an average 63.3 cents per pound for January to 68.6 cents for March followed by a generally downward trend to 52.5 cents for August and a rise to 57.1 for December. The average estimated price for 1977 was 59 cents compared with 64 cents for 1976.

Producer price in the United States approximated the LME pattern with price for refined cathode copper increasing in three steps, from 65 cents per pound at the start of the year to 74 cents in mid-March, then decreasing in four steps between May and August to a price of 60 cents. A modest advance in the LME prices led to a 3-cent increase in the domestic producer price in mid-December. The average for 1977 was 67 cents compared with 70 cents per pound in 1976.

FOREIGN TRADE

Exports of alloyed copper scrap, in gross weight, were 82,000 tons compared with 76,700 tons in 1976. Imports of alloyed copper scrap were 13,400 tons, gross weight, or 8,800 tons copper content.

Net imports of copper continued to be a relatively large supply component in 1977 as imports of unmanufactured copper excluding alloyed copper scrap fell slightly from 534,700 tons to 516,700 tons and exports decreased from 172,000 to 125,400 tons. The largest trade category, refined copper, had a small increase in imports from 381,500 tons to 390,800 tons and a 54% decrease in exports from 111,900 tons to 51,500 tons. Of the total imports, Canada supplied 25%, Chile 23%, Zambia 15%, and Peru 12%. Imports of blister copper were 46,200 tons compared with 44,500 tons in 1976. The other import categories of ore, concentrates, matte, and unalloyed copper scrap totaled 79,800 tons, and the other export categories of ore, concentrates, matte, blister, ash and residues, and unalloyed scrap totaled 73,800 tons.

WORLD REVIEW

World mine production of copper increased 2.8% to an estimated 8.50 million tons in 1977. The United States continued to lead the world in mine production with 18% of the total, followed by Chile 14%, the U.S.S.R. 11%, Canada 10%, Zambia 9%, Zaire 6%, Peru 5%, Poland 4%, the Philippines 3%, Australia 3%, the Republic of South Africa 3%, and Paupa New Guinea 2%. Market economy countries produced about 81% of the total production.

According to the World Bureau of Metal Statistics, refined copper consumption rose about 6% to 9.97 million tons, the highest recorded; however, because of higher world copper production and further buildup of world stocks, the price of copper, except for a temporary rise in March, trended downward in 1977. CIPEC held two ministerial level meetings during the year but failed to arrive at a unanimous decision to implement measures to reduce mine and refined production to levels below those of 1976. The major copper producing and consuming countries held four meetings in 1977, under the auspices of the United Nation's Conference on Trade and Development (UNCTAD), to examine the causes of market instability and to consider possible ways to correct the problem. No agreements were made but among items for further consideration were the formation of commodity agreements involving buffer stocks and the formation of an International Common Fund to finance commmodity agreement operations.

World stocks of refined copper, as reported by the World Bureau of Metal Statistics, grew to 2,010,000 tons by yearend, representing an increase of 9% over 1976. The reported stocks included producer, consumer, and merchant inventories of 622,000 tons (including 184,000 tons in COMEX warehouses) of refined copper in the United States, 323,000 tons in Japan, 261,000 tons combined between France, the Federal Republic of Germany, and the United Kingdom, plus 707,000 tons held in LME warehouses. The total reported refined stocks, valued at $2.4 billion represented the equivalent of 3.2 months demand based on the average monthly world market economy consumption of refined copper of 628,000 tons in 1977.

Australia.—Australian copper production continued at about the same level, 242,440 tons in 1977, for the third year; however, refinery production decreased about 4% to 169,928 tons. Continued poor market conditions forced some mine closures and production cutbacks. In August, Gunpowder Copper Ltd., owned 48% by Consolidated Gold Fields Ltd., closed its mine in Queensland. Mount Isa Mines Ltd. (MIM), for the fiscal year ending June 30, produced 153,340 tons of blister copper, 11,600 tons less than fiscal 1976. Although more ore was treated in fiscal 1977, the grade was lower resulting in decreased production. Copper ore reserves at the end of the fiscal year were 133 million tons averaging 3.2% copper. MIM's Townsville copper refinery produced 153,400 tons of refined copper, a decrease of 4.6% from the previous year. A $17 million program to mechanize the refinery's tankhouse was underway and in August MIM announced an $8 million program to install copper anode casting facilities at Mount Isa to save energy by eliminating the blister remelting process at the Townsville refinery. The new plant was expected to be operational by mid-1979.

Mount Lyell Mining & Railway Co. Ltd., (MLM), operators of copper mines near Queenstown, Tasmania, reduced production by 3,000 tons of realizable copper in concentrate in fiscal 1977 to 19,500 tons to reduce costs and minimize losses. MLM's North Lyell mines were closed and the work week shortened from 7 to 5 days. Late in 1977, the Government approved in 1977, short-term assistance to keep the mine from closing. Owing to mine closings and the severe economic situation, MLM's ore reserves were reduced by 23 million tons to 6.4 million tons grading 1.47% copper.

EZ Industries Ltd. (EZI) reported increased copper production in concentrate from 3,520 tons in fiscal 1976 to 4,180 tons for the year ending June 30, at its West Coast mines in Tasmania. Ore reserves in the three operating mines fell by 0.5 million tons to about 8.3 million tons grading 0.7% copper with significant zinc, lead, silver, and gold values.

Cobar Mines Pty., Ltd., a subsidiary of BH South Ltd., curtailed production at its copper-lead-zinc CSA mine at Cobar, New South Wales. Copper output in concentrate fell 18% to 7,680 tons in fiscal 1977 owing to reduced ore production and lower ore grades. The copper concentrate was sold to The Electrolytic Refining and Smelting Co. of Australia Ltd. at Port Kembla.

Exploration by base metal companies continued although the depressed state of the copper market prompted EZI and its joint venture partners, Amax Exploration (Australia) Inc. and Aztec Exploration Co. Pty. Ltd., to suspend further work on their Golden Grove, Western Australia, deposit which has a resource potential of 15 million tons grading 3.59% copper. Western Mining Corp. reported significant copper-uranium-rare earth mineralization in holes drilled at its Olympic Dam prospect particularily at the Roxby Downs site. Ore grades averaging 1.3% copper and 1 pound of uranium oxide per ton have been reported over intersections ranging from 25 feet to 800 feet thick. Economic evaluation of MIM's Teutonic Bore prospect in Western Australia was continuing. Drilling has delineated 2.8 million tons of ore with an average grade of 3.5% copper, 9.5% zinc, and 5 troy ounces of silver per ton.

Botswana.—Bamangwato Concessions Ltd. (BCL) owned 85% by Botswana RST, Ltd., and 15% by the Government, reached design capacity, 3,500 tons of copper-nickel matte per month after 2 years of difficult commissioning problems. Production was a record 21,275 tons of copper-nickel matte in the last 6 months of 1977. For the year, however, matte production was only 33,920 tons, 1,910 tons less than in 1976, owing to technical problems and overhaul of the flash furnace early in the year. All of the matte produced was shipped to AMAX's Port Nickel (Louisiana) refinery for processing into metal. Ore milled at the Pikwe-Selebi operation during 1977 was 2.1 million tons containing 1.02% nickel and 0.83% copper, compared with 2.3 million tons grading 1.07% nickel and 0.86% copper in 1976. Proven and probable reserves at BCL's Pikwe-Selebi deposits totaled 48.7 million tons of ore grading 1.07% nickel and 1.17% copper.

Canada.—Mine production increased 7% in 1977 to 860,500 tons of recoverable copper. Smelter output increased 2.4% to 551,500 tons but refinery production decreased slightly to 560,900 tons. Because of poor copper market conditions, some Canadian producers scaled-down production plans through mine closures, cutbacks, and expansion deferrals. British Columbia was the leading copper producing Province with 37% of the total followed by Ontario 36%, Quebec 14%, Manitoba 8%, and the remaining Provinces 5%.

Reviewing the activities of the Canadian copper industry for the year by Province, in British Columbia, Afton Mines Ltd., 56% owned by Teck Corp. Ltd., began mine and mill operations at its $80 million Afton open pit mine near Kamloops late in the year. A 7,000-ton-per-day concentrator was built containing two circuits, one a standard flotation circuit to recover sulfides and the other a gravity circuit to recover significant quantities of native copper present in the ore. Because of the high copper (66%) and low sulfur (5%) content in the combined mill concentrate, a top blown rotary converter (TBRC) smelter, to be operational in February 1978, has been adapted to smelt the ore. In the TBRC operation, concentrate mixed with lime and iron is melted by a natural gas-oxygen mixture resulting in a slag-metal separation from which a 99% pure blister copper can be drawn off. A decision to build the smelter was in part prompted by passage of the Province's Copper Smelting and Refining Incentives Act which authorizes payments up to $500,000 per year for 10 years to smelters to encourage upgrading of concentrate in British Columbia.

Bethlehem Copper Corp. Ltd., milled 6.1 million tons of ore grading 0.43% copper from open pit mines in the Highland Valley and produced a 44.84% copper concentrate containing 22,764 tons of copper compared with 27,561 tons in 1976. The lower output was mainly attributable to a 45-day labor strike at midyear. Reserves at the operating Iona and Jersey mines total 54 million tons of 0.4% copper minable at a 1:1 waste to ore ratio.

Owing to operating losses since late 1974, the Granduc mine, managed by the Granduc Operating Div. of Newmont Mines Ltd. and half owner with ASARCO Incorporated, was expected to close in May 1978 when developed ore was exhausted. For the year, Granduc milled 1.47 million tons of ore grading 1.31% copper producing 18,200 tons of copper in concentrates, 5% more than in 1976. Promising intersections of copper ore were encountered by drilling in the northern extension of the main Granduc mineral structure in 1977 and were to be further explored in 1978.

Similkameen Mining Co. Ltd., a subsidiary of Newmont Mining Corp., operated its open pit mine and mill near Princeton at close to design capacity, 22,000 tons per day since April, but owing to the milling of lower grade ore, production of copper in concentrate fell slightly to 25,300 tons. Mining in the southwest zone of the Ingerbelle pit was completed in February and the area was being backfilled with waste removed from other parts of the pit. The company began engineering and pit design studies to prepare the neighboring Copper Mountain ore bodies for eventual production. Reserves at the end of 1977 were 49.9 million tons averaging 0.54% copper compared with 54 million tons averaging 0.53% 1 year earlier.

Craigmont Mines ltd., 44.59% owned by Placer Development Ltd., announced in December that its copper mine near Merritt would be closed down in early 1979 due to exhaustion of economic ore. Exploration for additional ore reserves near the mine continued with no significant results by yearend. In 1977, Craigmont milled 2 million tons of ore grading 1.17% copper producing 81,000 tons of concentrate containing 22,658 tons of copper, 2,625 tons less than that of 1976.

Granby Mining Corp., operated the Granisle and Phoenix open pit mines. Granisle for the year ended September 30, treated 5.0 million tons of 0.44% copper ore compared with 4.3 million tons of 0.42% copper ore in the previous year. Copper production in concentrate increased 23% to 18,890 tons. Ore reserves at the end of September were 52.9 million tons with an average copper content of 0.42% at an average stripping ratio of 1.65 tons of waste per ton of ore. During the year new contracts with Japanese smelters were negotiated. Production at the Phoenix mine, 3,280 tons of copper in concentrate, was 29% lower than in 1976, owing to difficult loading and crushing conditions in handling stockpiled ore.

Gibraltar Mines Ltd., a Placer Development Ltd. subsidiary, milled 14.1 million tons of 0.38% copper ore in 1977, up substantially from the 8.5 million tons of 0.45% copper ore milled in strike-ridden 1976. Concentrate production totaled 154,500 tons containing 43,391 tons of copper. The Granite Lake, Stage I pit was mined until September when it was replaced by the Pollyanna Stage I pit from which ore production was expected for the next few years. Estimated ore reserves on December 31, at a cutoff grade of 0.25% copper, were 286 million tons at an average grade of 0.37% copper.

Brenda Mines Ltd., a Noranda Mines Ltd. subsidiary, operated one of the world's lowest grade porphyry copper-molybdenum mines at Peachland, British Columbia. Brenda milled 10.6 million tons of 0.19% copper and 0.047% molybdenum ore producing 68,000 tons of concentrate containing 17,800 tons of copper. The tonnage milled was below the 1976 record, 11.2 million tons, but higher ore grades and improved recovery resulted in a production increase of 1,700 tons of copper. Copper concentrate produced since April was sold in Japan and Korea at LME prices. Brenda's ore reserves at yearend totaled 109 million tons grading 0.165% copper and 0.040% molybdenum.

Noranda's Bell Copper Div. in Granisle, British Columbia mined 4.9 million tons of ore grading 0.428% copper and 0.009 troy ounce of gold per ton. Concentrate output of 65,500 tons contained 17,500 tons of copper and 23,000 troy ounces of gold. Reserves were 25 million tons averaging 0.492% copper with 0.012 troy ounce gold.

In Manitoba, Sheritt Gordon Mines Ltd., which operated the Ruttan and Fox mines in 1977, milled a combined total of 3.4 million tons of copper-zinc ore producing 37,192 tons of copper in concentrate. In November a revised pit mining plan was initiated at the Ruttan mine to raise the pit bottom by over 100 feet to the 600 level. The new plan reduced the open pit size, the stripping ratio, and ore reserves. Ore lost to pit mining was to be recovered through underground stopes permitting sustained annual production rates of 2.5 million tons through 1982. Ruttan open pit reserves at yearend were 5 million tons grading 1.37% copper and 1.78% zinc. Reserves at the Fox mine were 7.1 million tons averaging 1.83% copper and 2.12% zinc.

The Canadian Metals Div. of Hudson Bay Mining and Smelting Co., Ltd., operated nine copper-zinc mines and a copper smelter in the Flin Flon-Snow Lake area. About 1.82 million tons of ore averaging 2.2% copper were mined and milled to produce 202,765 tons of 18.13% copper concentrate. The copper smelter produced 68,938 tons of anode copper from feed supplied 49.6% by Hudson Bay mines and 50.4% purchased from other companies. Proven reserves in the company's mines in the Flin Flon-Snow Lake area at yearend totaled 17.5 million tons of 2.75% copper with 2.7% zinc, 0.036 troy ounce of gold, and 0.53 troy ounce of silver per ton.

Falconbridge Copper Ltd., 50.2% owned by Falconbridge Nickel Mines Ltd. (FNM), produced 46,185 tons of copper in 1977 compared with 41,470 tons in 1976, from its three operating divisions, Lake Dufault and Opemiska in Quebec, and Sturgeon Lake Joint Venture in Ontario. Ore reserves at yearend were as follows: Lake Dufault Div., 4 million tons of 3.22% copper; Opemiska, 3.74 million tons of 2.44% copper; and

Sturgeon Lake Joint Venture, 0.9 million tons grading 2.59% copper. Copper production at FNM's Intergrated Nickel Operations was significantly lower owing to 5 weeks total curtailment of operations beginning in September at Sudbury, Ontario, owing to depressed nickel prices and increasing nickel inventories. Ore delivered to treatment plants from FNM mines in the Sudbury area amounted to 2.9 million tons grading about 0.77% copper compared with 3.2 million tons of similar grade in 1976. Low levels of production were projected for 1978.

Copper output at INCO Ltd.'s, nickel operations at mines in Ontario and in Manitoba fell to 164,000 tons from 172,500 in 1976 owing to cutback in nickel production. INCO suspended or reduced operations at a number of mines in 1977, and was planning further reductions in operations in 1978. Except for the small depleted Victoria mine in Sudbury, the affected mines were to be maintained on a standby basis so they can be brought back into production when warranted.

At the Mattagami Lake mine, owned by Mattagami Lake Mines Ltd., ore milled was 1.0 million tons grading 0.52% copper and 6.6% zinc compared with 1.2 million tons of 0.55% copper and 7.3% zinc milled in 1976. Production of copper concentrate was 16,974 tons averaging 24.4% copper, down from the 20,641 tons of 24.2% copper produced in 1976. Reserves at yearend were 8.6 million tons averaging 0.58% copper and 7.2% zinc. All development at the company's Lyon Lake ore bodies was suspended at the end of November pending improved market conditions. Lyon Lake ore reserves were estimated to be 4 million tons grading 1.15% copper, 6.66% zinc, with significant lead, silver, and gold values.

Because of the poor world market conditions for copper and zinc, Texasgulf Inc., was stretching out construction of the Kidd Creek copper smelter and refinery and the development work in the No. 2 underground mine. The last ore was blasted at the open pit, in April. Stockpiled ore from the pit was adequate to supply the concentrator for the next 3 years. The No. 2 shaft was bottomed at 5,105 feet in September and was expected to be fully commissioned by late 1978. Kidd Creek ore reserves at the end of 1977 were estimated at 119 million tons of which 108.3 million tons were classified as proven and probable containing 2.84% copper, 5.03% zinc, 0.18% lead, and 1.99 ounces of silver per ton.

The Geco Div. of Noranda Mines Ltd., in Manitouwadge, Ontario, milled 1.75 million tons of ore grading 1.94% copper, 2.62% zinc, and 1.22 troy ounces of silver per ton producing concentrates containing 31,700 tons of copper, 20% more than in 1976. Reserves at yearend were 25.6 million tons averaging 1.80% copper, 3.73% zinc, and 1.53 troy ounces of silver per ton.

Gaspé Copper Mines Ltd. (Noranda) at Murdochville, Quebec, milled 1.4 million tons of 1.13% copper ore from the Needle Mountain underground mine and 10.8 million tons of 0.46% copper ore from the Copper Mountain open pit. The smelter processed 207,200 tons of concentrates, 52% of which was from Gaspé operations, producing 49,300 tons of copper in 1977 compared with 69,700 tons in 1976. Reserves at Needle Mountain were 12.3 million tons averaging 1.15% copper and at Copper Mountain combined oxide and sulfide reserves were estimated to be 212 million tons averaging 0.40% copper.

Chile.—Copper production in Chile was 1,164,260 tons in 1977, the highest output so far achieved by the industry. Production by the Government-owned Nacional del Cobre Chile (Codelco-Chile), operators of four divisions: Chuquicamata, El Teniente, Salvador, and Andina, accounted for almost 85% of total production and was a record 984,000 tons of copper, 50,500 tons higher than in 1976. The Chuquicamata Div. produced 526,000 tons or 53.5% of Codelco-Chile's copper output; the El Teniente Div. produced 304,000 tons or 30.9%; Salvador, 89,000 tons or 9.0%; and Andina, 65,000 tons or 6.6%. Production by type of copper product was as follows: Electrolytic, 511,600 tons; blister, 187,900 tons; fire refined, 133,100 tons; and concentrates, 151,400 tons. Codelco-Chile invested $100 million in its operations during the year to replace equipment, improve operating efficiency, and increase byproduct recovery.

The Government's program to encourage foreign investment in copper mining resulted in three agreements of exploration and development in 1977. Noranda Mines Ltd. signed an agreement with Empresa Nacional de Minera (ENAMI) to explore and if attractive, to develop the Andacollo porphyry copper deposit located about 25 miles southeast of the Port of Coquimbo. Reserves at the deposit were estimated at 300 million tons averaging 0.69% copper. St. Joe Minerals Corp. agreed to explore and possibly invest about $100 million in development of the El Indio copper-silver-gold deposit near La Serena. Joint development of the Quebrada Blanca deposit, 100 miles southeast of Iquique was agreed to by the Government who will hold (49%) with the Superior Oil Co., Falconbridge Nickel Mines Ltd., and McIntyre Mines Ltd. holding 51%. A 100,000-ton-per-year copper project costing about $500 million was envisioned. Reserves were estimated at 165 million tons at an average grade of 0.7% copper.

At yearend Exxon Minerals Corp. was formalizing an agreement for the purchase of Compañía Minera Disputada de Las Condes (MDC), for about $100 million. MDC, located near Calera about 30 miles east of Santiago, had reserves estimated at 800 million tons grading 0.82% copper. In 1977, MDC produced about 25,000 tons of copper in concentrate from ore averaging 1.15% copper.

Indonesia.—Freeport Indonesia Ltd. (FIL), produced about 189,000 tons of copper concentrate (30% copper) from its mine at Tembagapura, Irian Jaya. Production declined 17% from that of 1976 owing to the mining of lower ore grades and brief disruption of operations by political dissidents. FIL's original ore body, 32 million tons of ore grading about 2.35% copper, has been mined since 1972 and was expected to be exhausted in 1982. A second nearby ore body of similar size and grade, called Guung Bijih Timur (East Ore Mountain) was being explored. Proposals called for development of an underground mine beginning in 1978. Costs were projected to be about $80 million.

Iran.—Iranian ore reserves in active mines were estimated to be over 1 billion tons. The Sar Cheshmeh mine of Sar Cheshmeh Copper Mining Co. (SCCM), a Government-owned company, had 850 million tons of 1.2% copper and the Qal'eh Zari mine, of the Minak Co., a Japanese-Iranian joint venture had 200 million tons of 3% to 4% copper. Small operating copper mines had reserves of about 600,000 tons.

Production at the Qal'eh Zari mine, which opened in 1975, was about 15,400 tons of 30% copper concentrate in 1977, all of which was being exported to Japan. The mine, located south of Birjand in Khorasan Province, was being mined by underground methods.

SCCM was stockpiling ore at Sar Cheshmeh awaiting completion of the 40,000-ton-per-day concentrator and smelter complexes, both of which were expected to be in operation by 1978. Construction of a copper refinery with an annual capacity of 175,000 tons of electrolytic copper was expected to begin in 1978 with completion in 1981. The refinery complex was to include a nickel sulfate plant and facilities for recovering precious metals.

Korea, Republic of.—A 10-year contract beginning in 1979 to import 360,000 tons of copper concentrate per year for smelting and refining at a $180 million facility under construction at Onsan was signed late in the year. The contract between Onsan Copper Refinery Co. (OCR) and U.S. and Australian dealers, called for Onsan to import copper concentrates from the Philippines, Canada, Mexico, and Chile. OCR also concluded a separate agreement with Chile to import 33,000 tons of copper concentrates on a long-term basis.

Malaysia.—The Mamut Mines Development Co., a joint venture of private Malaysian interests, the Sabah Government, and a consortium of seven Japanese firms, increased production of copper in concentrates from 20,100 tons in 1976 to 26,500 tons in 1977. Technical problems in the mill were corrected early in the year, and in March, mill throughput was increased from 13,000 tons of ore per day to 18,000 tons. By mid-1978, Mamut expected to reach design capacity of 20,000 tons per day and a copper production of 33,000 tons per year.

Mexico.—Mine production of copper was up slightly in 1977, and smelter production at 107,428 tons was up 14%, but refined production at 80,537 tons declined 3%. A new Mexican mining tax and development law, to become effective on January 1, 1978, was enacted to simplify the tax structure and to provide for permanent and well-defined tax incentives to stimulate continued development of the mining industry.

Compañía Minera de Cananea, S.A., located 40 miles south of the Arizona border, completed early in 1977, an expansion program to increase mill capacity to 73,000 tons of ore per day and copper production to 77,000 tons per year. A further increase to 111,000 tons of copper per year was under study.

Mexicana de Cobre, S.A., 44% owned by the Government, planned initial production at its $900 million La Caridad copper project in Sonora to begin in December 1978, but owing to delays in completing the concentrator, production was not expected to begin until early 1979. The 100,000-ton-per-day open pit mine and mill operation was to be followed by a flash smelter and refinery complex near the railroad at Nacozari. Construction on the smelter complex, which has a planned capacity of 200,000 tons of copper per year, was expected to start in 1978 and be in operation 28 months later. Ore reserves were reported to be 760 million tons of 0.76% copper and 0.016% molybdenum.

Norway.—Eleven mines produced a total of 124,700 tons of copper concentrate containing about 30,985 tons of copper, compared with 31,210 tons of copper produced in 1976. Because of the poor copper market, the Government established a copper fund to ease the financial burden of the copper companies to insure that the mines remain open. The fund was designed to subsidize copper production if the market price was more than 10% lower than a stipulated trend price for copper and conversely, if the market price moves higher than 10% above the trend price, the producers would reimburse the fund, such that reserves could be built-up for the next market downturn.

Panama.—A detailed feasibility study of the large Cerro Colorado porphyry copper deposit, held by the State-owned Corporacion de Desarollo Minero (80%) and Texasgulf Inc. (20%), was expected to be completed by Texasgulf in May 1978. The companies involved envisioned a $1 billion project consisting of a 30-million-ton-per-year mine-mill operation, a smelter producing 200,000 tons of blister copper per year, and a phosphoric acid plant producing 290,000 tons of acid per year. Production was anticipated to begin in the mid-1980's. The concentrator was to be located adjacent to the mine while the smelter would be located on the Pacific coast at La Popa, 39 miles from the mine site. Concentrate was to be transported to the smelter by slurry pipeline. Reevaluation of the mineralization in 1977 at a cutoff of 0.4% copper, indicated the deposit contained 1.5 billion tons of ore grading 0.78% copper and 0.01% molybdenum with 0.003 troy ounce of gold and 0.164 troy ounce of silver per ton.

Papua New Guinea.—Bougainville Copper Pty., Ltd. (BCL), owned by Conzinc Riotinto of Australia Ltd. (53.6%); the Government (20.2%); public shareholders (25.3%); and the Panguna Development Foundation Ltd. (0.9%), treated 37.6 million tons of ore in 1977 producing 200,940 tons of copper, 719,324 troy ounces of gold, and 1.53 million troy ounces of silver in 679,000 tons of concentrates. The concentrate was shipped mainly to smelters in Japan, the Federal Republic of Germany, and Spain under long-term sales agreements. Shipments to Japan were curtailed during 1975-76, but full contractual deliveries were resumed in 1977. At the end of 1977, the BCL ore body contained 838 million tons of reserves averaging 0.45% copper and 0.015 troy ounce of gold per ton.

Exploration drilling in 1977 by Frieda Exploration Pty., Ltd. (FEL), a consortium of six Japanese companies headed by Sumitomo Metal Mining Co., increased the potential reserves at the Frieda River copper prospect in the north foothills of the Schatteburg Mountains to 550 million tons averaging 0.5% copper. FEL could earn a 40% interest in the deposit from MIM Holdings Ltd., by spending $6 million on exploration. When the feasibility study is completed in 1979, talks are to be held with the Government concerning the future of the Frieda River deposit.

The first phase of a drilling program at the OK Tedi copper deposit in Western Papua New Guinea was completed in January by a consortium composed of Dampier Mining Co., Ltd. (a subsidiary of Broken Hill Pty. Ltd.), 37.5%; Mt. Fubilan Development Co. Ltd. (a subsidiary of Standard Oil of Indiana), 37.5%; and Kupferexplorations Gesellschaft m.b.H. (a West German group), 25%. The program proved the presence of at least 275 million tons of ore grading 0.85% copper. A second drilling phase was underway as part of a feasibility study that was expected to be completed in 1979. If the deposit is developed, the Government has the right to acquire 20% equity interest in the project. An open pit mining operation is envisioned for possible start-up in 1983-84; however, development costs have been estimated to be about $700 million and may delay development.

Peru.—Owing to new mines and smelter developments Peruvian copper mine and smelter production increased 59% and 67% to 337,592 and 354,000 tons, respectively. Refinery production, aided by increased output from the Ilo refinery increased 30% to 201,600 tons. Copper exports increased 83% to 363,200 tons with refined copper representing 52% of the total compared with only 20% in 1976.

Southern Peru Copper Corp. (SPCC), a consortium composed of ASARCO Incorporated (51.5%), Cerro-Marmon Corp. (22.25%), Phelps Dodge Corp., (16%), and Newmont Mining Corp. (10.25%), was

Peru's largest copper producer accounting for almost 75% of the country's copper output. SPCC milled 14.5 million tons of 0.91% copper ore at its Toquepala mine compared with 16 million tons of 1.05% copper ore milled in 1976. Output of copper in concentrates was 107,800 tons, 14.6% lower than in 1976. The new $726 million Cuajone mine, a joint venture owned 90% by SPCC and 10% by Billiton B.V., a subsidiary of Royal Dutch Shell Oil Co., completed its first full year of operation. Ore and waste mined were 74.7 million tons, ore treated was 15.2 million tons grading 1.41% copper, and 179,000 tons of concentrate were produced. Copper concentrates from both the Toquepala and Cuajone mines were shipped to SPCC's Ilo smelter 60 miles away on the Pacific coast; blister copper production attributed to each operation in 1977 was 108,400 and 175,800 tons, respectively. At yearend, Cuajone ore reserves were 455 million tons averaging 0.97% copper and those of Toquepala were 210 million tons averaging 0.87% copper.

Empresa Minera del Peru (Minero Peru), a State-owned company, brought the oxide zone of its Cerro Verde copper mine into production in May and reached full capacity of 3,000 tons of copper per month in September. Development of underlying sulfide zone of the porphyry deposit, one of the largest in Peru, was delayed and the scale of the project reduced by three-fourths. Minero Peru, however, expected to arrange financing for the project in 1978. Plans called for construction of a 22,000-ton-per-day concentrator which will produce 220,000 tons of concentrate annually, equivalent to about 66,000 tons of copper. Cost of the initial phase was estimated at $250 million. Ore reserves of both the oxide and sulfide zones were estimated to be 1.2 billion tons grading 0.7% copper.

Empresa Minera del Centro del Peru (Centromin), the State-owned mining agency which operates six underground mines and one open pit copper mine, began a $467 million program to modernize and expand existing facilities and mines. Ore production at the Cobriza copper mine was to be increased at a cost of $160 million from 2,100 tons per day to 10,000 tons per day. Projected output in 1980 was expected to be 60,000 tons of copper in 246,000 tons of concentrate. Other projects to be undertaken by Centromin included increasing the copper capacity at the La Oroya copper smelter and refinery from 62,500 tons per year to 80,000 tons and replacing the cementation plant at the Cerro de Pasco mine with a 7,000-ton-per-year copper solvent-extraction electrowinning plant.

The new Aquila mine, owned by Mines Aquilo S.A. and located at Huaraz in Sihuas Province, was scheduled to come onstream in March 1978 with an annual production of 2,200 tons of copper per year. Concentrates from the mine were to be mixed with water, pumped across the Continental Divide, and then trucked 100 miles to the Port of Chimbote. The Aquila mine has proven and probable reserves of 22 million tons of 1.4% copper, with possible reserves of 45 million tons.

Philippines.—The Philippines was the ninth largest of the world's copper producers. Mine production increased 15% to 296,000 tons of copper in concentrate and direct shipping grade ore in 1977. The increased production was mainly attributable to initial production by Atlas Consolidated Mining and Development Corp. (Atlas) at its Carmen project and by the reopening of the Mankayan mine of Lepanto Consolidated Mining Corp. (Lepanto). A number of smaller operations, however, were temporarily closed during the year owing to the depressed copper market.

The Philippine Associated Smelting and Refining Corp. (PASAR), a joint venture of the Government, five Philippine copper companies, and foreign investors, decided to build the country's first copper smelter near Palompom on Leyte Island. PASAR was forced to withdraw from its original proposed site at San Juan, Batangas Province, in Luzon because of strong environmental opposition. A 150,000-ton-per-year copper smelter, up from the 93,000-ton-per-year unit originally proposed, was expected to be operational in 1981.

Atlas, one of the largest copper producers in Asia, milled 32.8 million tons of ore in 1977, an increase of 8.3 million tons over that milled in 1976. The Carmen project, rated at 35,000 tons of ore per day, came onstream 4 months early accounting for the large increase in milled ore. At yearend the company's combined milling capacity was about 110,000 tons per day, comparable to the Bougainville, Papua New Guinea mine in size. Production increased 25% to 142,186 tons of copper contained in 467,556 tons of concentrate. At yearend, Atlas ore reserves, including 350 million tons grading 0.43% estimated for the Carmen deposit, totaled 1.08 billion tons grading 0.46% copper.

Marinduque Mining and Industrial Corp.

operated the Sipalay open pit in Negros Oriental and Bagacay mine in Samar. At Sipalay production was 29,906 tons of copper in concentrate from a total tonnage milled of 6.5 million tons grading 0.53% copper. Owing to depressed copper prices the Bagacay operation was temporarily closed, and as a result production fell to 1,560 tons of copper in 1977 compared with 5,980 tons of copper in 1976. The Sipalay mine ore reserves at yearend totaled 716 million tons averaging 0.491% copper. The Bagacay mine reserves totaled about 0.9 million tons with a grade of 4.53% copper and 2.70% zinc.

Western Minolco, operator of the Boneng and Lobo mines at Benquet in northern Luzon, produced 35,452 tons of concentrates containing 8,490 tons of copper from 4 million tons of ore milled in 1977. Copper production was 14% lower than in 1976 owing to suspension of milling operations in November due to depressed copper prices and a shortage of exposed good minable ore in the pits. Ore reserves for the Boneng and Lobo deposits at yearend were 98 million tons grading 0.34% copper with 0.011 troy ounce of gold per ton.

Lepanto, operators of the Mankayan underground mine in northern Luzon, milled 915,000 tons of ore producing 64,000 tons of concentrate containing about 20,500 tons of copper, 75,000 troy ounces of gold, and 263,000 troy ounces of silver. Mining of higher grade reserves (3.5% copper) in the lower levels was expected by 1979 by way of the recently completed Tubo shaft. The company's reserves at yearend were about 8 million tons grading 2.57% copper and 0.013 troy ounce of gold per ton.

Marcopper Mining Corp., a subsidiary of Placer Development Ltd., milled a record 10.1 million tons of ore in 1977, up from 9.7 million tons in 1976. Copper recovered in concentrate, however, fell slightly to 52,069 tons owing to the processing of lower grade ores. Mining operations in the Tapian pit reduced reserves to 75 million tons with an average grade of 0.58% copper at a cutoff grade of 0.4% copper. Marcopper began development of its nearby San Antonio deposit which has estimated reserves at a cutoff grade of 0.4% copper in excess of 200 million tons grading 0.57% copper. After removal of extensive tailings overburden, mining was expected to commence in 1981.

Philex Mining Corp. increased production 7% in 1977 to 36,260 tons of copper contained in concentrate from 10.8 million tons of ore milled. Production at the Sto Nino mine continued to suffer because of poor recovery (64%); nonetheless, production was 5,170 tons of copper in concentrate, up 340 tons over that of 1976. Philex's ore reserves at yearend were 167 million tons grading 0.41% copper and 0.023 troy ounce of gold per ton.

Several copper projects progressed during the year. Benquet Consolidated Inc. was arranging financing for development of its Dizon copper-gold deposit near San Marcelino, Zambales Province. Planned output of the $85 million project was projected to be 30,000 tons of copper and 100,000 troy ounces of gold in concentrate per year. Ore reserves were estimated to be 85 million tons grading 0.47% copper. Consolidated Mines planned to have the new, 16,500-ton-per-day copper mill at its Ino deposit (112 million tons of ore grading 0.53% copper) on Marinduque Island in operation in 1978. The Construction and Development Corp. of the Philippines (CDCP) planned to have its newly completed 11,000-ton-per-day concentrator at Basay, Negros Oriental, in commercial operation early in 1978. CDCP's ore reserves were reported to be 113 million tons containing 0.544% copper. Sabena Mining Corp. was granted tax-exempt status by the Government to mine and mill copper from its property in New Bataan, Davao del Norte. Construction of an 11,000-ton-per-day mill began in May with startup expected in 1979. Ore reserves were 38 million tons grading 0.502% copper. Cost of the Sabena project was $28 million, of which $17 million would be supplied by foreign loans.

Poland.—The $1 billion Sieroszowice-Cedyina project, which includes new mines and a smelter and expansion of existing mines and facilities, was expected to boost the country's copper production to about 550,000 tons by the early 1980's. Development of mines at the Sieroszowice I and II copper deposits was underway and on completion is expected to yield about 55,000 tons of copper per year from ore grading 2% copper. A second smelter-refinery section employing an Outokumpu-designed flash smelter was under construction at the new 165,000-ton Glowgow-2 copper refinery. Full production at the refinery was expected by 1980.

Rhodesia, Southern.—M.T.D. (Mangula) Ltd. (MTD), a subsidiary of the Messina (Transvaal) Development Co., operated the

Mangula, Norah, and Silverside mines during the year ended September 30, 1977. At the Mangula mine 1.42 million tons of 0.93% copper ore were milled yielding 12,228 tons of copper in 27,970 tons of concentrate. Although the tonnage milled was up 9% over that of 1976, the ore grade declined about 9% owing mainly to dilution in mining pillars which constituted 40% of the ore mined. The Norah and Silverside mines, respectively, produced an additional 6,837 tons and 830 tons of copper in concentrate. Expansion of the Norah concentator to a capacity of 46,000 tons per month was completed in June. A 14% expansion of the Mangula concentrator was completed in November; this plus the Norah expansion was expected to increase MTD's copper output by 5,200 tons in 1978. Mining at the Silverside mine stopped in May owing to exhaustion of reserves. MTD's ore reserves at the end of September were 16.5 million tons averaging 1.25% copper at the Mangula mine and 3 million tons averaging 1.22% copper at the Norah mine.

Lomagundi Smelting and Refining Ltd. (LSR), also a Messina Transvaal subsidiary, produced 6,995 tons of copper in concentrate at its Shackleton mine and 306 tons at the Alaska mine. LSR, which milled 690,000 tons of 1.15% copper at the Shackleton mine in 1977, reported that reserves at the mine were only 815,000 tons averaging 1.58% copper at yearend. LSR's smelter was hampered by the quality and quantity of concentrates received and copper production declined from 34,222 tons in 1976 to 31,064 tons in 1977.

Corsyn Consolidated Mines Ltd., a Lonrho subsidiary, produced 5,435 tons of copper, down from 5,645 tons in 1976, at its Inyati and Muriel mines in the year ended September 30. Because of low copper prices the ore production rate at the Inyati mine was reduced in the last quarter from 30,000 tons per month to 14,000 tons and ore reserves were greatly reduced.

South Africa, Republic of.—Palabora Mining Co. Ltd., produced 117,400 tons of copper, a 14% increase over production of 1976. Milled ore was 27.4 million tons grading 0.52% copper in 1977, compared with 21.6 million tons grading 0.55% copper milled in 1976. Production was expected to be even higher in 1977, but two new autogenous grinding mills, part of a recently completed $100 million expansion program, developed cracks and were shutdown for 2 months. Ore reserves totaled 580 million tons grading 0.55% copper at yearend.

O'okiep Copper Co. Ltd., as part of a cost reduction program, halted production in July at some higher cost mines resulting in a 30% decrease in mine output in the latter half of 1977. For the year ore milled was 2,148,000 tons grading 1.46% copper compared with 2,628,000 tons grading 1.35% copper milled in 1976. Copper produced from O'okiep ores was 28,700 tons, 12% less than in 1976. At the end of 1977, total O'okiep ore reserves were 30 million tons averaging 1.70% copper compared with 30 million tons averaging 1.67% copper 1 year earlier.

South Africa's copper ore reserves, including those of the Messina (Transvaal) Development Co. and Prieska Mines Ltd., totaled 887 million tons averaging 0.64% copper.

South-West Africa, Territory of.—The Tsumeb Corp. Ltd. (TCL), mined 490,200 tons of ore averaging 4.71% copper from the Tsumeb mine, compared with 488,800 tons averaging 4.25% copper mined in 1976. At the Matchless mine, TCL mined 122,000 tons of ore averaging 2.23% copper; the Kombat and Asis Ost mines were not in production in 1977 but were scheduled to restart production in late 1978. The TCL smelter produced 39,650 tons of blister copper compared with 31,700 tons in 1976. Slightly more than 63% of 1977's smelter output was from TCL mines; the remainder was from toll and purchased material. Ore reserves of TCL mines were as follows: Tsumeb mine, 4.9 million tons averaging 4.4% copper; the Matchless mine, 996,000 tons averaging 2.32% copper; Kombat mine, 790,000 tons averaging 1.89% copper; and Asis Ost, 280,000 tons averaging 2.83% copper. At Asis West tentative ore reserves total 1.5 million tons averaging 7.8% copper.

The Oamites Mining Co., Ltd., a subsidiary of Falconbridge Nickel Mines Ltd., milled 683,000 tons of ore grading 1.2% copper. Recoverable copper in concentrate totaled 7,105 tons, 8% greater than that of 1976. At yearend ore reserves were 3.9 million tons grading 1.19% copper and 0.45 ounce of silver per ton.

The Ojtihase underground mine of Johannesburg Consolidated Investments Ltd., was placed on a care and maintenance basis at the end of 1977. The mine, which experienced operating problems since its startup in July 1976, was no longer viable owing to low copper prices and higher operating costs.

Yugoslavia.—Estimated production of copper by Rudarsko Topionicarski Bazen (RTB), Bor, Serbia, in 1977 included 133,400 tons of copper in concentrates, 182,000 tons of blister, and 84,350 tons of primary refined copper. RTB completed development of a nearby ore body, designated "X", and trial production was started. Reserves at the new ore body were estimated at 9 million tons grading 1.1% copper. Development work continued on the 660-million-ton, 0.5% copper deposit at Veliki Krivelj. The first phase of development was planned for completion in 1980 with initial production scheduled at 27,000 tons copper in concentrate. When fully developed in 1981 Krivelj, plus production from a small nearby rich deposit at Cerova, was expected to have an annual capacity of about 70,000 tons of copper in concentrate.

At Bucim, Macedonia, development of a copper mine and construction of a mill was continued by a Macedonian state enterprise, Bucim Rudnik za Bakar u Osnivanju. Plans called for production to begin in 1978 at an annual capacity of 23,000 tons of copper in concentrate. Recent exploration reportedly confirmed 100 million tons of ore, enough to sustain capacity output for 28 years.

Zaire.—In 1977, Zairian copper production in concentrate was 530,800 tons, 8% higher than that of 1976 but 3% lower than output in 1975. Total smelter and refinery production increased 11% and 50%, respectively, from that of 1976. Enormous problems owing mainly to the continual closure of the Benguela railroad were encountered in shipping output as well as importing parts and equipment. Fuel shortages also continued to hamper new production and pit development. Copper exports were channeled out of Shaba Province by way of a tedious internal route to the Zairian Port of Matadi, by railroad to East London in South Africa, and by the Tanzania-Zambia Railway to Dar es Salaam in Tanzania.

Copper was produced by two companies, the Government-owned La Générale des Carrières et des Mines du Zaire (GECAMINES) and a joint Government-private Japanese concern, Société de Development Industriel et Minière du Zaire (SODIMIZA). A third company, Société Minière de Tenke-Fungurume (SMTF) comprised of the Government (20%), Charter Consolidated Ltd., and associated companies (28%); Amoco Minerals Co. (28%); Mitsui Co. (14%); and three other partners (10%), announced in December that it planned in 1978 to restart development work suspended since January 1976 at its Tenke-Fungurume deposit (55 million tons of ore grading 5.5% copper and 0.4% cobalt). The new effort was expected to represent an initial investment of about $14 million. Since beginning the project in 1970, SMTF has invested $280 million and to carry the project to completion, a further $500 million was expected to be necessary. To obtain economies in cost and production, SMTF reduced its initial production target from 165,000 tons copper of per year to 110,000 tons.

In 1977, SODIMIZA produced about 30,890 tons of copper contained in 89,300 tons of concentrate at its Musoshi mine. The concentrates are shipped to Japan for processing. In October SODIMIZA brought the Tchinsenda (Kinsenda) mine into production; about 45,000 tons of ore averaging about 5% copper was produced from this operation in the last quarter of 1977. Plans called for production of 250,000 tons of ore in 1978, 300,000 tons in the following 2 years, and 350,000 tons in 1981. The Kinsenda operation was expected to significantly lower the unit cost of SODIMIZA's output owing to the fact that the ore grade at Kinsenda is about twice that of the company's Musoshi mine (2.5% copper).

GECAMINES, which operated 10 mines, 5 mills, a copper smelter at Lubumbashi, and 2 copper-cobalt refineries at Kolwezi and Luilu in Shaba Province, produced 499,000 tons of copper in concentrate, 497,000 tons of blister, and 108,900 tons of refined copper. Plans to increase annual production to 628,000 tons by 1980 continued to progress under GECAMINES $600 million, 5-year production development plan. The development program called for the opening of open pit mines at Dikuluwe and Mashambe and construction of a 38,000-ton-per-year flash smelter and a 110,000-ton-per-year electrolytic refinery which, at a later date, was to be enlarged to produce about 385,000 tons of copper per year. Expansion of the refinery at Lubumbashi to 176,000 tons annual capacity by 1980 continued.

Zambia.—The Zambian copper industry continued to be plagued by worsening transportation and production problems, loss of skilled and experienced labor, and a shortage of essential supplies. Faced with continuing depressed prices, some plant expansions, mine development, and exploration programs were delayed to reduce expenditures. Benefits accruing to the industry by the 20% devaluation of the Kwacha in July 1976 were rapidly eroded by increasing labor and production costs. Because of numerous problems, mine production for 1977 fell 7% to 723,115 tons of recoverable copper, blister production was down 8% to 718,168 tons, and refined production decreased 7% to 715,000 tons.

In the year ended June 30, 1977, Roan Consolidated Mines, Ltd. (RCM), mined 16.9 million tons of ore with an average grade of 1.99% copper yielding 302,050 tons of recoverable copper from mines at Mufulira, Chambishi, Luanshya, Chibuluma, and Kalengwa. For the fiscal year, total production of finished copper, 288,190 tons - comprised of 193,396 tons of wirebar, 77,405 tons of cathode, and 17,389 tons of leach cathodes - was 21,552 tons less than in fiscal 1976, mainly because the electric furnace at Mufulira was out of commission for maintenance for most of the first half of 1977. The wirebar casting plant at Mulfulira was closed in January owing to increasing market preference for cathodes over wirebars. All wirebar casting after January was done at the Ndola copper refinery. Ore reserves at RCM's operations as of June 30, totaled 354 million tons averaging 2.87% copper.

Nchanga Consolidated Copper Mines Ltd. (NCCM) for the year ended March 31, 1978, produced 415,743 tons of finished copper from operations at its Rokana, Konkola, and Chingola divisions. Production was about 53,000 tons less than targeted for the year and 12% lower than fiscal 1977 production. The unsatisfactory results were mainly attributed to the loss of skilled labor and the shortages of spare, parts both of which resulted in deteriorating maintenance in major plants. The Chingola Div. was the only profitable division; however, because of production interdependence between divisions, uneconomic operations in other divisions could not be readily closed down to reduce working costs. NCCM stopped mining in the upper ore body in the underground mine at Chingola Div. and put the North Shaft at the Mindola section of the Rokana Div. on a care and maintenance basis. Production was also affected by heavy rains early in the year which hampered the mining of high-grade mineralization in the Nchanga open pit and the underground mine of Chingola Div. Small-scale mining at Kansanshi Hill began in June at a rate of 16,500 tons of ore per month. A total of 140,000 tons of ore grading 3.3% copper was delivered by road to Chingola.

The copper reserves, including indicated and possible, of NCCM divisions as of December 31, 1977, were as follows:

Division	Tons (million)	Total copper (percent)
Rokana	140	2.36
Chingola	307	3.23
Konkola	133	3.52
Total or average	580	3.09

Comparable reserve estimates for 1976 were 592 million tons of ore grading 3.08% copper.

TECHNOLOGY

A study of alteration zones surrounding Chilean porphyry copper deposits revealed an anomalous rubidium content that may be useful in providing an enlarged exploration target.[2] Exploration for massive sulfide deposits may be guided by evaluation of hydrothermal systems as related to various geologic conditions and the intensity of copper mineralization.[3] An article described a case example of the use of an airborne electromagnetic survey in the discovery of a massive sulfide copper-nickel deposit.[4] Application of gamma-ray analysis techniques to small-diameter drill holes provides additional deposit information at reasonable cost.[5]

The trends in copper mining methods and practices were related to declining ore grades and other factors affecting costs of production.[6] The Bureau of Mines reported on field tests on in situ leaching of copper ore in a pit bottom and ore covered by 200 feet of overburden with data collected on parameters such as fragmentation, permeability, leaching rates, and ground water flow.[7] Laboratory studies on leaching native copper ores may be useful in determining conditions for further field testing.[8]

Experimental work on processing a copper-nickel ore by differential flotation resulted in producing a copper concentrate containing 25% copper and 0.5% nickel and a nickel concentrate containing 10% nickel and 1% copper.[9] An evaluation of an electrical induction process to upgrade native copper ore concluded that, if the capacity of the equipment can be increased, it would have an application in improving the efficiency of mining native copper deposits.[10]

Research on equilibria in the lead-copper-arsenic-sulfur system as applied to copper dross smelting concluded that one of the principal factors in the selectivity of the separation between copper and lead was a proper copper to arsenic ratio in the speiss phase of the smelting.[11] A laboratory investigation indicated the feasibility of recovering copper from chalcopyrite concentrates by a complex procedure of reaction with CaO and hydrogen followed by separation of the reaction products by screening, magnetic separation, leaching, decantation, filtration, and electrolytic refining of the metallic copper residue.[12] Another laboratory investigation showed that a chlorination-carbon reduction-flotation of segregated copper recovered more than 98% of the copper in a product suitable for a subsequent refining stage.[13] Bench-scale tests obtained good conversion of chalcopyrite concentrates to copper-iron chlorides and elemental sulfur by reacting the concentrates with chlorine in a vertical shaft reactor at 550° to 750° C.[14] It has been demonstrated that injection of carbon into molten copper slag could yield a product containing approximately 95% iron and 2% copper that can be used in recovery of copper by cementation.[15] A review article compared the advantages and disadvantages of various smelting processes, especially with respect to energy requirements.[16]

A paper analyzed the technical and economic factors that must be considered if hydrometallurgical processes for application to sulfide concentrates are to gain widespread acceptance.[17] Cyprus Mines Corp. announced, after extensive tests of a new, essentially pollution-free hydrometallurgical process, that the process was competitive with conventional smelting processes. The process starts with two leaching steps using a chloride solution followed by crystallization to obtain cuprous chloride crystals, then reduction of the crystals in a hydrogen bed reactor to obtain pure copper.[18] Research indicated that the use of fluid bed electrolysis can recover good-quality copper from heap-leach solutions with low copper concentrations.[19] Other research indicated that a silver catalyzed, ferric sulfate oxidative leaching process developed for copper sulfide concentrates has promise for commercial applications.[20]

An experimental furnace for the continuous smelting of copper-bearing scrap was developed. Test results indicated a substantial savings in energy needed and an upgrading of the scrap to a product ranging from 83% to 95% copper.[21]

Information was published on development of a new copper radiator design that improves manufacturing efficiency to maintain competitiveness with substitute materials.[22] An investigation of accelerated corrosion of copper-nickel piping indentified turbulence as a major contributing factor and resulted in a number of recommendations to correct the problem.[23]

---

[1]Physical scientist, Division of Nonferrous Metals.

[2]Armbrust, G. A., J. Oyarzun, and J. Arias. Rubidium as a Guide to Ore in Chilean Porphyry Copper Deposits. Econ. Geol., v. 72, No. 6, September-October 1977, pp. 1086-1100.

[3]Hodgson, C. J., and J. W. Lydon. Geological Setting of Volcanogenic Massive Sulphide Deposits and Active Hydrothermal Systems: Some Implications for Reexploration. CIM Bull., v. 70, No. 786, October 1977, pp. 95-106.

[4]Blecha, M., H. Thalenhorst, and A. Komura. Techk's Montcalm Copper Nickel Deposit: AEM Survey Brings Major Discovery. Can. Min. J., v. 98, No. 4, April 1977, pp. 21-28.

[5]Nargolwalla, S., and H. O. Seigel. In-situ Mineral Deposit Evaluation With the Metalog System. Can. Min. J., v. 98, No. 4, April 1977, pp. 75-89.

[6]Goldsmith, C. R. H. New Techniques in Copper Mining. Min. Mag., v. 238, No. 2, February 1978, pp. 111-118.

[7]D'Andrea, D. V., W. C. Larson, L. R. Fletcher, P. G. Chamberlain, and W. C. Engelmann. In Situ Leaching Research in a Copper Deposit at the Emerald Isle Mine. BuMines RI 8236, 1977, 43 pp.

[8]Hockings, W. A. Kinetics of Leaching Native Copper Ores With Dilute Ammonium Carbonate Solutions (Research grant No. G0254034). BuMines Open File Rept. 87-77, September 1976, 95 pp.; available for consulation at the Bureau of Mines facilities in Tuscaloosa, Ala., College Park, Md., Twin Cities, Minn., Rolla, Mo., Boulder City and Reno, Nev., Albany, Oreg., and Salt Lake City, Utah; the National Library of Natural Resources, U.S. Department of the Interior, Washington, D. C.; and from the National Technical Information Service, Springfield, Va. PB 266 798/AS.

[9]Iwasaki, I., and A. Malicsi. Separation of Copper-Nickel From Duluth Gabbro by a Differential Flotation-Matte Smelting-Matte Separation Process (Research grant No. G0144109). BuMines Open File Rept. 86-77, Nov. 18, 1976, 152 pp.; available for consulation at the Bureau of Mines facilities in Tuscaloosa, Ala., College Park, Md., Twin Cities, Minn., Rolla, Mo., Boulder City and Reno, Nev., Albany, Oreg., and Salt Lake City, Utah,; the National Library of Natural Resources, U.S. Department of the Interior, Washington, D.C.; and from the National Technical Information Service, Springfield, Va. PB 266 853 /AS.

[10]Schultz, C. W., and C. W. Karkkainen. An Evaluation of the USBM Sorting Machine on Native Copper Ores of the Keweenaw District (Research contract No. J0265059). BuMines Open File Rept. 158-77, July 1, 1977, 63 pp.; available for consulation at the Bureau of Mines facilities in Tuscaloosa, Ala., College Park, Md., Twin Cities, Minn., Rolla, Mo., Boulder City and Reno, Nev., Albany, Oreg., and Salt Lake City, Utah, the National Library of Natural Resources, U.S. Department of the Interior, Washington, D.C.; and from the National Technical Information Service, Springfield, Va. PB 274 413/AS.

[11]Matyas, A. G. Metallurgy of Lead-Copper Dross Smelting. Trans. Inst. Min. Met. (Sect. C: Mineral Processing and Extractive-Metallurgy), v. 86, December 1977, pp. C190-C194.

[12]Habashi, F., and B. I. Yostos. Copper From Chalcopyrite by Direct Reduction. J. Met., July 1977, pp. 11-16.

[13]Marcuson, S. W., and H. H. Kellogg. Studies on Segregation of Roasted Copper Concentrate. Trans. Inst. Min. Met. (Sect. C: Mineral Process and Extractive-Metallurgy), v. 86, December 1977, pp. C195-201.

[14]Yee, D. H., R. S. Olsen, and T. T. Campbell. Chlorination of Chalcopyrite. BuMines RI 8229, 1977, 17 pp.

[15]Paulson, D. L. and W. L. Hunter. Recovering Iron From Copper Smelting Furnace Slags by Carbon Injection. BuMines RI 8211, 1977, 14 pp.

[16]Sharma, S. N. and W. L. Davis, Jr. Energy Conservation: A New Challenge for Copper Smelting. Soc. of Min. Eng., May 1977, pp. 38-41.

[17]Agarwal, J. C., D. S. Davies, V. K. Kakaria, and N. L. Nemser. Comparative Analyses of Hydrometallurgical Processes. Pres. at 16th Ann. Conf. of Metal, and 7th Ann. Hydrometallurgical Meeting, Can. Inst. of Min., Vancouver, British Columbia, Canada, Aug. 21-25, 1977, pp. 1-12.

[18]Engineering and Mining Journal. Cyprus Reveals Details of New Copper Process. V. 178, No. 11, November 1977, pp. 27-33.

[19]Simpson, C. C., Jr. Purity of Copper Produced by Fluid Bed Electrolysis of a Heap-Leach Solution. J. Met., v. 29, No. 7, July 1977, pp. 6-10.

[20]Snell, G. J., and M. C. Sze. New Oxidative Leaching Process Uses Silver to Enhance Copper Recovery. Eng. and Min. J., v. 178, No. 10, October 1977, pp. 100-105, 167.

[21]Pulling, D. H., and F. A. Garner. Application of a Continuous Technique to Secondary Copper Smelting. CIM Bull., v. 70, No. 788, December 1977, pp. 122-134.

[22]International Copper Research Association, Inc. The Automotive Radiator - Cost-Saving Copper/Brass Radiator Introduced In Europe. INCRA, No. 7, September 1977, 8 pp.

[23]National Materials Advisory Board. Accelerated Corrosion of Copper-Nickel Piping. Nat. Acad. Sci.-Nat. Res. Council, December 1977, 36 pp.

Table 2.—Copper produced from domestic ores, by source

(Thousand short tons)

Year	Mine	Smelter	Refinery
1973	1,718	1,705	1,698
1974	1,597	1,532	1,421
1975	1,413	1,374	1,286
1976	1,606	1,461	1,423
1977	1,504	1,394	1,411

Table 3.—Copper ore and recoverable copper produced, by mining method

(Percent)

Year	Open pit		Underground	
	Ore	Copper[1]	Ore	Copper[2]
1973	89	78	11	22
1974	89	81	11	19
1975	89	80	11	20
1976	90	84	10	16
1977	90	83	10	17

[1]Includes copper from dump leaching.
[2]Includes copper from in-place leaching.

Table 4.—Mine production of recoverable copper in the United States, by month

(Short tons)

Month	1976	1977
January	119,319	138,178
February	115,507	129,831
March	132,516	147,939
April	134,931	139,500
May	135,438	138,024
June	128,140	135,990
July	126,244	97,932
August	142,096	100,930
September	142,825	108,019
October	146,210	119,741
November	141,209	123,914
December	141,156	123,968
Total	1,605,586	1,503,966

Table 5.—Mine production of recoverable copper in the United States, by State

(Short tons)

State	1973	1974	1975	1976	1977
Arizona	927,271	858,783	813,211	1,024,421	923,778
California	369	194	344	375	221
Colorado	3,123	3,012	3,560	2,431	1,896
Idaho	3,625	2,841	3,192	3,362	4,052
Maine	1,107	1,522	2,024	1,766	1,337
Michigan	72,221	67,012	73,690	43,707	42,375
Missouri	10,273	12,665	14,258	11,050	11,737
Montana	132,466	131,131	87,959	91,111	86,203
Nevada	93,702	84,101	81,210	58,160	67,061
New Mexico	204,742	196,585	146,263	172,360	164,698
Oregon	W	W	W	--	6
Pennsylvania	1,845	--	--	W	W
Tennessee	8,500	6,304	10,041	11,131	6,187
Utah	256,589	230,593	177,155	185,458	194,130
Other States[1]	2,107	2,259	459	254	285
Total	1,717,940	1,597,002	1,413,366	1,605,586	1,503,966

W Withheld to avoid disclosing company proprietary data; included in "Other States."
[1]Includes Pennsylvania and Washington (1977).

Table 6.—Twenty-five leading copper-producing mines in the United States in 1977, in order of output

Rank	Mine	County and State	Operator	Source of copper
1	Utah Copper	Salt Lake, Utah	Kennecott Copper Corp	Copper ore, copper precipitates.
2	Twin Buttes	Pima, Ariz	Anamax Mining Co	Copper ore.
3	San Manuel	Pinal, Ariz	Magma Copper Co	Copper ore, copper tailings.
4	Morenci	Greenlee, Ariz	Phelps Dodge Corp	Copper ore, copper precipitates, copper tailings.
5	Sierrita	Pima, Ariz	Duval Corp	Copper ore.
6	Tyrone	Grant, N. Mex	Phelps Dodge Corp	Copper ore, copper precipitates.
7	Berkeley Pit	Silver Bow, Mont	The Anaconda Company	Do.
8	Ray Pit	Pinal, Ariz	Kennecott Copper Corp	Do.
9	Pinto Valley	Gila, Ariz	Cities Service Co	Do.
10	Chino	Grant, N. Mex	Kennecott Copper Corp	Do.
11	Pima	Pima, Ariz	Cyprus Pima Mining Co	Do.
12	Metcalf	Greenlee, Ariz	Phelps Dodge Corp	Copper ore, copper tailings, copper cleanup.
13	White Pine	Ontonagon, Mich	Copper Range Co	Copper ore.
14	Magma	Pinal, Ariz	Magma Copper Co	Do.
15	New Cornelia	Pima, Ariz	Phelps Dodge Corp	Do.
16	Yerington	Lyon, Nev	The Anaconda Company	Copper ore, copper precipitates.
17	Ruth Pit	White Pine, Nev	Kennecott Copper Corp	Copper ore.
18	Bagdad	Yavapai, Ariz	Cyprus Bagdad Copper Co	Do.
19	Mission	Pima, Ariz	ASARCO Incorporated	Do.
20	Continental	Grant, N. Mex	UV Industries, Inc	Do.
21	Lakeshore	Pinal, Ariz	Hecla Mining Co	Do.
22	Sacaton Unit	do	ASARCO Incorporated	Do.
23	Inspiration	Gila, Ariz	Inspiration Consolidated Copper Co.	Copper ore, copper precipitates.
24	Silver Bell	Pima, Ariz	ASARCO Incorporated	Do.
25	Mineral Park	Mohave, Ariz	Duval Corp	Do.

Table 7.—Mine production of recoverable copper in 1977, by method of treatment

Method of treatment	Ore treated (thousand short tons)	Recoverable copper		Remarks
		Thousand pounds	Percent yield	
Copper ore:				
By concentration	240,151	2,432,773	0.51	See table 9.
By smelting	300	1,842	.31	See table 10.
By leaching	19,523	261,494	.67	See table 11.
Total	259,974	2,696,109	.52	
Tailings, dump, in-place material by leaching	--	268,430	--	See table 11.
Miscellaneous from cleanup, tailings, noncopper ores	--	43,393	--	
Total	XX	3,007,932	XX	--

XX Not applicable.

Table 8.—Copper ore shipped directly to smelters or concentrated in the United States, by State in 1977, with copper, gold, and silver content in terms of recoverable metal

State	Ore shipped or concentrated (thousand short tons)	Recoverable metal content				Value of gold and silver per ton of ore
		Copper		Gold (troy ounces)	Silver (troy ounces)	
		Thousand pounds	Percent			
Arizona	153,005	1,494,038	0.49	87,720	6,680,543	$0.29
Idaho	150	1,846	.62	W	58,282	W
Michigan	3,510	84,750	1.21	--	335,479	.44
Montana	15,476	149,130	.48	21,181	3,081,451	1.12
Nevada	10,211	68,526	.34	W	387,248	W
New Mexico	24,266	285,924	.59	10,985	757,793	.21
Tennessee[1]	1,250	12,374	.49	13	60,246	.22
Utah	32,583	338,020	.52	W	W	W
Other States[2]	([3])	7	10.10	225,848	1,884,348	1.35
Total	240,451	2,434,615	.51	345,747	13,245,390	.47

W Withheld to avoid disclosing company proprietary data; included in "Other States."
[1]Copper-zinc ore.
[2]Includes data for Alaska, Idaho, Nevada, Oregon, and Utah.
[3]Less than 1/2 unit.

Table 9.—Copper ore concentrated[1] in the United States, by State in 1977, with content in terms of recoverable copper

State	Ore concentrated (thousand short tons)	Recoverable copper content	
		Thousand pounds	Percent
Arizona	152,814	1,492,877	0.49
Idaho	150	1,846	.62
Michigan	3,510	84,750	1.21
Montana	15,476	149,130	.48
Nevada	10,159	67,998	.33
New Mexico	24,221	285,896	.59
Tennessee[2]	1,250	12,374	.49
Utah	32,571	337,902	.52
Total	240,151	2,432,773	.51

[1]Includes following methods of concentration: "Dual process" (leaching followed by concentration); "LPF"(leach-precipitation-flotation); and froth flotation.
[2]Copper-zinc ore.

Table 10.—Copper ore shipped directly to smelters[1] in the United States, by State in 1977, with content in terms of recoverable copper

State	Ore shipped to smelters		
	Short tons	Recoverable copper content	
		Pounds	Percent
Arizona	191,282	1,160,887	0.30
Nevada	51,762	527,995	.51
New Mexico	45,098	28,273	.03
Utah	11,980	117,541	.49
Other States	35	7,069	10.10
Total	300,157	1,841,765	.31

[1]Primarily smelter fluxing material.

Table 11.—Copper precipitates (leached from dump and in-place material and tailings) shipped directly to smelters, and copper ore and tailings leached (heap, vat, or tank) in the United States, by State in 1977, with content in terms of recoverable copper

State	Precipitates and tailings leached or shipped (short tons)	Recoverable copper content (pounds)	Ore leached (short tons)	Recoverable copper content (pounds)	Percent
Arizona	84,116	[1]141,565,206	[2]15,595,484	208,345,801	0.67
Montana	16,771	22,786,718	--	--	--
Nevada	8,986	12,439,904	3,927,049	53,148,087	.68
New Mexico	28,652	42,260,800	--	--	--
Utah	31,447	49,377,160	--	--	--
Total	169,972	268,429,788	19,522,533	261,493,888	.67

[1]Includes copper from newly generated tailings.
[2]Includes 9,126,649 short tons of ore leached for electrowinning.

Table 12.—Copper ore smelted and copper ore concentrated in the United States, and average yield in copper, gold, and silver

Year	Smelting ore		Concentrating ore		Total				
	Thousand short tons	Yield in copper (percent)	Thousand short tons[1 2]	Yield in copper (percent)	Thousand short tons[1]	Yield in copper (percent)	Yield per ton in gold (ounce)	Yield per ton in silver (ounce)	Value per ton in gold and silver
1973	337	1.40	272,688	0.53	289,998	0.53	0.0018	0.058	$0.32
1974	305	1.26	269,016	.50	293,443	.49	.0014	.048	.45
1975	357	1.85	239,614	.48	263,003	.47	.0014	.051	.44
1976	260	.32	258,371	.50	283,736	.51	.0013	.053	.39
1977	300	.31	240,151	.51	259,974	.52	.0014	.055	.47

[1]Includes some ore classed as copper-zinc and minor amount of tailings.
[2]Excludes tank or vat and heap leaching. (See tables 7 and 11.)

Table 13.—Copper produced by primary smelters in the United States

(Short tons)

Year	Domestic	Foreign	Secondary	Total
1973	1,705,065	38,898	77,815	1,821,778
1974	1,532,066	37,750	79,543	1,649,359
1975	1,374,324	72,804	49,357	1,496,485
1976	1,461,256	73,366	51,045	1,585,667
1977	1,394,432	40,744	49,434	1,484,610

Table 14.—Primary and secondary copper produced by primary refineries and electrowinning plants in the United States

(Short tons)

	1973	1974	1975	1976	1977
PRIMARY					
From domestic ores, etc.:[1]					
Electrolytic	1,510,334	1,275,545	1,140,754	1,221,140	1,160,188
Electrowon	26,485	23,167	30,972	103,941	139,456
Fire refined	161,518	122,193	114,463	97,642	111,353
Total	1,698,337	1,420,905	1,286,189	1,422,723	1,410,997
From foreign ores, etc.:[1]					
Electrolytic [2]	170,151	233,753	157,189	116,585	85,187
Electrowon	--	W	W	W	W
Fire refined	W	W	W	--	W
Total refinery production of primary copper	1,868,488	1,654,658	1,443,378	1,539,308	1,496,184
SECONDARY					
Electrolytic [2]	377,523	398,976	265,413	281,070	265,163
Electrowon	--	W	W	W	W
Fire refined	14,290	13,543	5,467	7,616	W
Total secondary	391,813	412,519	270,880	288,686	265,163
Grand total	2,260,301	2,067,177	1,714,258	1,827,994	1,761,347

W Withheld to avoid disclosing company proprietary data; included in "Electrolytic."
[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 electrowon and fire refined quantities indicated by symbol W.

Table 15.—Copper cast in forms at primary refineries in the United States

	1976		1977	
	Thousand short tons	Percent	Thousand short tons	Percent
Billets	50	3	50	3
Cakes	76	4	71	4
Cathodes	910	50	932	53
Ingots and ingot bars	125	7	130	7
Wire bars	643	35	545	31
Other forms	24	1	33	2
Total	1,828	100	1,761	100

Table 16.—Production, shipments, and stocks of copper sulfate

(Short tons)

Year	Production		Shipments	Stocks Dec. 31[1]
	Quantity	Copper content		
1973	43,360	10,840	44,092	4,580
1974	42,092	10,523	43,598	3,074
1975	35,614	9,204	31,822	6,866
1976	32,122	8,421	30,431	8,557
1977	30,100	7,935	30,957	7,700

[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% basis) produced in the United States

(Short tons)

Year	Copper plants[2]	Lead plants	Zinc plants[3]	Total
1973	1,088,322	146,591	819,537	2,054,450
1974	1,277,440	132,594	830,969	2,241,003
1975	1,784,744	129,756	711,769	2,626,269
1976	2,281,591	145,872	799,773	3,227,236
1977	2,357,366	140,983	737,781	3,236,130

[1]Includes acid from foreign materials.
[2]Excludes acid made from pyrites concentrates.
[3]Excludes acid made from native sulfur.

Table 18.—Secondary copper produced in the United States

(Short tons)

	1973	1974	1975	1976	1977
Copper recovered as unalloyed copper	484,623	513,308	355,512	390,729	402,036
Copper recovered in alloys[1]	892,534	831,012	616,453	754,545	794,440
Total secondary copper[1]	1,377,157	1,344,320	971,965	1,145,274	1,196,476
Source:					
New scrap	890,943	860,888	602,792	726,148	744,608
Old scrap	486,214	483,432	369,173	419,126	451,868
Percentage equivalent of domestic mine output	80	84	69	71	80

[1]Includes copper in chemicals, as follows: 1973—3,704; 1974—2,649; 1975—2,480; 1976—4,007; and 1977—3,619.

Table 19.—Copper recovered from scrap processed in the United States by kind of scrap and form of recovery

(Short tons)

	1976	1977
Kind of scrap		
New scrap:		
Copper-base	705,392	722,709
Aluminum-base	20,444	21,724
Nickel-base	282	142
Zinc-base	30	33
Total	726,148	744,608
Old scrap:		
Copper-base	404,144	435,830
Aluminum-base	14,516	15,482
Nickel-base	321	296
Tin-base	8	8
Zinc-base	137	252
Total	419,126	451,868
Grand total	1,145,274	1,196,476
Form of recovery		
As unalloyed copper:		
At primary plants	288,686	265,163
At other plants	102,043	136,873
Total	390,729	402,036
In brass and bronze	700,844	739,333
In alloy iron and steel	2,186	2,249
In aluminum alloys	47,017	48,742
In other alloys	491	497
In chemical compounds	4,007	3,619
Total	754,545	794,440
Grand total	1,145,274	1,196,476

Table 20.—Copper recovered as refined copper, in alloys and in other forms from copper-base scrap processed in the United States

(Short tons)

Recovered by—	From new scrap		From old scrap		Total	
	1976	1977	1976	1977	1976	1977
Secondary smelters	57,419	74,926	188,162	224,191	245,581	299,117
Primary copper producers	144,215	128,214	144,471	136,949	288,686	265,163
Brass mills	486,878	501,383	30,207	30,529	517,085	531,912
Foundries and manufacturers	14,698	15,795	39,455	42,921	54,153	58,716
Chemical plants	2,182	2,391	1,849	1,240	4,031	3,631
Total	705,392	722,709	404,144	435,830	1,109,536	1,158,539

Table 21.—Production of secondary copper and copper-alloy products in the United States

(Short tons)

Item produced from scrap	1976	1977
UNALLOYED COPPER PRODUCTS		
Refined copper by primary producers	288,686	265,163
Refined copper by secondary smelters	86,469	120,255
Copper powder	15,564	16,605
Copper castings	10	13
Total	390,729	402,036
ALLOYED COPPER PRODUCTS		
Brass and bronze ingots:		
Tin bronzes	34,421	20,868
Leaded red brass and semired brass	120,233	144,872
High-leaded tin bronze	26,143	26,552
Yellow brass	13,089	15,045
Manganese bronze	9,850	10,544
Aluminum bronze	6,736	7,028
Nickel silver	3,090	3,179
Silicon bronze and brass	2,911	4,278
Copper-base hardeners and master alloys	12,204	11,804
Total	228,677	244,170
Brass-mill products	649,713	664,043
Brass and bronze castings	36,486	41,544
Brass powder	614	715
Copper in chemical products	4,007	3,619
Grand total	1,310,226	1,356,127

Table 22.—Composition of secondary copper-alloy production

(Short tons)

	Copper	Tin	Lead	Zinc	Nickel	Aluminum	Total
Brass and bronze production: [1]							
1976	173,060	11,398	16,870	26,831	449	69	228,677
1977	194,976	13,257	19,747	29,147	446	59	257,632
Secondary metal content of brass-mill products:							
1976	517,676	322	3,371	124,485	3,826	33	649,713
1977	530,314	561	4,507	125,479	3,129	53	664,043
Secondary metal content of brass and bronze castings:							
1976	29,195	946	2,211	4,059	31	44	36,486
1977	33,666	1,067	2,486	4,246	44	35	41,544

[1] About 92% from scrap and 8% from other than scrap.

Table 23.—Stocks and consumption of purchased copper scrap in the United States in 1977

(Short tons)

Class of consumer and type of scrap	Stocks Jan. 1	Receipts	Consumption: New scrap	Consumption: Old scrap	Consumption: Total	Stocks Dec. 31
SECONDARY SMELTERS						
No. 1 wire and heavy copper	2,098	29,207	3,609	24,628	28,237	3,068
No. 2 wire, mixed heavy and light copper	6,227	93,526	24,441	67,949	92,390	7,363
Composition or red brass	4,691	66,894	13,817	52,994	66,811	4,774
Railroad-car boxes	450	2,099	--	2,294	2,294	255
Yellow brass	6,532	46,660	5,583	39,647	45,230	7,962
Cartridge cases and brass	126	70	--	125	125	71
Auto radiators (unsweated)	4,139	70,629	--	70,160	70,160	4,608
Bronze	2,046	20,990	3,334	17,638	20,972	2,064
Nickel silver and cupronickel	747	3,154	231	2,833	3,064	837
Low brass	560	3,322	1,248	2,050	3,298	584
Aluminum bronze	114	458	382	47	429	143
Low-grade scrap and residues	13,323	94,783	72,199	17,879	90,078	18,028
Total	41,053	431,792	124,844	298,244	423,088	49,757
PRIMARY PRODUCERS						
No. 1 wire and heavy copper	2,621	119,556	48,237	63,448	111,685	10,492
No. 2 wire, mixed heavy and light copper	15,639	124,634	77,405	50,323	127,728	12,545
Refinery brass	17,730	3,129	367	3,273	3,640	16,247
Low-grade scrap and residues		155,189	42,931	113,230	156,161	
Total	35,990	402,508	168,940	230,274	399,214	39,284
BRASS MILLS[1]						
No. 1 wire and heavy copper	12,814	163,611	134,411	29,200	163,611	13,985
No. 2 wire, mixed heavy and light copper	5,042	61,383	59,729	1,654	61,383	8,094
Yellow brass	26,342	270,115	270,115	--	270,115	27,275
Cartridge cases and brass	9,334	82,109	82,109	--	82,109	13,959
Bronze	800	5,212	5,212	--	5,212	796
Nickel silver and cupronickel	4,558	27,957	27,957	--	27,957	2,652
Low brass	4,026	67,407	67,407	--	67,407	3,876
Aluminum bronze	53	353	353	--	353	44
Total[1]	62,969	678,147	647,293	30,854	678,147	70,681
FOUNDRIES, CHEMICAL PLANTS, AND OTHER MANUFACTURERS						
No. 1 wire and heavy copper	2,858	32,453	9,214	23,378	32,592	2,719
No. 2 wire, mixed heavy and light copper	1,277	7,426	3,301	4,459	7,760	943
Composition or red brass	435	5,875	1,894	4,049	5,943	367
Railroad-car boxes	1,370	5,434	--	5,919	5,919	885
Yellow brass	426	8,922	5,963	2,882	8,845	503
Auto radiators (unsweated)	750	10,848	--	10,365	10,365	1,233
Bronze	146	1,588	58	669	727	1,007
Nickel silver and cupronickel	6	121	--	116	116	11
Low brass	67	1,490	989	473	1,462	95
Aluminum bronze	84	345	113	255	368	61
Low-grade scrap and residues	29	--	20	--	20	9
Total	7,448	74,502	[2]21,552	[2]52,565	74,117	7,833
GRAND TOTAL						
No. 1 wire and heavy copper	20,391	344,827	195,471	140,654	336,125	30,264
No. 2 wire, mixed heavy and light copper	28,185	286,969	164,876	124,385	289,261	28,945
Composition or red brass	5,126	72,769	15,711	57,043	72,754	5,141
Railroad-car boxes	1,820	7,533	--	8,213	8,213	1,140
Yellow brass	33,300	325,697	281,661	42,529	324,190	35,740
Cartridge cases and brass	9,460	82,179	82,109	125	82,234	14,030
Auto radiators (unsweated)	4,889	81,477	--	80,525	80,525	5,841
Bronze	2,992	27,790	8,604	18,307	26,911	3,867
Nickel silver and cupronickel	5,311	31,232	28,188	2,949	31,137	3,500
Low brass	4,653	72,219	69,644	2,523	72,167	4,555
Aluminum bronze	251	1,156	848	302	1,150	248
Low-grade scrap and residues[3]	31,082	253,101	115,517	134,382	249,899	34,284
Total	147,460	1,586,949	962,629	611,937	1,574,566	167,555

[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, 2,502 tons new and 1,292 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
1976:						
Copper scrap	425,790	662,454	--	68,912	356,789	1,513,945
Refined copper[1]	--	584,755	1,364,048	35,563	7,519	1,991,885
Brass ingot	--	8,320	--	[2]228,204	--	236,524
Slab zinc	--	157,398	--	2,252	6,594	166,244
Miscellaneous	--	--	--	200	5,702	5,902
1977:						
Copper scrap	399,214	678,147	--	74,117	423,088	1,574,566
Refined copper[1]	--	628,619	1,511,202	38,511	6,627	2,184,959
Brass ingot	--	7,282	--	[2]250,907	--	258,189
Slab zinc	--	131,957	--	2,486	6,995	141,438
Miscellaneous	--	--	--	200	7,848	8,048

[1]Detailed information on consumption of refined copper will be found in table 28.
[2]Shipments to foundries by smelters plus decrease in stocks at foundries.

Table 25.—Foundry consumption of brass ingot, by types, in the United States

(Short tons)

	1973	1974	1975	1976	1977
Tin bronzes	47,963	53,702	40,982	33,117	38,193
Leaded red brass and semired brass	136,012	117,038	84,839	97,732	107,029
Yellow brass	34,820	58,922	65,799	23,167	26,280
Manganese bronze	10,868	9,773	6,843	5,695	5,838
Hardeners and master alloys	6,633	6,053	4,420	3,385	3,841
Nickel silver	2,908	3,104	2,437	2,249	2,311
Aluminum bronze	6,882	7,743	5,287	5,923	6,748
Total	246,086	256,335	210,607	171,268	190,240

Table 26.—Foundry consumption of brass ingot by type, refined copper, and copper scrap, in the United States in 1977, by geographic division and State

(Short tons)

Geographic division and State	Tin bronzes	Leaded red brass and semi-red brass	Yellow brass	Man-ganese bronze	Hardeners and master alloys	Nickel silver	Alumi-num bronze	Total brass ingot	Refined copper con-sumed	Copper scrap con-sumed
New England:										
Connecticut	1,035	2,268	1,161	20	6			4,862	655	426
Massachusetts	619	2,105	586	192	4	329	447	3,699	1,298	68
Maine, New Hampshire, Rhode Island, Vermont	236	2,168	94	260	4			2,973		
Total	1,890	6,541	1,841	472	14	329	447	11,534	1,953	494
Middle Atlantic:										
New Jersey	793	729	142	213	78	56	118	1,962	3,702	3,132
New York	1,105	9,222	1,044	547				12,085		2,085
Pennsylvania	6,857	7,328	1,728	458	1,053	375	1,796	19,595	5,219	4,083
Total	8,755	17,279	2,914	1,218	1,131	431	1,914	33,642	8,921	9,300
East North Central:										
Illinois	2,053	13,835	1,007	603	80	7	848	18,433	684	2,127
Indiana	4,418	6,778	1,185	329	1,173	237	59	14,107	2,244	9,007
Michigan	311	5,236	511	385			477	6,992	3,314	3,295
Ohio	11,422	10,521	3,069	758	1,076	346	440	26,392	11,781	7,557
Wisconsin	1,505	5,395	2,904	137			229	11,410		3,612
Total	19,709	41,765	8,676	2,212	2,329	590	2,053	77,334	18,023	25,598
West North Central:										
Iowa, Kansas, Minnesota	274	3,909	1,570	337	75	26	589	6,292	2,162	170
Missouri, Nebraska, South Dakota	101	1,832	701	194				3,316		2,125
Total	375	5,741	2,271	531	75	26	589	9,608	2,162	2,295

Table 26.—Foundry consumption of brass ingot by type, refined copper, and copper scrap, in the United States in 1977, by geographic division and State —Continued

(Short tons)

Geographic division and State	Tin bronzes	Leaded red brass and semi-red brass	Yellow brass	Manganese bronze	Hardeners and master alloys	Nickel silver	Aluminum bronze	Total brass ingot	Refined copper consumed	Copper scrap consumed
South Atlantic:										
Delaware, District of Columbia, Florida, Georgia, Maryland	497	310	89	72	3	722	108	1,800	2,230	573
North Carolina, South Carolina, Virginia, West Virginia	290	6,261	426	129			255	7,362		4,968
Total	787	6,571	515	201	3	722	363	9,162	2,230	5,541
East South Central:										
Alabama, Kentucky, Mississippi, Tennessee	2,266	12,684	3,028	558	198	93	31	18,858	2,581	9,042
West South Central:										
Arkansas, Louisiana, Oklahoma, Texas	2,554	2,517	4,798	208	--	49	1,028	11,154	970	1,169
Mountain:										
Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah	241	420	167	34	2	--	28	892	58	425
Pacific:										
California	1,464	13,406	2,064	321	89	71	132	17,546	1,195	14,044
Oregon and Washington	152	105	6	83			163	510		2,415
Total	1,616	13,511	2,070	404	89	71	295	18,056	1,195	16,459
Grand total	38,193	107,029	26,280	5,838	3,841	2,311	6,748	190,240	38,093	70,323

Table 27.—Primary refined copper supply and withdrawals on domestic account

(Short tons)

	1973	1974	1975	1976	1977
Production from domestic and foreign ores, etc	1,868,488	1,654,658	1,443,378	1,539,308	1,496,184
Imports [1]	202,955	313,569	146,805	381,524	390,776
Stocks Jan. 1[1]	57,000	37,000	101,000	207,000	190,000
Total available supply	2,128,443	2,005,227	1,691,183	2,127,832	2,076,960
Copper exports [1]	189,396	126,526	172,426	111,887	51,529
Stocks Dec. 31 [1]	37,000	101,000	207,000	190,000	234,000
Total	226,396	227,526	379,426	301,887	285,529
Apparent withdrawals on domestic account [2]	1,902,000	1,778,000	1,312,000	1,826,000	1,791,000

[1] May include some copper refined from scrap.
[2] Excludes copper, if any, delivered to industry from national stockpile sales.

Table 28.—Refined copper consumed by class of consumer

(Short tons)

Year and class of consumer	Cathodes	Wire bars	Ingots and ingot bars	Cakes and slabs	Billets	Other	Total
1976:							
Wire mills	588,604	766,863	W	--	--	8,581	1,364,048
Brass mills	263,834	23,792	92,141	121,911	83,077	--	584,755
Chemical plants	--	--	--	--	--	501	501
Secondary smelters	3,645	W	3,872	--	--	2	7,519
Foundries	1,193	1,159	12,653	--	W	361	15,366
Miscellaneous[1]	3,627	W	7,077	148	W	8,844	19,696
Total	860,903	791,814	115,743	122,059	83,077	18,289	1,991,885
1977:							
Wire mills	672,035	827,992	W	--	--	11,175	1,511,202
Brass mills	290,071	33,275	86,986	115,022	103,265	--	628,619
Chemical plants	--	--	--	--	--	418	418
Secondary smelters	3,413	--	3,212	--	--	2	6,627
Foundries	675	W	12,391	--	W	1,108	14,174
Miscellaneous[1]	4,599	W	8,089	W	W	11,231	23,919
Total	970,793	861,267	110,678	115,022	103,265	23,934	2,184,959

W Withheld to avoid disclosing company proprietary data; included in "Other."
[1]Includes iron and steel plants, primary smelters producing alloys other than copper, consumers of copper powder and copper shot, and miscellaneous manufacturers.

Table 29.—Stocks of copper in the United States, Dec. 31

(Short tons)

Year	Blister and materials in process of refining[1]	Refined copper				
		Primary producers	Wire rod mills	Brass mills	Other[2]	New York Commodity Exchange
1973	265,000	37,000	42,000	30,000	5,600	5,900
1974	324,000	101,000	108,000	36,000	6,900	43,200
1975	312,000	207,000	119,000	31,000	6,100	100,000
1976	321,000	190,000	114,000	36,000	7,000	201,000
1977	346,000	234,000	116,000	34,000	7,000	184,000

[1] Includes copper in transit from smelters in the United States to refineries therein.
[2] Includes secondary smelters, chemical plants, foundries, and miscellaneous plants.

Table 30.—Dealers' monthly average buying price for copper scrap and consumers' alloy-ingot prices at New York in 1977

(Cents per pound)

Grade	Jan.	Feb.	Mar.	Apr.	May	June
No. 2 copper scrap	34.00	35.73	41.50	40.63	39.62	35.91
No. 1 composition scrap	28.50	30.10	39.50	38.93	37.31	35.32
No. 1 composition ingot	69.00	70.84	74.70	76.00	73.81	72.00

Grade	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
No. 2 copper scrap	35.00	34.04	33.00	33.00	33.00	33.00	35.70
No. 1 composition scrap	35.00	34.04	33.00	33.00	33.00	33.00	34.23
No. 1 composition ingot	70.40	66.39	65.00	65.00	66.50	66.50	69.68

Source: Metal Statistics, 1978.

Table 31.—Average monthly quoted prices of electrolytic copper for domestic delivered, in the United States and for spot copper at London

(Cents per pound)

Month	1976			1977		
	Domestic delivered		London spot[1]	Domestic delivered		London spot[1]
	American Metal Market	Metals Week	Metals Week	American Metal Market	Metals Week	Metals Week
January	63.63	63.63	54.09	66.13	66.24	63.29
February	63.63	63.63	55.29	68.63	68.63	64.66
March	64.73	64.68	60.25	72.28	72.55	68.63
April	69.26	69.24	68.50	74.41	74.39	64.75
May	70.63	70.63	68.56	72.77	72.61	62.19
June	70.63	70.63	70.26	70.13	71.20	59.51
July	74.63	74.63	74.66	68.10	68.00	56.60
August	74.63	74.63	69.73	63.89	63.79	52.54
September	74.63	74.63	66.20	60.63	60.63	54.20
October	72.34	72.06	58.30	60.63	60.63	54.86
November	70.63	70.63	57.98	60.63	60.63	53.62
December	66.10	65.77	58.41	62.11	61.94	57.13
Average	69.62	69.56	63.92	66.96	66.77	59.44

[1]Based on average monthly rates of exchange.

Table 32.—Average weighted prices of copper delivered

(Cents per pound)

Year	Domestic copper	Foreign copper
1973	59.5	80.8
1974	77.3	93.5
1975	64.2	56.0
1976	69.6	63.5
1977	66.8	59.3

Source: Metals Week.

Table 33.—U.S. exports of copper, by class and destination

Year and destination	Ore, concentrates, and matte (copper content)		Ash and residues (copper content)		Refined		Scrap		Blister	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
1976	14,853	$13,690	5,113	$3,457	111,887	$156,389	37,473	$37,079	2,723	$2,622
1977:										
Africa	--	--	--	--	60	124	114	143	--	--
Belgium-Luxembourg	2,933	1,992	5,703	2,633	3,200	3,952	1,479	861	105	90
Brazil	--	--	19	6	126	176	59	45	--	--
Canada	1,299	1,130	2,809	913	8,100	10,568	5,949	5,584	42	54
Denmark	--	--	--	--	331	477	--	--	--	--
Finland	--	--	--	--	110	151	--	--	--	--
France	(1)	1	--	--	9,754	13,901	4	3	56	114
Germany, Federal Republic of	7,567	4,975	939	834	10,248	12,557	2,824	2,618	404	323
India	--	--	--	--	66	93	693	808	--	--
Iran	--	--	--	--	1	2	--	--	--	--
Israel	--	--	--	--	13	28	--	--	2	2
Italy	--	--	--	--	6,198	9,851	596	465	--	--
Japan	2,969	3,900	166	571	1,492	2,006	5,988	5,339	8	7
Korea, Republic of	988	614	281	95	257	337	14,907	15,357	2,877	2,048
Mexico	(1)	1	1,084	64	15	78	302	222	1	2
Netherlands	--	--	40	55	2,397	3,088	60	58	--	--
Oceania	--	--	106	367	4	17	--	--	--	--
Pakistan	--	--	--	--	--	--	459	460	--	--
Philippines	--	--	--	--	77	121	--	--	--	--
Saudi Arabia	1	3	--	--	(1)	1	--	--	1	1
Spain	--	--	252	93	26	45	454	414	4,772	3,376
Sweden	--	--	--	--	1,455	1,966	249	213	--	--
Switzerland	--	--	--	--	173	310	--	--	--	--
Taiwan	--	--	15	4	20	32	2,159	2,030	--	--
U.S.S.R	--	--	--	--	--	--	--	--	--	--
United Kingdom	59	37	411	355	7,342	10,031	618	378	28	16
Venezuela	--	--	--	--	7	12	--	--	7	25
Other	4	1	4	2	56	104	978	1,008	1	4
Total	15,820	12,654	11,829	5,992	51,529	70,028	37,892	36,006	8,304	6,062

See footnotes at end of table.

Table 33.—U.S. exports of copper, by class and destination —Continued

Year and destination	Pipes and tubing		Plates and sheets		Wire and cable, bare		Wire and cable, insulated		Other copper manufactures[2]	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
1976	2,552	$5,935	423	$1,067	4,789	$12,427	57,216	$140,158	4,922	$8,435
1977:										
Africa	175	470	2	9	76	231	17,821	41,728	292	657
Belgium-Luxembourg	1	4	4	11	34	163	314	3,060	34	51
Brazil	14	45	1	3	1	15	593	2,035	25	53
Canada	941	2,078	1,213	2,056	871	2,422	20,255	28,675	1,621	2,588
Denmark	--	--	--	--	29	102	39	267	60	70
Finland	--	--	--	--	(1)	1	20	146	(1)	3
France	38	140	15	65	4	12	226	3,409	32	52
Germany, Federal Republic of	24	107	31	94	39	205	397	4,200	19	48
India	--	--	--	--	(1)	7	465	788	13	26
Iran	103	234	28	56	84	70	7,581	39,641	4	6
Israel	63	163	1	9	9	85	591	3,250	13	19
Italy	10	37	4	13	8	31	114	1,480	888	1,244
Japan	10	16	3	10	16	57	669	2,638	18	51
Korea, Republic of	--	--	--	--	1	19	62	584	--	--
Mexico	18	76	117	364	2,246	5,447	8,360	16,650	341	609
Netherlands	5	14	1	19	11	21	194	1,466	90	126
Oceania	6	17	1	2	12	52	343	2,472	57	368
Pakistan	8	19	--	--	2	5	314	568	9	25
Philippines	(1)	5	1	7	41	99	606	1,597	1	2
Saudi Arabia	192	507	12	30	1,027	1,745	13,234	32,900	180	314
Spain	86	167	--	--	6	20	89	632	57	103
Sweden	23	56	2	21	36	97	81	953	--	--
Switzerland	--	--	--	--	1	7	160	660	22	30
Taiwan	74	163	2	8	111	352	1,083	3,815	1	8
Thailand	--	--	5	16	9	13	38	149	3	3
U.S.S.R	598	2,163	--	--	95	218	1,007	6,350	--	--
United Kingdom	66	165	5	17	71	262	1,439	7,199	178	333
Venezuela	57	164	15	60	67	196	595	2,693	2,456	3,353
Other	568	1,501	73	190	923	2,127	7,340	25,780	506	781
Total	3,080	8,311	1,536	3,060	5,830	14,081	84,030	235,785	6,920	10,923

[1]Less than 1/2 unit.
[2]Does not include wire cloth: 1976-1,238,812 square feet ($832,196) and 1977-2,903,787 square feet ($1,259,741).

Table 34—U.S. exports of copper, by class

	Ore, concentrate and matte (copper content)		Blister		Refined copper and semimanufactures	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
1975	8,307	$6,917	1,545	$1,270	258,165	$465,553
1976	14,853	13,960	2,723	2,622	176,877	313,377
1977	15,820	12,654	8,304	6,062	146,004	331,265

	Other copper manufactures[1]		Total	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
1975	9,518	$14,158	277,535	$487,898
1976	r4,922	8,435	r199,375	338,394
1977	6,920	10,923	177,048	360,904

[1]Does not include wire cloth: 1975-2,268,914 square feet ($1,064,516); 1976-1,238,812 square feet ($832,196) and 1977-2,903,787 square feet ($1,259,741).

Table 35.—U.S. exports of copper-base alloy (including brass and bronze), by class

Class	1976		1977	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Ingots	483	$2,042	356	$1,541
Scrap and waste	76,706	64,120	82,023	65,596
Bars, rods, shapes	7,584	13,945	7,938	15,281
Plates, sheets, strips	4,126	18,318	4,313	18,069
Pipes and tubing	6,213	19,596	3,521	10,001
Pipe fittings	8,588	28,365	7,160	26,316
Plumber's brass goods	1,472	4,592	1,536	3,060
Welding rods and wire	2,403	8,655	2,086	7,862
Castings and forgings	958	2,868	882	2,577
Powder and flakes	1,849	4,513	1,741	4,356
Foil	283	1,490	541	2,528
Articles of copper and copper-base alloys, n.e.c	(1)	8,766	(1)	10,119
Total	110,665	177,270	112,097	167,306

[1]Quantity not reported.

Table 36.—U.S. exports of unfabricated copper-base alloy[1] ingots, bars, rods, shapes, sheets, and strip

Year	Quantity (short tons)	Value (thousands)
1975	11,245	$26,767
1976	12,193	34,305
1977	12,607	34,891

[1] Includes brass and bronze.

Table 37.—U.S. exports of copper sulfate (blue vitriol)

Year	Quantity (short tons)	Value (thousands)
1975	1,248	$2,067
1976	2,071	2,935
1977	2,616	3,370

Table 38.—U.S. exports of copper scrap, by country

Country	Unalloyed copper scrap				Copper alloy scrap			
	1976		1977		1976		1977	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Argentina	170	$198	--	--	83	$59	--	--
Belgium-Luxembourg	2,658	1,701	1,479	$861	8,889	5,710	6,689	$3,450
Brazil	51	108	59	45	111	82	714	720
Canada	6,374	7,632	5,949	5,584	6,194	6,961	5,645	5,385
Denmark	--	--	--	--	80	50	18	43
Finland	--	--	--	--	354	391	554	1,053
France	4	4	4	3	4,442	2,582	170	136
German Democratic Republic	--	--	118	105	--	--	159	111
Germany, Federal Republic of	1,771	1,301	2,824	2,618	3,809	3,481	6,971	3,796
Hong Kong	282	269	465	478	722	680	788	727
India	363	405	693	808	3,091	2,637	7,213	6,712
Italy	1,137	855	596	465	9,452	7,282	3,751	2,730
Japan	4,723	5,399	5,988	5,339	15,563	13,986	18,286	15,388
Korea, Republic of	12,481	13,034	14,907	15,357	10,093	9,113	16,239	14,689
Mexico	2,018	1,656	302	222	254	187	135	107
Netherlands	209	256	60	58	815	805	398	401
Pakistan	35	14	459	460	40	35	192	168
Portugal	--	--	--	--	--	--	371	285
Spain	1,496	1,502	454	414	5,128	4,703	5,807	2,989
Sweden	619	290	249	213	728	511	834	1,023
Switzerland	--	--	--	--	1,444	1,318	1,444	792
Taiwan	2,156	1,818	2,159	2,030	3,009	1,586	3,488	2,738
Thailand	79	91	224	257	176	166	594	518
Turkey	--	--	--	--	379	360	399	359
United Kingdom	776	479	618	378	1,494	1,233	661	822
Venezuela	--	--	--	--	139	119	346	286
Other	71	67	285	311	[r]217	[r]83	157	168
Total	37,473	37,079	37,892	36,006	76,706	64,120	82,023	65,596

[r]Revised.

Table 39.—U.S. imports for consumption of copper scrap, by country

Country	Unalloyed copper scrap (copper content) 1976 Quantity (short tons)	1976 Value (thousands)	1977 Quantity (short tons)	1977 Value (thousands)
Bahamas	32	$35	59	$55
Belgium-Luxembourg	8	14	127	169
Canada	11,199	11,218	13,234	13,779
Canal Zone	97	108	178	249
Chile	1,098	1,491	--	--
Dominican Republic	277	285	469	451
France	112	242	481	1,080
Germany, Federal Republic of	17	13	75	122
Guatemala	213	149	102	80
Honduras	27	23	53	44
Hong Kong	137	149	9	8
Jamaica	86	55	116	91
Japan	36	43	66	35
Mexico	5,507	4,541	4,114	3,724
Netherlands Antilles	234	124	272	271
Nicaragua	181	176	71	76
Panama	7	6	89	93
Trinidad and Tobago	64	67	38	38
Other	r403	r492	303	376
Total	19,735	19,231	19,856	20,741

Country	Copper alloy scrap 1976 Gross weight (short tons)	1976 Content (short tons)	1976 Value (thousands)	1977 Gross weight (short tons)	1977 Content (short tons)	1977 Value (thousands)
Bahamas	151	96	$97	125	78	$85
Belgium-Luxembourg	20	14	17	198	139	204
Canada	10,865	6,924	10,122	11,372	7,376	10,024
Canal Zone	21	15	16	67	53	51
Dominican Republic	184	146	128	249	168	162
Guatemala	2	2	1	39	27	22
Hong Kong	1,446	1,112	1,329	175	171	156
Israel	27	27	27	--	--	--
Jamaica	17	10	1	54	33	31
Japan	78	76	70	9	7	4
Mexico	1,126	714	760	803	501	467
Netherlands Antilles	122	96	87	89	64	65
Nicaragua	88	62	62	14	9	9
Norway	--	--	--	31	23	25
Panama	389	265	336	60	44	45
Trinidad and Tobago	13	9	11	22	16	17
United Kingdom	39	39	32	--	--	--
Other	r55	r39	r45	53	44	32
Total	14,643	9,646	13,141	13,360	8,753	11,399

Table 40.—U.S. imports[1] of unmanufactured copper (copper content), by class and country

Year and country	Ore, concentrates: Quantity (short tons)	Ore, concentrates: Value (thousands)	Matte: Quantity (short tons)	Matte: Value (thousands)	Blister: Quantity (short tons)	Blister: Value (thousands)
1975	64,879	$71,821	9,092	$35,781	88,951	$96,879
1976:						
Australia	465	332	--	--	9	17
Belgium-Luxembourg	--	--	--	--	--	--
Botswana	--	--	14,224	55,665	--	--
Canada	47,179	60,696	110	88	158	131
Chile	--	--	--	--	30,817	35,280
Honduras	160	169	--	--	--	--
Italy	--	--	--	--	--	--
Japan	--	--	--	--	--	--
Mexico	4	1	--	--	3,144	3,467
New Guinea	1,949	2,884	--	--	--	--
Nicaragua	533	611	--	--	--	--
Norway	--	--	--	--	--	--
Peru	4,323	5,351	--	--	6,726	8,269
Philippines	15,047	19,295	--	--	--	--
Rhodesia, Southern	1,025	574	--	--	--	--
South Africa, Republic of	--	--	3,949	22,524	--	--
South-West Africa, Territory of	--	--	--	--	2,521	2,780
United Kingdom	--	--	--	--	--	--
Yugoslavia	--	--	--	--	--	--
Zaire	--	--	--	--	--	--
Zambia	--	--	--	--	1,108	1,407
Other	2	([2])	--	--	1	2
Total	70,687	89,913	18,283	78,277	44,484	51,353
1977:						
Australia	3,352	2,775	--	--	--	--
Belgium-Luxembourg	--	--	--	--	--	--
Botswana	--	--	12,411	49,427	--	--
Canada	16,547	20,332	254	103	--	--
Chile	--	--	172	61	31,945	35,481
France	--	--	--	--	--	--
Germany, Federal Republic of	--	--	--	--	--	--
Mexico	--	--	--	--	4,668	6,730
Netherlands	--	--	--	--	--	--
Nicaragua	324	396	--	--	--	--
Norway	--	--	--	--	--	--
Peru	3,793	4,277	--	--	9,551	11,480
Philippines	18,057	20,713	--	--	--	--
South Africa, Republic of	1	2	4,993	30,518	--	--
Sweden	--	--	--	--	--	--
United Kingdom	--	--	--	--	21	27
Yugoslavia	--	--	--	--	--	--
Zambia	--	--	--	--	--	--
Other	8	5	--	--	([1])	([1])
Total	42,082	48,500	17,830	80,109	46,185	53,718

Year and country	Refined: Quantity (short tons)	Refined: Value (thousands)	Scrap: Quantity (short tons)	Scrap: Value (thousands)	Total: Quantity (short tons)	Total: Value (thousands)
1975	146,805	$170,086	14,399	$14,459	324,126	$389,026
1976:						
Australia	1,329	1,525	60	50	1,863	1,924
Belgium-Luxembourg	3,664	3,846	8	14	3,672	3,860
Botswana	--	--	--	--	14,224	55,665
Canada	94,025	123,115	11,199	11,218	152,671	195,248
Chile	69,873	81,295	1,098	1,491	101,788	118,066
Honduras	--	--	27	23	187	192
Italy	3,307	3,175	--	--	3,307	3,175
Japan	--	--	36	43	36	43
Mexico	424	536	5,507	4,541	9,079	8,545
New Guinea	--	--	--	--	1,949	2,884
Nicaragua	--	--	181	176	714	787
Norway	180	204	--	--	180	204
Peru	29,034	32,274	--	--	40,083	45,894
Philippines	--	--	--	--	15,047	19,295
Rhodesia, Southern	162	217	--	--	1,187	791
South Africa, Republic of	992	1,046	--	--	4,941	23,570
South-West Africa, Territory of	--	--	--	--	2,521	2,780
United Kingdom	3,316	3,510	25	19	3,341	3,529
Yugoslavia	44,984	49,599	--	--	44,984	49,599
Zaire	2,582	2,779	--	--	2,582	2,779

See footnotes at end of table.

Table 40.—U.S. imports[1] of unmanufactured copper (copper content), by class and country —Continued

Year and country	Refined: Quantity (short tons)	Refined: Value (thousands)	Scrap: Quantity (short tons)	Scrap: Value (thousands)	Total: Quantity (short tons)	Total: Value (thousands)
1976 —Continued						
Zambia	127,162	$149,881	--	--	128,270	$151,288
Other	490	323	1,594	$1,656	2,087	1,981
Total	381,524	453,325	19,735	19,231	534,713	692,099
1977:						
Australia	221	283	--	--	3,573	3,058
Belgium-Luxembourg	14,083	17,389	127	169	14,210	17,558
Botswana	--	--	--	--	12,411	49,427
Canada	101,184	133,239	13,234	13,779	131,219	167,453
Chile	87,565	101,269	--	--	119,682	136,811
France	18	38	481	1,080	499	1,118
Germany, Federal Republic of	10,416	13,116	75	122	10,491	13,238
Mexico	6,327	7,701	4,114	3,724	15,109	18,155
Netherlands	10,442	10,928	(2)	1	10,442	10,929
Nicaragua	--	--	71	76	395	472
Norway	156	192	--	--	156	192
Peru	48,979	57,041	--	--	62,323	72,798
Philippines	--	--	25	18	18,082	20,731
South Africa, Republic of	5,956	7,571	--	--	10,950	38,091
Sweden	10,304	11,902	54	30	10,358	11,932
United Kingdom	404	525	--	--	425	552
Yugoslavia	16,794	20,031	--	--	16,794	20,031
Zambia	77,866	94,914	--	--	77,866	94,914
Other	61	93	1,675	1,742	1,744	1,840
Total	390,776	476,232	19,856	20,741	516,729	679,300

[1] Data are general imports, that is, they include copper imported for immediate consumption plus material entering the country under bond.
[2] Less than 1/2 unit.

Table 41.—U.S. imports for consumption of copper (copper content), by class

Year	Ore and concentrates: Quantity (short tons)	Ore and concentrates: Value (thousands)	Matte: Quantity (short tons)	Matte: Value (thousands)	Blister: Quantity (short tons)	Blister: Value (thousands)
1975	29,301	$35,649	5,675	$20,560	78,969	$90,846
1976	35,197	49,861	14,097	54,878	19,388	22,144
1977	18,007	21,423	3,257	12,153	9,063	11,843

Year	Refined: Quantity (short tons)	Refined: Value (thousands)	Scrap: Quantity (short tons)	Scrap: Value (thousands)	Total value (thousands)
1975	142,945	$166,159	14,399	$14,459	$327,673
1976	381,343	453,279	19,735	19,231	599,393
1977	386,865	471,666	19,856	20,741	537,826

Table 42.—Copper: World mine production, by country[1]

(Short tons)

Country	1975	1976	1977
North and Central America:			
Canada[2]	808,905	805,712	860,501
Cuba	3,043	[e]3,175	[e]13,200
Guatemala	2,822	3,185	2,275
Honduras	[e]220	401	539
Mexico	86,196	98,073	98,835
Nicaragua[3]	711	696	589
United States[2]	1,413,366	1,605,586	1,503,966
South America:			
Argentina	419	298	371
Bolivia	[4]7,045	5,277	4,045
Brazil	2,119	60	28

See footnotes at end of table.

Table 42.—Copper: World mine production, by country[1] —Continued

(Short tons)

Country	1975	1976	1977
South America —Continued			
Chile	913,043	1,108,042	1,164,260
Colombia	([5])	575	992
Ecuador	263	[e]300	[e]330
Peru	[r]213,020	242,805	385,809
Europe:			
Albania[6]	[r]10,000	[r]11,000	11,000
Austria	2,186	1,295	--
Bulgaria	60,580	[r] [e]63,000	[e]63,000
Czechoslovakia[e]	[r]11,800	[r]9,400	9,900
Finland	42,770	45,842	50,982
France	551	550	330
German Democratic Republic	[r]18,200	[r]17,600	18,700
Germany, Federal Republic of	2,162	1,778	1,324
Greece	1,533	1,080	--
Hungary	440	330	220
Ireland[3]	10,803	4,519	5,291
Italy[7]	880	1,020	770
Norway[7]	30,991	31,210	30,985
Poland	254,000	294,000	313,900
Portugal[7]	[r]5,573	4,955	4,273
Romania[e 6]	[r]50,000	[r]60,000	55,000
Spain[7 8]	43,344	39,193	[e]45,000
Sweden	44,791	49,450	49,344
U.S.S.R.[e 2 6 7]	880,000	930,000	940,000
United Kingdom	[r]719	608	440
Yugoslavia	126,649	132,420	128,108
Africa:			
Algeria[e]	440	440	440
Botswana	7,154	13,759	12,994
Congo (Brazzaville)[3]	1,010	450	1,114
Ethiopia[e]	440	440	440
Kenya	80	80	--
Mauritania	7,839	8,231	10,606
Morocco[3]	5,291	4,514	3,338
Mozambique[3]	755	[r] [e]2,200	[e]3,300
Rhodesia, Southern	43,531	34,969	[e]29,000
South Africa, Republic of[9]	197,233	217,023	229,597
South-West Africa, Territory of (Namibia)	38,471	47,950	55,226
Uganda	9,370	[r] [e]7,700	[e]7,700
Zaire	[r]545,423	489,902	530,817
Zambia	746,177	781,391	723,115
Asia:			
Burma[10]	94	101	49
China, People's Republic of[e 2]	110,000	110,000	110,000
Cyprus[7]	[r]10,882	8,818	7,538
India	26,720	31,747	34,392
Indonesia	69,140	76,137	62,964
Iran[11]	[r]4,134	[e]6,600	[e]6,600
Israel	8,270	2,755	--
Japan[3 12]	93,674	89,955	89,723
Korea, North[e 2]	[r]20,000	22,000	22,000
Korea, Republic of	2,944	2,486	1,927
Malaysia (Sabah)	4,189	20,062	25,351
Nepal	--	--	1
Philippines	249,366	256,463	295,760
Taiwan[e]	2,100	2,200	2,200
Turkey	40,319	25,794	24,886
Oceania:			
Australia	241,363	240,833	242,440
Papua New Guinea[3]	190,123	193,793	200,652
Total	7,725,676	8,272,228	8,503,477

[e]Estimate. [p]Preliminary. [r]Revised.

[1]Data presented represent copper content (recoverable, where indicated) of ore mined wherever possible. If such data are not available, the figures presented are the nonduplicated total copper content of ores, concentrates, matte, metal and/or other copper-bearing products measured at the least stage of processing for which data are available.

[2]Recoverable.

[3]Copper content of concentrates produced.

[4]Actual production by Corporacion Minera de Bolivia (COMIBOL) plus exports by medium and small mines.

[5]Revised to zero.

[6]Smelter production.

[7]Includes copper content of cupriferous pyrite.

[8]Excludes an unreported quantity of copper iron pyrite which may or may not be recovered.

[9]Year ending September 30 of that stated.

[10]Copper content of matte produced.

[11]Year beginning March 21 of that stated.

[12]Copper content by analyses of run-of-mine ore was as follows in short tons: 1975—93,952; 1976—90,181; 1977—Not available.

Table 43.—Copper: World smelter production, by country[1]

(Short tons)

Country	1975	1976	1977[p]
North America:			
Canada[2]	547,076	538,582	551,457
Mexico[3]	84,188	93,889	107,428
United States	1,447,128	1,534,622	1,435,176
South America:			
Argentina	[e] [r]1,100	1,693	[e]1,650
Brazil	1,442	428	--
Chile[3]	798,513	943,908	979,292
Peru[3]	[r]172,633	203,430	337,592
Europe:			
Albania	9,370	[e]11,000	[e]11,000
Austria	1,874	992	[e]1,100
Belgium[e]	[r]16,500	[r]15,400	14,300
Bulgaria[e]	66,000	66,000	66,000
Czechoslovakia[e]	11,000	11,000	11,000
Finland[3]	51,731	56,787	67,838
German Democratic Republic[e] [2]	18,200	17,600	19,800
Germany, Federal Republic of	194,974	213,512	208,990
Hungary[2]	2,760	5,730	6,060
Norway	29,045	25,786	29,294
Poland[2]	254,000	265,000	287,000
Portugal	3,527	3,086	3,638
Romania[2]	44,100	46,740	45,668
Spain	91,490	101,960	109,680
Sweden	45,793	51,236	51,440
U.S.S.R.[e]	880,000	930,000	940,000
Yugoslavia	[2]178,587	[e]158,886	107,362
Africa:			
Rhodesia, Southern	33,100	25,900	30,900
South Africa, Republic of[2]	183,865	185,188	207,675
South-West Africa, Territory of (Namibia)	40,135	39,793	58,863
Uganda	9,149	7,716	[e]7,700
Zaire	509,929	449,996	498,638
Zambia	726,453	778,127	718,168
Asia:			
China, People's Republic of[e] [2]	110,000	110,000	110,000
India[3]	24,273	27,342	25,892
Iran[e]	4,400	4,400	7,700
Japan	817,914	848,117	935,200
Korea, North[e]	20,000	22,000	22,000
Korea, Republic of	18,739	14,991	21,164
Taiwan[3]	7,826	12,897	12,677
Turkey	29,026	30,373	[e]34,192
Oceania: Australia	198,457	184,467	184,496
Total	7,684,297	8,038,574	8,268,030

[e]Estimate. [p]Preliminary. [r]Revised.

[1]Unless otherwise noted, data presented for each country represent primary copper metal output, whether produced by thermal or electrowinning methods.

[2]Including secondary.

[3]Apparently including secondary, if any is produced (output is regarded as negligible).

Table 44.—Copper: World refinery production, by country[1]

(Short tons)

Country	1975	1976	1977[p]
North and Central America:			
Canada[2]	[r]583,339	562,695	560,819
Mexico	69,610	83,134	80,537
United States	1,443,378	1,539,308	1,496,184
South America:			
Argentina	[r] [e]1,100	1,693	[e]1,650
Brazil[3]	[r]1,442	428	--
Chile	589,960	646,700	745,162
Peru	58,390	154,451	200,620
Europe:			
Albania[e]	8,540	8,800	8,800
Austria[2]	29,686	31,514	34,951
Belgium[4]	393,551	531,080	620,909
Bulgaria	57,276	[e] [r]58,000	[e]57,000
Czechoslovakia[2]	25,159	24,306	[e]25,000
Finland	39,423	42,052	47,129
France	21,491	21,264	24,491
German Democratic Republic[e]	52,900	52,900	55,000
Germany, Federal Republic of[3]	[r]284,619	314,799	304,414
Hungary[2]	12,677	14,440	15,432
Norway	21,688	19,574	22,020
Poland	[r]274,034	297,624	338,409
Portugal	[r]3,023	3,036	3,739
Romania[e]	[r]55,000	[r]55,000	53,000
Spain	152,833	165,640	176,370
Sweden	54,529	61,240	60,142
U.S.S.R.[e]	[r]840,000	[r]880,000	890,000
United Kingdom	83,226	56,832	48,927
Yugoslavia	136,562	134,027	102,489
Africa:			
Rhodesia, Southern[e]	[r]29,800	[r]25,900	31,100
South Africa, Republic of	[r]96,900	105,400	160,800
Zaire[5]	249,128	72,772	108,807
Zambia	693,518	766,043	715,399
Asia:			
China, People's Republic of[e]	165,000	165,000	165,000
India	18,016	23,040	23,214
Iran[e]	7,700	7,700	7,700
Japan[3]	[r]817,891	848,549	935,405
Korea, North[e]	[r]20,000	28,000	28,000
Korea, Republic of	[r]24,203	34,074	47,267
Taiwan	9,413	12,853	12,689
Turkey	[r]27,800	30,900	34,943
Oceania: Australia	182,730	176,719	169,928
Total	7,635,535	8,057,487	8,413,446

[e]Estimate. [p]Preliminary. [r]Revised.

[1]Unless otherwise noted, data presented represent total primary refined copper (both fire refined and electrolytically refined), including material produced from imported crude copper (blister and electrolytic anode).

[2]Including secondary.

[3]Series revised to exclude secondary.

[4]Data include leach cathodes from Zaire, secondary and alloy material.

[5]Data exclude leach cathodes which are included with Belgium.

Diatomite

By A. C. Meisinger[1]

U.S. production of processed diatomite in 1977 increased 3% in quantity and 16% in value compared with that of 1976. Filtration, with 59% of domestic demand, continued to be the major use for diatomite during the year. Exports of processed diatomite, as in 1976, increased and again represented 24% of domestic production. Imports, however, declined substantially from the record year of 1976.

DOMESTIC PRODUCTION

Production of domestic processed diatomite in 1977 was 648,043 tons valued at $64 million. Compared with that in 1976, production increased 3% in quantity and 16% in value.

U.S. output came from four Western States: California, Nevada, Oregon, and Washington, of which, California diatomite operations accounted for 61% of the national total. The Kansas operation of NL Industries, Inc., was shutdown in 1977, but 15 mine and plant facilities were in operation by the following producers: Johns-Manville Sales Corp. at Lompoc, Calif.; Grefco, Inc. (Dicalite Div.), at Lompoc, Calif., and Mina, Nev.; Excel-Minerals Co., Taft, Calif.; Airox Earth Resources, Inc., Santa Maria, Calif.; Eagle-Picher Industries, Inc., Sparks and Lovelock, Nev.; Cyprus Mines Corp., Fernley, Nev.; American Fossil, Inc., Christmas Valley, Oreg.; and Inorganic Specialties Div. Witco Chemical Corp., Quincy, Wash.

Witco Chemical Corp. held dedication ceremonies (October 18, 1977) for its new diatomite-processing plant at Quincy, Wash.[2] The company, through its Inorganic Specialties Division, mines diatomaceous earth in Grant County, about 19 miles from the new plant site. The highly automated plant will enable Witco to substantially increase its production of Kenite diatomite products, particularly filter aids.

Table 1.—Diatomite sold or used by producers in the United States

	1973	1974	1975	1976	1977
Domestic production (sales) short tons	608,906	664,303	572,582	631,380	648,043
Average value per ton	$59.26	$76.31	$80.01	$87.08	$98.56

CONSUMPTION AND USES

Consumption of diatomite increased 3% compared with that of 1976. With the exception of diatomite used for pozzolans, lightweight aggregates, and fertilizer coatings, all end uses increased in 1977, with filtration accounting for 59% of domestic demand. Other major uses were fillers and insulation. Other end uses for diatomite (table 2) included abrasives, absorbents, additives, admixtures, carriers, and coating agents for numerous applications, primarily in the agricultural, chemical, and construction industries.

Table 2.—Domestic consumption of diatomite, by principal use

(Percent of total consumption)

Use	1973	1974	1975	1976	1977
Filtration	61	60	60	60	59
Fillers	W	W	W	W	W
Insulation	4	5	4	5	5
Other	35	35	36	35	36

W Withheld to avoid disclosing individual company confidential data; included with "Other."

PRICES

The weighted average price per ton of processed diatomite sold by producers was $98.56, an increase of 13% compared with the 1976 price of $87.08. The continued high cost of fuels used in the processing plants was a major factor for the increase.

Price increases were substantial for diatomite in all major end-use categories, as shown in table 3. Insulation use, which did not increase in price in 1976, increased the least in 1977.

Table 3.—Average annual value per ton of diatomite, by use

Use	1976	1977
Filtration	$99.34	$109.79
Insulation	62.36	70.08
Abrasives	146.04	156.07
Fillers	92.44	106.62
Lightweight aggregate	55.87	66.37
Miscellaneous	48.10	62.12
Weighted average	87.08	98.56

FOREIGN TRADE

The quantity and value of U.S. exports of processed diatomite increased 2% and 11% respectively compared with those of 1976. The quantity exported (152,388 tons) represented 24% of domestic production in 1977, as in 1976. Principal destinations were Canada (34,533 tons); Japan (17,918 tons); West Germany (15,019 tons); the United Kingdom (13,645 tons); and Australia (10,994 tons). The average value of exports was $124.18 per ton compared with $113.64 per ton in 1976. Diatomite imports totaled only 651 tons, compared with the record quantity of 5,154 tons imported in 1976. Canada (336 tons), Mexico (314 tons), and West Germany (1 ton), were the import sources in 1977.

[1]Industry economist, Division of Nonmetallic Minerals.
[2]Pit and Quarry. Witco Chemical Dedicates Diatomite Plant in Quincy, Wash. V. 70, March 1978, pp. 88-89.

Table 4.—U.S. exports of diatomite

(Thousand short tons and thousand dollars)

Year	Quantity	Value
1975	147	15,314
1976	149	16,932
1977	152	18,876

Table 5.—Diatomite: World production, by country

(Short tons)

Country	1975	1976	1977[p]
North America:			
Canada[e]	550	550	550
Costa Rica	[e]1,100	790	750
Mexico	25,048	28,984	31,000
United States	[r]572,582	631,380	648,043
South America:			
Argentina	16,535	15,267	17,324
Brazil (marketable)	[r]3,088	5,989	[e]5,100
Chile	205	364	[e]365
Colombia	[r]33,069	[r] [e]33,100	[e]30,100
Peru	14,000	19,003	[e]20,000
Europe:			
Austria	1,731	2,075	267
Denmark:			
Diatomite[e]	23,000	23,000	28,000
Moler[e]	250,000	250,000	250,000
France[e]	[r]210,000	[r]220,000	230,000
Germany, Federal Republic of (marketable)	60,219	58,365	[e]60,000
Iceland[1]	[e]24,800	25,021	[e]25,300
Italy[e]	35,000	35,000	38,000
Portugal	2,304	2,359	3,737
Romania[e]	40,000	45,000	45,000
Spain	[r]22,454	[e]22,000	[e]22,000
Sweden	466	360	[e]330
U.S.S.R.[e]	450,000	460,000	470,000
United Kingdom	3,858	3,900	3,900
Africa:			
Algeria	11,000	16,500	[e]16,500
Egypt	[r]1,764	360	270
Kenya	1,983	2,941	2,691
South Africa, Republic of	715	682	734
Asia: Korea, Republic of	21,258	14,862	[e]25,331
Oceania:			
Australia	6,110	911	[e]770
New Zealand	3,368	(2)	--
Total	[r]1,836,207	1,918,763	1,976,062

[e]Estimate. [p]Preliminary. [r]Revised.
[1]Exports.
[2]Revised to none.

Feldspar, Nepheline Syenite, and Aplite

By Michael J. Potter[1]

The quantity of feldspar produced in 1977 (table 1) was slightly lower than in 1976, and some sharp ups and downs took place during the year. With the severe winter of 1977, transportation, mining activities, and gas supplies for customers were severely curtailed. Because of these problems there was a temporary shortage of feldspar later in the year when customers began to catch up. Costs of electric power, fuel for drying, and equipment were advancing at the rate of 10% per year or more. Transportation costs of feldspathic products were also steadily advancing.

In the latter part of 1977, Indusmin, Ltd., of Canada purchased all shares of Lawson-United Feldspar and Mineral Co. in Spruce Pine, N.C. Indusmin produces nepheline syenite at Nephton, Ontario.[2]

Legislation and Government Programs.— According to provisions of the Tax Reform Act of 1969, which continued in force throughout 1977, the depletion rate allowed on feldspar production (both domestic and foreign operations) was 14%.

Table 1.—Salient feldspar statistics

	1973	1974	1975	1976	1977
United States:					
Feldspar produced[1] short tons	791,900	762,723	669,898	739,684	733,963
Value thousands	$12,830	$11,396	$11,728	[2]$17,531	[2]$17,186
Exports short tons	9,554	18,319	9,543	6,144	6,202
Value thousands	$466	$662	$507	$352	$394
Imports for consumption short tons	367	92	290	93	242
Value thousands	$26	$4	$23	$18	$8
Consumption, apparent[3] short tons	782,713	744,496	660,645	733,633	728,003
World production thousand short tons	3,050	3,319	[r]2,895	[r]2,936	3,045

[r]Revised.
[1]Includes hand-cobbed feldspar, flotation-concentrate feldspar, and feldspar in feldspar-silica mixtures.
[2]Data represent a more refined product and are not comparable to previous years.
[3]Measured by quantity produced plus imports, minus exports.

FELDSPAR

DOMESTIC PRODUCTION

The quantity of feldspar in 1977 ready to be put into final form for use (that is, the total quantity of hand-cobbed feldspar, flotation concentrate feldspar, and feldspar content of feldspar-silica mixtures) was down slightly in tonnage and value compared with that of 1976. The values in table 2 for 1976 and 1977 represent a more refined product.

Feldspar was mined in 10 States with North Carolina in the lead, followed in descending order by Connecticut, Georgia, California, Oklahoma, South Dakota, Arizona, Wyoming, Colorado, and Maine. The combined output of the first four States named amounted to 93% of the U.S. total.

Most of the feldspar used in glassmaking is ground no finer than 20 mesh, and substantial tonnages of feldspathic sands (feldspar-quartz mixtures) enter into glass furnace feeds with no further reduction in particle size. Feldspar to be used in ceramic and filler applications is usually pulverized to minus 200 mesh or finer. In 1977, 14 U.S. companies operating 16 plants produced feldspar in 10 States for shipment to destinations in at least 24 States, Puerto Rico, Canada, and Mexico. North Carolina had five plants, California had two, and the other producing States had one plant each: Arizona, Colorado, Connecticut, Georgia, Maine, Oklahoma, South Dakota, and Wyoming. In October of 1977, Indusmin, Ltd., of Canada purchased all shares of Lawson-United Feldspar and Mineral Co., Spruce Pine, N.C., through its subsidiary, American Nepheline Corp., Columbus, Ohio.[3] Indusmin produces nepheline syenite at Nephton, Ontario. In Maine, operation of the feldspar mill at West Paris was to resume in the spring of 1978 under the new owner, Oxford Feldspar and Mineral Corp.

Table 2.—Feldspar produced in the United States

(Thousand short tons and thousand dollars)

Year	Hand-cobbed		Flotation concentrate		Feldspar-silica mixtures[1]		Total[2]	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1973	53	636	546	9,789	193	2,406	792	12,830
1974	46	412	580	8,784	137	2,199	763	11,396
1975	17	274	531	9,260	122	2,193	670	11,728
1976[3]	28	321	601	13,606	111	3,603	740	17,531
1977[3]	23	309	568	12,602	142	4,276	734	17,186

[1]Feldspar content.
[2]Data may not add to totals shown because of independent rounding.
[3]Value data represent a more refined product and are not comparable to those of previous years.

Table 3.—Feldspar sold or used by producers, by use

Use	1976		1977	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Hand-cobbed:				
Glass	100	$4	--	--
Pottery	W	W	W	W
Other	26,903	925	24,600	$988
Total	27,003	929	24,600	988
Flotation concentrate:				
Glass	401,899	8,474	309,233	6,652
Pottery	180,200	4,827	W	W
Other	731	13	259,644	7,982
Total	582,830	13,314	568,877	14,634
Feldspar-silica mixture:[1]				
Glass	89,679	2,911	104,851	3,208
Pottery	W	W	W	W
Other	31,301	1,232	36,293	1,665
Total	120,980	4,143	141,144	4,873
Total:				
Glass	491,678	11,389	414,084	9,860
Pottery	221,740	6,102	253,375	7,755
Other[2]	17,395	895	67,162	2,880
Total	730,813	18,386	734,621	20,495

W Withheld to avoid disclosing individual company confidential data; included with "Other."
[1]Feldspar content.
[2]Includes soaps, abrasives, sanitary ware, rubber, electrical insulators, etc.; totals for "Quantity" and "Value" do not correspond to the sums of the subtotals of the three "Other" categories above.

Table 4.—Feldspar sold or used by producers in the United States in 1977, by State

(Short tons)

Destination	Quantity
Arkansas	5,488
California	40,151
Colorado	W
Illinois	36,971
Indiana	30,820
Kentucky	10,145
Louisiana	16,189
Maryland	5,041
Massachusetts	18,369
Michigan	848
Minnesota	W
Mississippi	20,780
Missouri	7,618
New Jersey	45,064
New York	20,637
Ohio	63,292
Oklahoma	34,339
Pennsylvania	53,737
Rhode Island	W
Tennessee	21,677
Texas	39,423
Washington	W
West Virginia	36,978
Wisconsin	W
Other destinations[1]	227,054
Total	734,621

W Withheld to avoid disclosing individual company confidential data; included with "Other destinations."
[1]Includes other States, States indicated by symbol W, and exports to foreign destinations.

CONSUMPTION AND USES

In 1977, there was as usual no significant consumption of feldspar in the raw, unprocessed state in which it is taken from the mine. The majority of users acquired their supplies already ground and sized by the feldspar producers, although some manufacturers of pottery, soaps, and enamels continued to purchase feldspar for grinding to their preferred specifications in their own mills. It should be noted that a substantial portion of the material classified as feldspar-silica mixtures serves in glassmaking without additional processing.

The 1977 end use distribution of feldspar in the United States indicated that 56% of the total was consumed in glassmaking and 34% was used in pottery. The remaining 10% was used in a diversity of applications, including glazes, enamels, soaps, abrasives, sanitary ware, rubber products, and electrical insulators.

PRICES

Engineering and Mining Journal, December 1977, listed the following prices for feldspar, per short ton, f.o.b. mine or mill, carload lots, bulk, depending on grade (prices were generally about $2.50 per ton higher than the corresponding quotations of the preceding year):

North Carolina:	
20 mesh, flotation	$20.25
40 mesh, flotation	$29.00- 30.50
200 mesh, flotation	30.75- 44.00
Georgia:	
40 mesh, granular	29.00- 30.50
200 mesh	39.50- 43.30
Connecticut:	
20 mesh, granular	24.50
200 mesh	32.00

Feldspar prices were quoted by Industrial Minerals (London), December 1977, as follows (converted from pounds sterling per metric ton to dollars per short ton):

Ceramic grade, powder, 200 mesh, bagged, ex-store	$77-$86
Sand, 2-3 millimeters, ceramic and/or glass grade, c.i.f. main European port	43- 55

FOREIGN TRADE

In 1977, U.S. exports classified as feldspar, leucite, and nepheline syenite (but presumably all or mostly feldspar) amounted to 6,202 tons valued at $393,845. This was about the same tonnage reported in 1976 and a 12% increase in value. Chief recipients of the exported material were Canada, 70%; Mexico, 9%; and Ecuador, 6%. The remaining 15% was shared among 11 other countries.

U.S. imports for consumption of feldspar in 1977, although higher than in 1976, still amounted to only a small fraction of the quantity exported (4% of the tonnage, 2% of the total value). In addition to feldspar and nepheline syenite, U.S. imports in 1977 included 1,431 tons of material, probably feldspathic in nature, that was classified as "Other mineral fluxes, crushed" with a total value of $197,255.

The tariff schedule in force throughout 1977 provided for a 3-1/2% ad valorem duty on ground feldspar; imports of unground feldspar were admitted duty-free.

Table 5.—U.S. imports for consumption of feldspar

Country	1976		1977	
	Quantity (short tons)	Value	Quantity (short tons)	Value
Crude: Canada	93	$17,614	--	--
Ground, crushed, or pulverized: Sweden	--	--	242	$8,115

WORLD REVIEW

Japan.—A comprehensive journal article featured the industrial mineral industries of Japan.[4] Feldspar was briefly discussed; annual production has been about 50,000 tons per year during the past few years, largely from the Taishu mine in Nagasaki Prefecture operated by Kyoritsu Ceramic Materials Co., Ltd. Another producer is Kamamare Feldspar Co. To supplement the domestic production, some 5,000 tons per year of feldspar is imported from the Republic of Korea, the People's Republic of China, and India.[5]

Norway.—Very good results were achieved in the purification of a feldspar-quartz flotation feed during a 4-month test program at KS Norfloat's Lillesand plant. A high-gradient magnetic separator was used. Although the feed contained fairly large amounts of tramp iron, there was no clogging requiring plant shutdown.[6]

Pakistan.—Large reserves of nepheline syenite were said to have been reported in North-West Frontier Province. Although domestic demand is limited, the provincial government was expected to make detailed investigations of the deposit to assess its potential in terms of export markets.[7]

Portugal.—Large outcrops of granitic and pegmatitic rock have been exploited commercially for quartz and feldspar in the past dozen years. The potash feldspar varies between 11.3% and 12.5% K_2O. The Unimil-Minerals/Quartzograno organization holds some 10 concessions for feldspar, all within 93 miles of Oporto. Two quartz-feldspar mines were in operation. The company predicted that production for 1977 would be 6,600 to 11,000 tons of potash feldspar and 1,100 to 2,200 tons of soda feldspar.[8]

Thailand.—Thailand's feldspar mining industry began in February 1972, with the startup of an operation in Rat Buri Province with a production of 1,400 tons.[9] Subsequently, production was begun in three or four other provinces. In 1975, production for the entire country was approximately 14,300 tons. The main producers were Thep Prathan Co. and Cermas Co. Both soda and potash feldspars were produced.

United Kingdom.—Imports of feldspar (ground and unground) in 1976 amounted to 146,308 tons. Principal countries of origin and the share supplied were Norway, 57%; Finland, 27%; and Sweden, 13%. Nepheline syenite imports were 43,000 tons in 1976 and came from Norway, 81%, and Canada, 19%.[10]

Table 6.—Feldspar: World production, by country

(Short tons)

Country[1]	1975	1976	1977[p]
North America:			
Guatemala	[e]33,000	[r] [e]22,000	14,408
Mexico	158,521	80,732	[e]83,000
United States	669,898	739,684	733,963
South America:			
Argentina	[r]63,934	75,204	85,274
Brazil[2]	[r]73,167	92,742	[e]94,000
Chile	421	106	[e]110
Colombia	36,376	[e]36,500	36,500
Peru	[e]3,300	4,305	[e]4,500
Uruguay	1,939	1,262	1,700
Europe:			
Finland	75,593	75,192	[e]77,000
France	[r]219,360	207,234	[e]215,000
Germany, Federal Republic of	436,331	462,944	[e]475,000
Italy	[r]206,522	201,287	[e]244,000
Norway[3]	49,557	41,546	44,000
Poland[e]	33,000	33,000	33,000
Portugal	14,506	14,686	11,908
Romania[e]	64,000	64,000	66,000
Spain[4]	95,102	[r] [e]100,000	[e]100,000
Sweden	49,320	49,324	[e]50,000
U.S.S.R.[e]	310,000	310,000	320,000
United Kingdom (china stone)[e]	55,000	55,000	55,000
Yugoslavia	60,129	27,983	[e]27,600
Africa:			
Egypt	[r]937	2,346	[e]2,400
Kenya	1,781	[e]1,800	2,060
Madagascar	753	--	--
Mozambique[e]	950	950	1,000
Nigeria[e]	5,500	5,500	5,500
South Africa, Republic of	33,460	50,858	56,172
Zambia	1,294	570	[e]900
Asia:			
Burma	840	981	1,356
Hong Kong	2,270	2,534	[e]2,800
India	[r]46,817	58,878	[e]58,741
Japan[5]	43,494	45,434	[e]47,000
Korea, Republic of	22,198	28,889	54,425
Pakistan	2,981	3,299	[e]3,300
Philippines	4,307	16,799	15,988
Sri Lanka	859	3,526	3,600
Thailand	14,358	13,511	[e]14,000
Oceania: Australia	3,366	4,958	[e]3,300
Total	[r]2,895,141	2,935,564	3,044,505

[e]Estimate. [p]Preliminary. [r]Revised.

[1]In addition to the countries listed, the People's Republic of China, Czechoslovakia, and the Territory of South-West Africa (Namibia) produce feldspar, but output is not officially reported and available general information is inadequate to formulate reliable estimates of output levels.

[2]Series revised to represent sum of (1) run-of-mine production for direct sale and (2) salable beneficiated product; total run-of-mine production was as follows in short tons: 1975, 84,248; 1976, 93,822; 1977, (estimated) 95,000.

[3]Described in source as lump feldspar; does not include nepheline syenite as follows in short tons: 1975, 203,326; 1976, [e]200,000; 1977, not available.

[4]Includes pegmatite.

[5]In addition, the following quantities of aplite were produced in short tons: 1975, 357,056; 1976, 394,533; 1977, not available.

TECHNOLOGY

Extracting alumina from anorthosite (essentially a monomineralic soda-lime feldspar rock) was one of the processes slated for testing by the Federal Bureau of Mines in its program on extracting alumina from nonbauxitic sources. Some laboratory work on the anorthosite testing was being performed; however, for the time being, emphasis is being placed on recovering alumina from clays, using nitric and hydrochloric acid processes.

A patent was granted for the purification of feldspar (and other minerals) containing titanium oxide or iron oxide gangue minerals. This is done by passing the particulate mineral through an elongated chamber having a plurality of parallel ferromagnetic filaments.[11]

The importance of air with constant temperature and humidity in glass melting was discussed. Large amounts of air (fan, blower, and compressed) are used around a glass plant for cooling and combustion for tanks, mold cooling, tempering of flat glass, etc. Air temperature and its humidity vary greatly between night and day, from day to day, and over the different seasons of the year.[12]

Glass fibers might replace the copper in cable for telephone and other telecommunication uses. In this new field of glass circuitry, telephone conversations, television broadcasts, etc., are sent through glass fibers instead of conventional copper wires. A typical copper telephone cable used under big city streets is 3 inches thick and weighs 9 pounds per foot. A comparable glass cable would be one-half inch thick and would weigh one-tenth pound per foot. A major difficulty is manufacturing glass of a very high purity. Several firms in North America, Japan, and Europe, and two independent scientists in the United States were working to produce highly pure glass fiber at the lowest possible cost.[13]

Fiber glass, a popular reinforcement for automobiles and boats, is finding new applications in construction materials such as gypsum products and cement. Products such as decorative gypsum ceiling wall panel systems were entering the marketplace. Development was being carried out on fiber glass reinforced concrete slab-on-grade foundation construction.[14]

Glass-fiber reinforced plastics are finding use in pressure vessels, especially in the chemical processing industry. Pressure vessels have long been a bastion of an all-metal technology. Switching to plastic rests on the right combination of structural strength with chemical resistance, weight, and cost savings.[15]

As part of an energy conservation program at its sulfur mine, a U.S. company was converting from use of a thin, low-density, blanket-type pipe insulation to a thick, high-density, molded fiber glass insulation. As a result, this new reusable fiber glass insulation saved both energy and maintenance costs.[16]

Information on production and producers, trade, consumption, etc., of the raw materials used in the glass industry became available.[17] Another work dealt with the use of waste glass in the production of foam glass insulation, both in the bulk or rigid board form and pellet form.[18]

NEPHELINE SYENITE

Nepheline syenite is a light-colored rock that, although resembling medium-grained granite in texture, contains a significantly smaller proportion of quartz and consists principally of nepheline and alkali feldspars, usually in association with minor amounts of other minerals. Large quantities of nepheline syenite (after processing to remove objectionable substances, especially iron-bearing minerals) are consumed in making glass and ceramics. There is no domestic production of nepheline syenite in grades suitable for these purposes, however, and U.S. needs are wholly supplied by imports.

In Canada, two firms mine nepheline syenite from the deposit at Blue Mountain, Ontario: Indusmin, Ltd., and International Minerals & Chemical Corp. (Canada) Ltd. Canadian production in 1976, the last year for which an estimate is available, totaled approximately 596,000 tons valued at $10.8 million. This represented a 15% increase in tonnage and a 22% increase in value compared with that of 1975. The quantity exported to the United States in 1977 was 502,556 tons.

Other than Canada, only two countries are known to produce significant quantities of nepheline syenite—Norway with 345,000 tons in 1976, and the U.S.S.R. where, although production figures are not released, the mineral is known to serve the customary applications of the glass and ceramics industries and also as a major source of cell-feed alumina for electrolytic aluminum plants.

The price range quoted for imported nepheline syenite in Ceramic Industry magazine, January 1978, was from $13.60 to $36.75 per ton, depending upon grade, purity, grind, packaging, transportation, quantity sold, and other factors. Industrial Minerals (London), December 1977, quoted price ranges for Norwegian nepheline syenite, c.i.f. main European port, as follows (converted from pounds sterling per metric ton to dollars per short ton):

Glass grade, 32 mesh (Tyler), bulk, per short ton	$46-$48
Ceramic grade, 325 mesh (Tyler), bagged, per short ton	71

Prices for Canadian material were listed as "nominal."

The June 5, 1978, issue of American Paint & Coatings Journal quoted paint-grade nepheline syenite in 50-pound bags, carload lots, f.o.b. Ontario, at $38.50 to $56.00 per ton.

Table 7.—U.S. imports for consumption of nepheline syenite

Year	Crude		Ground	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
1975	6,275	$98	424,838	$6,869
1976	2,112	38	499,135	8,785
1977	860	17	501,696	9,118

APLITE

Aplite is another natural material of granitic texture containing quartz mixed with varying proportions of soda or lime-soda feldspar; it is usually not suitable for use in ceramics but, if sufficiently low in iron, finds ready acceptance in the manufacture of glass, especially container glass. Japan, with an annual production of 400,000 to 500,000 tons, is the world's foremost producer of aplite.

Aplite of glassmaking quality was produced in the United States in 1977 only from two open pit operations in central Virginia. The Feldspar Corp. mined aplite near Montpelier, Hanover County, and treated the material by wet-grinding, classification, and gravity separation, followed by dewatering, drying, and high-intensity magnetic separation to eliminate iron-bearing minerals. IMC Chemical Group, Inc., operated an aplite mine near Piney River, Nelson County, and removed ferruginous material from the dry-ground ore by a high-intensity magnetic process.

Domestic output tonnage was about the same in 1977 as in 1976. The amount of aplite sold during the year was estimated at 190,000 to 200,000 tons. The price for low-iron material was $16.00 per ton, f.o.b. plant.[19]

---

[1]Physical scientist, Division of Nonmetallic Minerals.
[2]Rogers, C., Jr. Feldspar. Min. Eng., v. 30, No. 5, May 1978, p. 530.
[3]American Ceramic Society Bulletin. Indusmin Buys Lawson-United. V. 57, No. 1, January 1978, p. 155.
[4]Harben, P. The Industrial Minerals of Japan. Ind. Miner., No. 118, July 1977, pp. 17-53.
[5]Page 33 of work cited in footnote 4.
[6]Industrial Minerals. Feldspar/Quartz and Magnetic Separation. No. 120, September 1977, p. 12.
[7]——. Company News and Mineral Notes. No. 120, September 1977, p. 70.
[8]——. Quartzograno (Feldspar/Quartz/Mica Producer). No. 112, January 1977, p. 40.
[9]——. The Industrial Minerals of Thailand. No. 117, June 1977, p. 29.
[10]——. UK 1976 Mineral Imports. No. 115, April 1977, p. 48.
[11]Clark, N. O., and J. H. P. Watson (assigned to English Clays, Lovering Pochin & Co., Ltd.). Magnetic Separation. Can. Pat. 1,015,316, Aug. 9, 1977.
[12]Ceramic Industry. Controlling Air Temperature and Humidity in Glass Melting. V. 108, No. 2, February 1977, p. 26.
[13]The Washington Star. Glass Fibers About To Revolutionize Communications. Aug. 28, 1977, pp. A-1, F-6.
[14]Ceramic Industry. Fiber Glass Now Reinforcing Inorganic Minerals. V. 109, No. 6, December 1977, p. 9.
[15]Forger, G. R. Light, Chemical-Resistant Plastics Give Pressure Vessels a Boost. Mater. Eng., v. 86, No. 5, November 1977, pp. 58-61.
[16]Engineering and Mining Journal. Reusable Pipe Insulation Saves Energy and Speeds Up Installation and Maintenance. V. 178, No. 2, February 1977, pp. 80-81.
[17]Raw Materials for the Glass Industry. Metal Bulletin, Ltd. (London) special publication, 1977, 132 pp.
[18]Oakseson, W. G., J. G. Lee, S. K. Goyal, T. Robson, and I. B. Cutler. Foam Glass Insulation From Waste Glass. The University of Utah, Dept. of Materials Science and Engineering, Salt Lake City, Utah, 1977, 140 pp.
[19]Work cited in footnote 2.

Ferroalloys

By Frederick J. Schottman[1]

Total production and shipments of ferroalloys were about 8% lower in 1977, compared with those in 1976. The most important change was a significant decline in the production of manganese alloys. Domestic producer prices of the major ferroalloys were generally lower to compete with foreign alloys offered at low prices. Prices of special ferroalloys including ferrocolumbium and ferromolybdenum were higher. There was concern about the ability of molybdenum producers to meet rising demand in the near future.

Consumption of manganese and silicon alloys was little changed, but consumption increased for many of the other alloys used to provide special properties in steel. Increased stainless steel production resulted in higher demand for ferrochromium and ferronickel. Consumption of ferroboron, ferrovanadium, and ferrocolumbium increased.

The trade deficit in ferroalloys increased slightly, with lower exports and higher imports. Exports remained only a small fraction of imports. Imports of ferroalloys totaled over 1 million tons, valued at over $452 million. Imports from Japan were down sharply from those in 1976, while those from Canada and Latin American countries increased.

Legislation and Government Programs.—The inventory of ferroalloys in Government stockpiles is shown in table 1. After study, the administration reaffirmed the stockpile goals, based on planning for a 3-year emergency, which had been adopted in 1976. Of the materials listed in table 1, stocks of four were below goals. These materials and goals were as follows: Ferrochromium-silicon, 69,000 tons; medium-carbon ferromanganese, 99,000 tons; silicomanganese, 81,000 tons; and ferrotungsten, 8,884 tons.

Table 1.—Government inventory of ferroalloys, December 31, 1977

(Thousand short tons)

Alloy	National stockpile	Supplemental stockpile	Total[1]
Ferrochromium:			
High-carbon	126	276	403
Low-carbon	128	191	319
Ferrochromium-silicon	26	33	58
Ferrocolumbium (contained columbium)	0.5	--	0.5
Ferromanganese:			
High-carbon	30	570	600
Medium-carbon	29	--	29
Ferrotungsten (contained tungsten)	1	--	1
Silicomanganese	24	--	24

[1]Data may not add to totals shown because of independent rounding.

Table 2.—Ferroalloys produced and shipped from furnaces in the United States[1]

	1976				1977			
	Production		Shipments		Production		Shipments	
	Gross weight (short tons)	Alloy element contained (average percent)	Gross weight (short tons)	Value (thousands)	Gross weight (short tons)	Alloy element contained (average percent)	Gross weight (short tons)	Value (thousands)
Ferromanganese[2]	482,662	79	494,222	$207,505	334,134	79	337,930	$141,560
Silicomanganese	128,917	66	132,364	52,649	119,753	66	121,651	43,112
Ferrosilicon[3]	860,799	57	890,844	409,726	894,765	56	898,455	392,152
Chromium alloys:								
Ferrochromium:								
High-carbon	167,125	66	161,757	82,774	177,552	68	193,006	84,932
Low-carbon	28,140	69	30,912	39,059	23,126	70	23,107	24,703
Ferrochromium-silicon	54,182	37	50,680	32,620	53,273	37	42,949	20,770
Other alloys[4]	19,800	60	20,195	21,481	15,836	63	17,228	29,292
Total	269,247	60	263,544	175,934	269,787	62	276,290	159,697
Ferrocolumbium	1,205	65	933	6,359	1,119	65	1,211	10,851
Ferrophosphorus	110,903	24	92,689	11,173	88,644	24	85,467	12,026
Other[5]	56,485	XX	50,942	134,322	46,029	XX	49,745	159,813
Grand total	1,910,218	XX	1,925,538	997,668	1,754,231	XX	1,770,749	919,211

XX Not applicable.
[1]Does not include alloys consumed in the making of other ferroalloys.
[2]Includes fused-salt electrolytic low-carbon ferromanganese (massive manganese).
[3]Includes silicon metal, silvery iron, and miscellaneous silicon alloys.
[4]Includes chromium briquets, exothermic chromium additives, other miscellaneous chromium alloys, and chromium metal.
[5]Includes ferroaluminum, ferroboron and other complex boron additive alloys, ferromolybdenum, ferronickel, ferrotitanium, ferrotungsten, ferrovanadium, ferrozirconium, spiegeleisen, and other miscellaneous alloys.

DOMESTIC PRODUCTION

Total production and total shipments of ferroalloys were lower in 1977 than in the previous year. The gross weight of both production and shipments, and the value of shipments, all declined 8%. Of the major alloy groups, production and shipments of the silicon alloys and the chromium alloys each increased slightly, while those for manganese alloys dropped. Production of ferrochromium continued to shift from low-carbon to high-carbon grades. The Ferroalloys Association reported that its members used 8.27 billion kilowatt-hours of electricity in 1977, 8% lower than that used in 1976.

With lower overall production, several plants were shutdown, at least temporarily. Ohio Ferro-Alloys Corp. permanently closed its ferrosilicon plant at Brilliant, Ohio, and temporarily stopped production at Powhatan Point, Ohio. The Brilliant plant had a reported capacity of 30,000 to 40,000 tons per year of 75% ferrosilicon. Union Carbide Corp. stopped production of ferromanganese at the Tenn-Tex Alloy plant in Houston, Tex. The plant had three furnaces with a capacity of 40,000 tons per year. Union Carbide leased the plant from Sandgate Corp. until 1980, but found the plant uneconomical in the current market for ferromanganese. The only blast furnace producing ferromanganese in the United States was closed by Bethlehem Steel Corp. when its Johnstown, Pa. plant was heavily damaged by a flood. As part of a plan to reduce steelmaking activity at the plant, it was decided not to restart ferromanganese production.

A new 40-megawatt ferrosilicon furnace was started at the new Bridgeport, Ala. plant of Tennessee Alloys Co. This new plant was to be operated by the TAC Alloys division of International Minerals & Chemical Corp. (IMC) and was owned 75% by IMC and 25% by Allegheny Ludlum Steel Corp. The new furnace replaced the three small furnaces at the old Bridgeport plant. This resulted in a 50% increase in capacity to 75,000 tons per year of 50% ferrosilicon.

Molycorp, Inc., a producer of specialty ferroalloys, merged with and became a subsidiary of Union Oil Co. of California. Molycorp's holdings of stock also gave Union Oil an interest in Kawecki-Berylco Industries, Inc., a producer of silicon metal and ferrocolumbium.

Table 3.—Producers of ferroalloys in the United States in 1977

Producer	Plant location	Products[1]	Type of furnace
Airco, Inc., Airco Alloys Div.	Calvert City, Ky; Charleston, S.C; Mobile, Ala; Niagara Falls, N.Y	FeCr, FeCrSi, FeMn, FeSi, SiMn.	Electric.
Alabama Alloy Co., Inc	Bessemer, Ala	FeSi	Do.
Aluminum Co. of America, Northwest Alloys, Inc.	Addy, Wash	Si, FeSi	Do.
AMAX Inc. Climax Molybdenum Co. Div.	Langeloth, Pa	FeMo	Metallothermic.
Bethlehem Steel Corp	Johnstown, Pa	FeMn	Blast.
Chromasco Ltd., Chromium Mining & Smelting Corp. Div.	Woodstock, Tenn	FeCr, FeSi	Electric.
Diamond Shamrock Corp., Chemetals Div.	Kingwood, W. Va	FeMn	Fused salt electrolytic.
Engelhard Minerals & Chemicals Corp.:			
Minerals and Chemicals Div	Strasburg, Va	FeV	Metallothermic.
Philipp Brothers Div. Roane Electric Furnace Co., Inc.	Rockwood, Tenn	FeMn, FeSi SiMn.	Electric.
Foote Mineral Co., Ferroalloys Div.	Cambridge, Ohio; Graham, W. Va; Keokuk, Iowa	FeSi, FeV, silvery pig iron, other.[2]	Do.
Hanna Mining Co., The:			
Hanna Nickel Smelting Co	Riddle, Oreg	FeNi, FeSi	Do.
Silicon Div	Wenatchee, Wash	FeSi, Si	Do.
Interlake, Inc., Globe Metallurgical Div.	Beverly, Ohio; Selma, Ala	FeCr, FeCrSi, FeSi, Si.	Do.
International Minerals & Chemical Corp., Industry Group TAC Alloys Div.			
TAC Alloys	Kimball, Tenn	FeSi	Do.
Tennessee Alloys Co	Bridgeport, Ala	FeSi	Do.
Kawecki-Berylco Industries, Inc.:			
National Metallurgical Div	Springfield, Oreg	Si	Do.
Penn Rare Metals Div	Revere, Pa	FeCb	Metallothermic.
Metallurg, Inc., Shieldalloy Corp.	Newfield, N.J	FeAl, FeB, FeCb, FeTi, FeV, other.[2]	Do.
Ohio Ferro-Alloys Corp	Brilliant, Ohio; Montgomery, Ala; Philo, Ohio; Powhatan Point, Ohio	FeB, FeMn, FeSi, Si, SiMn.	Electric.
Pennzoil Co., Duval Corp	Sahuarita, Ariz	FeMo	Metallothermic.
Pesses Co., The	Solon, Ohio	FeCb	Do.
Reactive Metals and Alloys Corp	West Pittsburg, Pa	FeTi, other[2]	Electric.
Reading Alloys, Inc.	Robesonia, Pa	FeCb, FeV	Metallothermic.
Reynolds Metals Co	Sheffield, Ala	Si	Electric.
Sandgate Corp., Tenn-Tex Alloy Corp. of Houston (leased to Union Carbide Corp.)	Houston, Tex	FeMn, SiMn	Do.
Satra Corp., Satralloy, Inc. Div.	Steubenville, Ohio	FeCr, FeCrSi, FeMn.	Do.
Teledyne, Inc., Teledyne Wah Chang, Albany Div.	Albany, Oreg	FeCb	Metallothermic.
Union Carbide Corp., Metals Div.	Alloy, W. Va; Ashtabula, Ohio; Marietta, Ohio; Niagara Falls, N.Y; Portland, Oreg; Sheffield, Ala	FeB, FeCr, FeCrSi, FeMn, FeSi, FeV, FeW, Si, SiMn, other.[2]	Electric.
Union Oil Co. of California, Molycorp. Inc.	Washington, Pa	FeB, FeM, FeW.	Electric and metallothermic.
Ferrophosphorus:			
Electro-Phos Corp	Pierce, Fla	FeP	Electric.
FMC Corp., Industrial Chemical Div.	Pocatello, Idaho	FeP	Do.
Mobil Oil Corp., Mobil Chemical Co. Div.	Nichols, Fla	FeP	Do.
Monsanto Co., Monsanto Industrial Chemicals Co.	Columbia, Tenn; Soda Springs, Idaho	FeP	Do.
Occidental Petroleum Corp., Hooker Chemical Div., Hooker Chemicals & Plastics Corp.	Columbia, Tenn	FeP	Do.
Stauffer Chemical Co., Industrial Chemical Div.	Mt. Pleasant, Tenn; Silver Bow, Mont; Tarpon Springs, Fla.	FeP	Do.

[1]FeAl, ferroaluminum; FeB, ferroboron; FeCb, ferrocolumbium; FeCr, ferrochromium; FeCrSi, ferrochromium-silicon; FeMn, ferromanganese; FeMo, ferromolybdenum; FeNi, ferronickel; FeP, ferrophosphorus; FeSi, ferrosilicon; FeTi, ferrotitanium; FeV, ferrovanadium; FeW, ferrotungsten; Si, silicon metal; SiMn, silicomanganese.
[2]Includes specialty silicon alloys, zirconium alloys, and miscellaneous ferroalloys.

CONSUMPTION AND USES

Consumption of ferromanganese, silicomanganese, and ferrosilicon was little changed in 1977 compared with that in 1976. Ferromanganese consumption declined slightly with most of the decrease due to lower consumption in carbon steel. Total consumption of silicomanganese dropped 4% with lower consumption in steel. Total ferrosilicon consumption was up slightly, with a larger amount going into alloy steel but less into carbon grades.

The total consumption of ferrochromium increased 8%, largely due to increased production of stainless and heat-resisting steel. Consumption of low-carbon ferrochromium continued to decline. The increased production of stainless and heat-resisting steel resulted in higher consumption of ferro-

Table 4.—Consumption by end use of ferroalloys as additives in the United States in 1977[1]

(Short tons of alloys)

End use	FeMn	SiMn	FeSi	FeTi	FeP	FeB
Steel:						
Carbon	701,182	81,293	120,472	778	13,470	623
Stainless and heat-resisting	15,351	7,502	[2]33,767	1,867	8	18
Other alloy	161,642	34,810	[2]90,399	670	1,163	511
Tool	1,095	55	[2]2,500	W	--	--
Unspecified	778	2,803	17,897	--	--	--
Total steel[3]	880,048	126,463	265,035	3,315	14,641	1,152
Cast irons	21,305	16,514	408,924	92	6,990	13
Superalloys	430	W	391	W	--	18
Alloys (excluding alloy steels and superalloys)	16,194	2,412	62,944	205	68	35
Miscellaneous and unspecified	2,130	2,370	53,329	57	14,587	--
Total	920,107	147,759	790,623	3,669	36,286	1,218
Percent of 1976	98	96	102	97	133	118

W Withheld to avoid disclosing company proprietary data; included in "Miscellaneous and unspecified."

[1]FeMn, ferromanganese including spiegeleisen and manganese metal; SiMn, silicomanganese; FeSi, ferrosilicon including silicon metal, silvery pig iron, and inoculant alloys; FeTi, ferrotitanium; FeP, ferrophosphorus including other phosphorus materials; FeB, ferroboron including other boron materials.

[2]Part included in "Unspecified."

[3]Except for data withheld.

Table 5.—Consumption by end use of ferroalloys as alloying elements in the United States in 1977[1]

(Short tons of contained elements)

End use	FeCr	FeMo	FeW	FeV	FeCb	FeNi
Steel:						
Carbon	3,661	107	--	694	585	--
Stainless and heat-resisting	186,924	637	47	27	283	24,553
Other alloy	51,285	883	[2]77	[3]3,255	886	5,227
Tool	3,322	368	259	603	([4])	--
Unspecified	W	W	([2])	W	7	--
Total steel[5]	245,192	1,995	383	4,579	1,761	29,780
Cast irons	8,637	1,522	1	44	--	175
Superalloys	8,064	180	65	15	398	427
Alloys (excluding alloy steels and superalloys)	4,586	441	25	[3]10	32	1,335
Miscellaneous and unspecified	2,155	80	1	45	3	67
Total	268,634	4,218	475	4,693	2,194	31,784
Percent of 1976	108	97	92	113	129	102

W Withheld to avoid disclosing company proprietary data; included in "Miscellaneous and unspecified."

[1]FeCr, ferrochromium including other chromium ferroalloys and chromium metal; FeMo, ferromolybdenum including calcium molybdate; FeW, ferrotungsten including melting base self-reducing tungsten; FeV, ferrovanadium including other vanadium-carbon-iron ferroalloys; FeCb, ferrocolumbium including small amount of ferrotantalum-columbium, tantalum metal, and other columbium-tantalum materials; FeNi, ferronickel.

[2]"Unspecified" included with "Other alloy."

[3]Part included in "Miscellaneous and unspecified."

[4]Included with "Unspecified."

[5]With minor exceptions as denoted by W and footnote 3 where applicable.

nickel. The total consumption was only 2% higher, however, because of lower consumption in other steel and in cast irons.

In specialty ferroalloys, consumption of ferrotitanium and ferromolybdenum both declined 3%. Consumption of ferrotungsten was 8% lower because of lower consumption in tool steels and superalloys. On the other hand, consumption of ferroboron, ferrovanadium, and ferrocolumbium increased significantly. Much of the increase for ferrocolumbium was for use in superalloys, for which consumption of ferrocolumbium increased 89%.

Reported consumption of ferrophosphorous increased 33%, but most of the increase was for miscellaneous nonmetallurgical uses. Consumption in steel and cast iron increased only 5%. Figures do not include the substantial quantity of material consumed for the production of vanadium materials.

STOCKS

Total yearend stocks of both manganese ferroalloys and silicon alloys declined slightly as an increase in producer stocks was more than balanced by a drop in consumer stocks. Total stocks of manganese ferroalloys were 17% lower, with the largest change being a drop in consumer stocks of silicomanganese. Total consumer stocks of silicon alloys were 23% lower.

While total and consumer stocks of ferrochromium increased, producer stocks were lower due to lower stocks of high-carbon ferrochromium.

Consumer stocks of ferronickel dropped by 56%, as supplies of ferronickel were readily available from domestic and foreign suppliers. On the other hand, both producer and consumer stocks of ferromolybdenum increased by almost 30%, reflecting fears of possible future shortages. Consumer stocks of ferrophosphorus increased 24%, following significantly increased consumption.

Table 6.—Stocks of ferroalloys held by producers and consumers in the United States at yearend

(Short tons)

	Producer		Consumer		Total	
	1976 (gross weight)	1977 (gross weight)	1976 (gross weight)	1977 (gross weight)	1976 (gross weight)	1977 (gross weight)
Manganese ferroalloys[1]	154,820	174,830	218,164	181,267	372,984	356,097
Silicon alloys[2]	117,760	129,066	68,130	52,298	185,890	181,364
Ferrochromium[3]	96,116	89,548	69,948	79,366	166,064	168,914
Ferroboron[4]	485	395	246	292	731	687
Ferrophosphorus[5]	62,162	59,534	13,624	16,928	75,786	76,462
Ferrotitanium[6]	W	W	1,232	986	1,232	986
Total	431,343	453,373	371,344	331,137	802,687	784,510
	1976 (contained element)	1977 (contained element)	1976 (contained element)	1977 (contained element)	1976 (contained element)	1977 (contained element)
Ferrocolumbium[7]	r397	327	481	345	r878	672
Ferromolybdenum[8]	317	406	750	970	1,067	1,376
Ferronickel	W	W	r6,905	3,895	r6,905	3,895
Ferrotungsten[9]	W	W	136	97	136	97
Ferrovanadium[10]	924	1,374	924	669	1,848	2,043
Total	r1,638	2,107	r9,196	5,976	r10,834	8,083

rRevised. W Withheld to avoid disclosing company proprietary data.
[1]Includes ferromanganese, silicomanganese, and manganese metal.
[2]Includes ferrosilicon, miscellaneous silicon alloys, and silicon metal.
[3]Includes other chromium alloys and chromium metal.
[4]Consumer totals include other boron materials.
[5]Consumer totals include other phosphorus materials.
[6]Consumer totals include other titanium materials.
[7]Consumer totals include small amount of ferrotantalum-columbium, tantalum metal, and other columbium-tantalum materials.
[8]Consumer totals include calcium molybdate.
[9]Consumer totals include melting base self-reducing tungsten.
[10]Includes other vanadium-iron-carbon ferroalloys.

PRICES

Prices of the main ferroalloys nearly all declined as supply continued to exceed demand and imported material was available at a substantial discount from domestic producer price. List price for standard ferromanganese decreased 6% in March, and, as the year progressed, discounts were reportedly being offered of over 10% for domestic material and over 20% for imported material.

Although even larger discounts for imported 75% ferrosilicon developed, the domestic producer list price did not change. For 50% ferrosilicon, the producer price decreased 3% in March. Producer prices for ferrochromium were reduced in August, by 5% for high-carbon ferrochromium and by 12% for low-carbon ferrochromium. Imported high-carbon ferrochromium was quoted at 10% to 15% below domestic prices for much of the year, and imported 50% to 55% ferrochromium was quoted as much as 20% below domestic list prices at yearend.

An increase in the domestic producer price for ferronickel announced late in 1976 did not hold up in the face of persistent oversupply and competition between the various forms of primary nickel. The list price remained unchanged, but a market price of $2.10 was reported towards the end of the year, which represented a 10% decrease to a level below that at the beginning of 1976. For other specialty ferroalloys except ferrovanadium, prices were higher. While the price of ferrovanadium was unchanged, the price of ferrocolumbium was increased by 8% at midyear, and that of ferromolybdenum by 13% slightly later. The price of ferrotungsten fluctuated in response to ore markets, resulting at yearend in a price 31% higher than that a year earlier.

Alloy	Price in 1977[1]	
	Beginning	Yearend
Charge chromium (66% to 70%)	$0.43	$0.41
Low-carbon ferrochromium, 0.02% maximum carbon (Simplex)	.85	.75
Standard 78% ferromanganese, per long ton of alloy	425.00	399.50
Ferromolybdenum, lump	4.43	4.99
Ferronickel	2.34	2.34
Ferrosilicon, 50%	.345	.335
Ferrosilicon, 75%	.37	.37

[1]Per pound contained, except as noted otherwise.

Source: Metals Week.

FOREIGN TRADE

The trade deficit in ferroalloys rose 4% to $416 million in 1977, with imports valued 12 times higher than exports. In terms of gross weight, imports were almost 26 times that of exports.

Exports of ferroalloys continued to decline from the relatively high levels of 1975. Exports in 1977 were 17% and 58% lower than those in 1976 and 1975, respectively. The value of exports in 1977 declined by 31% compared with that in 1976. The lower total value was largely due to declines in exports of the high value materials ferromolybdenum and ferrovanadium, both of which dropped by about one-half. Although the quantity of alloys exported in the "ferroalloys, n.e.c." class increased slightly, the value was 35% lower. Exports of ferrosilicon and ferromanganese made up about two-fifths of total exports, but were less than 2% of the production of these materials.

Total ferroalloy imports were little higher than those in 1976. The total value of imports increased by an even smaller percentage. In the major groups, imports of manganese alloys were little changed, those of ferrosilicon were higher, and those of ferrochrome decreased. Imports of silicon alloying materials were up strongly in 1977. In addition to the increase in ferrosilicon imports, which consisted mostly of a 22% increase in imports of the 60% to 80% ferrosilicon grade, imports of silicon metal increased 177%.

With lower consumption of low-carbon

ferrochromium, and a weakening market for it, imports dropped 44%. Some of that decrease was made up by increased imports of high-carbon ferrochromium and ferrosilicon chromium, but total imports of chromium alloys were 7% lower. With both lower prices and a shift from higher price to lower price material, the value of chromium alloys fell by an even larger percentage. Imports of ferronickel were up 44%, but, due to lower prices, the value increased only 32%.

The principal sources for ferroalloy imports were Western Europe and Africa, each with about a one-third share. Countries of the Western Hemisphere supplied about one-fifth of the total; Asia and Oceania combined, about 12%. A major shift occurred since 1976 when Asia and Oceania held a one-fifth share and the Western Hemisphere held a 12% share. Imports from Japan were down sharply in 1977 (59,000 tons and $29 million in 1977 compared with 162,000 tons and $77 million in 1976). In the same time, imports from Canada and Latin America were increasing.

The three leading supplying countries were the Republic of South Africa (293,000 tons and $99 million), France (151,000 tons and $50 million), and Norway (92,000 tons and $36 million). Canada, Brazil, Southern Rhodesia, and Japan each supplied between 59,000 and 73,000 tons of ferroalloys, valued at $29 to $30 million. As the two major suppliers of relatively high value ferronickel, the Dominican Republic ($50 million) and New Caledonia ($39 million) ranked high based on the value of the material which they supply. The major suppliers for particular alloys, in decending order of quantity, were for manganese alloys, the Republic of South Africa, France, and Brazil; for silicon alloys, Norway, Canada, and France; and for chromium alloys, the Republic of South Africa, Southern Rhodesia, and Yugoslavia. Ninety-three percent of imported ferronickel was supplied by New Caledonia and the Dominican Republic. In specialty alloys, Canada and Norway were the leading suppliers of ferrovanadium, and almost all imported ferrozirconium was from France.

In March, Congress passed and the President signed a bill restoring United States participation in the embargo of chromium ores, metal, and alloys imported from Southern Rhodesia. Chromium materials had been exempted from the embargo since 1971.

After an investigation in response to a petition by domestic low-carbon ferrochromium producers, the International Trade Commission found that imports of low-carbon ferrochromium were not a substantial threat or cause of injury to the domestic industry, and recommended that no action be taken against the imports. At the end of the year final decisions were pending on trade cases involving several ferroalloys.

Table 7.—U.S. exports of ferroalloys

Alloy	1975		1976		1977	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Ferrocerium and alloys	50	$300	60	$335	260	$1,043
Ferrochromium	13,218	9,075	13,563	8,785	12,472	7,268
Ferromanganese	32,487	10,743	6,789	3,462	6,051	3,391
Ferromolybdenum	1,121	4,798	1,798	9,447	798	4,863
Ferrophosphorus	437	57	1,636	153	2,381	297
Ferrosilicon	39,712	15,732	12,416	7,449	10,548	6,035
Ferrotungsten	17	137	--	--	2	31
Ferrovanadium	1,018	7,952	1,211	9,180	658	4,954
Ferroalloys, n.e.c	8,970	9,886	6,687	13,121	7,982	8,558
Spiegeleisen	335	208	5,471	901	40	13
Total	97,365	58,888	49,631	52,833	41,192	36,453

Table 8.—U.S. imports for consumption of ferroalloys and ferroalloy metals

Alloy	1976 Gross weight (short tons)	1976 Content (short tons)	1976 Value (thousands)	1977 Gross weight (short tons)	1977 Content (short tons)	1977 Value (thousands)
Manganese alloys:						
Ferromanganese containing less than 1% carbon	1,704	1,461	$1,195	3,904	3,330	$2,812
Ferromanganese containing over 1% and less than 4% carbon	73,903	60,025	34,577	52,505	42,595	25,759
Ferromanganese containing 4% or more carbon	461,802	355,947	128,926	478,014	370,156	127,091
Ferrosilicon-manganese (Mn content)	80,118	53,693	24,549	87,900	58,329	25,651
Total manganese alloys	617,527	471,126	189,247	622,323	474,410	181,313
Ferrosilicon:						
8%-60% silicon	31,575	13,983	11,368	32,717	14,503	11,511
60%-80% silicon	66,205	49,238	28,014	80,691	59,475	32,306
80%-90% silicon	160	132	117	184	151	69
Over 90% silicon	r354	r328	r149	1,196	1,125	485
Total ferrosilicon	r98,294	r63,681	r39,648	114,788	75,254	44,371
Chromium alloys:						
Ferrochromium containing 3% or more carbon	178,846	107,307	70,035	188,314	109,847	69,916
Ferrochromium containing less than 3% carbon	63,750	42,961	54,784	35,768	24,363	30,612
Ferrosilicon-chromium	15,725	(1)	7,593	16,228	(1)	8,281
Total chromium alloys	258,321	XX	132,412	240,310	XX	108,809
Ferronickel	55,721	(1)	72,161	80,436	(1)	95,275
Other ferroalloys:						
Ferrocerium and other cerium alloys	20	(1)	167	23	(1)	262
Ferromolybdenum	5	4	28	96	64	612
Ferrophosphorous	40	(1)	9	6	(1)	9
Ferrotitanium and ferrosilicon titanium	899	(1)	1,438	1,136	(1)	1,991
Ferrotungsten and ferrosilicon tungsten	521	422	5,451	309	252	4,565
Ferrovanadium	411	259	2,448	506	337	3,438
Ferrozirconium	671	(1)	554	956	(1)	785
Ferroalloys n.e.c.[2]	1,965	(1)	7,817	2,201	(1)	11,203
Total other ferroalloys	4,532	XX	17,912	5,233	XX	22,865
Total ferroalloys	r1,034,395	XX	r451,380	1,063,090	XX	452,633
Metals:						
Manganese	7,082	(1)	5,258	6,841	(1)	5,244
Silicon (96%-99% silicon)	8,257	(1)	5,533	22,065	(1)	16,494
Silicon (99%-99.7% silicon)	1,269	1,255	950	4,330	4,291	3,375
Chromium	2,306	(1)	9,142	2,493	(1)	10,893
Total ferroalloy metals	18,914	XX	20,883	35,729	XX	36,006
Grand total	r1,053,309	XX	r472,263	1,098,819	XX	488,639

rRevised. XX Not applicable.
[1]Not recorded.
[2]Principally ferrocolumbium.

WORLD REVIEW

Statistics on world production of ferroalloys are summarized in table 9. While most ferroalloys were in abundant supply due to the depressed state of world steel production, new production capacity was being added. Most of the new capacity was being built near the supply of ore rather than near the point of consumption.

Albania.—Albania, with the help of the People's Republic of China, plans to develop its nickel reserves and to build a ferronickel plant at Elbasan. A ferrochromium plant was under construction at Buvrel.

Argentina.—Stein Ferroaleaciones of Mendoza was building a 3-megavolt-ampere furnace for calcium silicon. The company had a 3.5-megavolt-ampere furnace producing rare-earth magnesium ferrosilicon.

Brazil.—Production of ferroalloys in Brazil rose 19% between 1976 and 1977 to 409,000 short tons, and exports rose 28% to 127,000 short tons. The ferroalloy industry continued plans for expansion with 11 new furnaces totaling 130 megavolt-amperes expected to start production between 1978 and 1981. In 1977, Cia. Paulista de Ferro Ligas started operations at a new ferromanganese plant with two 4-megavolt-ampere furnaces at Corumba, State of Mato Grosso. Bozel Mineração Ferroligas A/S introduced a 12-megavolt-ampere furnace for calcium silicon.

Canada.—Chromasco, Ltd. started a new 24-megavolt-ampere ferrosilicon furnace at its Beauharnois, Quebec, plant increasing its capacity to 90,000 tons per year.

Colombia.—Empresa Colombiana de Niquel announced that a contract had been signed to construct a ferronickel plant at Cerro Matoso, with construction to begin in 1978 and production to begin in late 1979. The project is to have a capacity of 42 million pounds of contained nickel per year and is estimated to cost $300 million. Hanna Mining Co. and Standard Oil of California have a two-thirds interest in the project.

Greece.—Nickel production capacity was being expanded by Soc. Minière et Métallurgique de Larymna S.A. (Larco). Larco's mines on Euboea Island were expanded and a 6-mile conveyor belt to the Port of Politika was under construction. In addition, equipment improvements were being made to the smelting plant at Larymna. The proposed nickel smelter to be built on Euboea Island by Eleusis Bauxite Mines was awaiting Government approval. With respect to chromium, the Government-sponsored Hellenic Industrial and Mining Co. continued a study of the feasibility of building a ferrochromium plant.

Iceland.—Construction continued on the Icelandic Alloys Ltd. plant. The 50,000-ton-per-year ferrosilicon plant is 55% owned by the Government of Iceland and 45% owned by Elkem-Spigerverket A/S. First production is planned for 1978.

India.—Sandur Manganese & Iron Ores Ltd. commissioned a ferrosilicon plant with two 20-megavolt-ampere furnaces rated at a total of 24,000 tons per year. Two projects were intended to produce ferromanganese principally for export. In the first, Maharashtra Electrosmelt Ltd. started operation of a new furnace with a capacity of 50,000 tons per year high-carbon ferromanganese. In the second, a new company, Uni-ferro International Ltd., was formed to build a 50,000-short-ton-per-year per year ferromanganese and silicomanganese plant at Tumsar, Maharashtra. The company is 40% owned by Philbros-Asia Ltd. A ferrochromium plant with a 3.5-megavolt-ampere furnace was proposed for the Byrapura District, Karnataka. The plant would be built by Mysore Minerals with Japanese help. A 50,000-ton-per-year ferrochromium plant, intended to use local chromite fines, was proposed for Orissa. Union Carbide Corp. was discussing with the Government of India the possibility of building a ferrovanadium plant.

Indonesia.—Indonesia Nickel Development Co. (Indeco), which had been formed by seven Japanese companies, decided against building the nickel smelter which had been considered for Gebe Island.

Japan.—With relatively weak demand and high imports, Japanese ferroalloys producers were forced to idle a number of furnaces, and at least one ferrochromium producer went out of business. Japanese producers considered several measures to relieve pressure from low price imports, including cartel arrangements, changes in import duties, and in the case of ferrochromium, attempted to negotiate a voluntary restraint agreement with South African producers.

Mexico.—Three Mexican ferroalloys producers increased their capacity in 1977. Cia. Minera Autlán S.A. de C. V. started the second of two new 33-megawatt ferromanganese furnaces at its new plant at Tamós with the result that this plant can provide 100,000 tons per year of standard ferromanganese. Ferralver, S.A. added a furnace to bring its capacity to 15 megavolt-amperes and 23,000 tons per year of ferromanganese. Ferroaleaciones de Mexico, S.A. added a furnace to bring its capacity to 50,000 tons per year of ferromanganese.

New Caledonia.—Amax, Inc. and Bureau de Recherches Géologiques et Minières, the French minerals agency, agreed to develop New Caledonian nickel deposits in a $620 million project. Planned output was 26,000 tons per year of ferronickel. Amax will have a 45% interest in the project.

Norway.—A/S Hafslund was building a new furnace and rebuilding a second to raise its ferrosilicon capacity from 35,000 to 55,000 tons per year. The Government of Norway approved a fourth furnace at the Salten Verk of Elkem-Spigerverket A/S which will raise the company's ferrosilicon capacity from 80,000 to 112,000 tons per year. Orkla Industrier A/S is also planning a new furnace, if power is available, which will raise its capacity to 40,000 tons of ferrosilicon per year in 1979. Producers in Norway were faced with present and future power shortages. Because low rainfall reduced the amount of available hydropower, noncontract power to metallurgical producers was cut off in September. The Government of Norway also set a goal for future power consumption which may limit growth of the industry.

South Africa, Republic of.—Total ferroalloy production increased 13% to 1,030,000 short tons. South African Iron and Steel Industrial Corp. Ltd., the major iron and steel producer in South Africa, offered to sell its 45% interest in South African Manganese Amcor Ltd. (Samancor). However, the sale was blocked by the Government on the grounds that it would be anticompetitive. Two new ferrochromium plants were commissioned during the year, each with a capacity of 120,000 tons per year. The new Tubatse Ferrochrome (Pty.) Ltd. plant, at Steelport, Transvaal, operated two of its three 30-megavolt-ampere furnaces during the year. Tubatse Ferrochrome is a joint venture of General Mining and Finance Corp. Ltd. and Union Carbide Corp. The second new plant, at Lydenburg, Transvaal, is owned by Consolidated Metallurgical Industries Ltd., a subsidiary of Johannesburg Consolidated Investment Co., Ltd. In manganese, Samancor, at its Metalloys subsidiary at Meyerton, Transvaal, started a 75-megavolt-ampere furnace. Transalloys (Pty.), a subsidiary of Highveld Steel and Vanadium Corp. Ltd. started operation of a new silicomanganese furnace.

Spain.—The new 75-megavolt-ampere ferrosilicon furnace at the Monzon plant of Hidro Nitro Española S.A. began operation in 1977, bringing the company's 75% ferrosilicon capacity to about 50,000 tons per year. A new plant built by Sociedad Española de Carburos Metálicos S.A. at Dumbria was not in operation because of lack of electric power. The plant had a 50-megavolt-ampere furnace for ferrosilicon and an 18-megavolt-ampere furnace to be used for ferrosilicon or ferrochromium as needed. Ferroastur began production of ferromolybdenum at its new works at Magua.

Yugoslavia.—A 71,000-short-ton-per-year ferronickel plant was under construction in Davadarci Province and was expected to be in operation by 1979. Plans were also announced for mines and a plant in Kosovo Province to produce 54,000 tons per year of ferronickel plus a smaller amount of nickel and cobalt metal starting late in 1980.

Table 9.—Ferroalloys: World production by furnace type, alloy type, and country

(Thousand short tons)

Country,[1] furnace type,[2] and alloy type[3]	1974	1975	1976	1977[p]
Argentina: Electric furnace:				
Ferromanganese	26	32	26	[e]28
Silicomanganese	8	6	2	[e]2
Ferrosilicon	[r]20	19	21	[e]22
Total	[r]54	57	49	[e]52
Australia: Electric furnace:[4]				
Ferromanganese	47	43	55	[e]66
Silicomanganese	24	12	16	[e]17
Ferrosilicon	10	([5])	6	[e]16
Ferrochromium	[r]3	2	--	--
Total	[r]84	57	77	[e]99
Austria: Electric furnace, undistributed	7	7	9	8
Belgium: Electric furnace, ferromanganese[6 7]	144	108	93	80
Brazil: Electric furnace:				
Ferromanganese	88	[r]96	110	142
Silicomanganese	36	43	70	83
Ferrosilicon	57	60	50	66

See footnotes at end of table.

Table 9.—Ferroalloys: World production by furnace type, alloy type, and country —Continued

(Thousand short tons)

Country,[1] furnace type,[2] and alloy type[3]	1974	1975	1976	1977[p]
Brazil: Electric furnace —Continued				
Ferrochromium	42	58	66	73
Ferrochromium-silicon	2	[r]2	7	4
Ferronickel	11	11	11	12
Other	15	[r]12	30	29
Total	251	[r]282	344	409
Bulgaria: Electric furnace, undistributed	50	[r]56	61	55
Canada: Electric furnace:				
Ferromanganese[8]	[e]100	[r] [e]56	[r] [e]86	[e]81
Ferrosilicon	105	[r]63	[r] [e]91	[e]109
Undistributed[e] [9]	68	[r]57	[r]71	23
Total	273	176	248	213
Chile: Electric furnace:				
Ferromanganese	9	7	9	2
Silicomanganese	3	3	2	1
Ferrosilicon	3	4	5	3
Other	1	1	1	([5])
Total	16	15	17	6
China, People's Republic of: Furnace and alloy type undistributed[e]	660	660	720	770
Colombia: Electric furnace, ferrosilicon	([5])	1	1	1
Czechoslovakia:				
Blast furnace, undistributed	37	31	2	--
Electric furnace, undistributed	140	[r]145	150	193
Total	177	[r]176	152	193
Dominican Republic: Electric furnace, ferronickel	[e]88	67	75	78
Egypt: Electric furnace, undistributed	[r]4	5	[e]5	[10]5
Finland: Electric furnace, ferrochromium	53	44	44	37
France:				
Blast furnace:				
Spiegeleisen	10	8	--	10
Ferromanganese	578	463	404	395
Electric furnace:				
Silicomanganese[11]	9	13	13	22
Ferrosilicon	261	267	261	260
Ferrochromium[12]	123	[r]110	112	111
Other[13]	[r]101	[r]94	108	117
Total	[r]1,082	[r]955	898	915
German Democratic Republic:				
Blast furnace spiegeleisen	2	4	--	--
Electric furnace, undistributed	158	164	166	166
Total	160	168	166	166
Germany, Federal Republic of:				
Blast furnace:				
Ferromanganese[7]	353	238	243	193
Ferrosilicon	130	103	100	96
Electric furnace, undistributed	312	283	263	231
Total	795	624	606	520
Greece: Electric furnace, ferronickel[e]	61	61	67	39
Hungary: Electric furnace:				
Ferromanganese	3	[e]3	[e]3	[e]3
Ferrosilicon	9	[e]8	[e]8	[e]8
Total	12	11	11	11
India: Electric furnace:				
Ferromanganese	161	157	194	184
Silicomanganese	2	[r] [e]3	([5])	3
Ferrosilicon	33	44	59	49
Ferrochromium	17	11	19	19
Ferrochromium-silicon	2	4	6	4
Other[13]	([5])	([5])	([5])	3
Total	215	[r]219	278	262

See footnotes at end of table.

Table 9.—Ferroalloys: World production by furnace type, alloy type, and country —Continued

(Thousand short tons)

Country,[1] furnace type,[2] and alloy type[3]	1974	1975	1976	1977[p]
Italy:				
Blast furnace:				
Spiegeleisen	6	4	3	7
Ferromanganese	77	64	69	64
Electric furnace:				
Ferromanganese	11	15	17	19
Silicomanganese	45	40	46	44
Ferrosilicon	72	78	87	84
Ferrochromium	44	49	50	44
Ferrochromium-silicon	--	(5)	(14)	(14)
Other	19	[12]15	[12]12	[12]19
Total	274	265	284	281
Japan: Electric furnace:				
Ferromanganese	688	716	697	581
Silicomanganese	494	479	411	368
Ferrosilicon	407	361	345	321
Ferrochromium	597	536	511	440
Ferrochromium-silicon	16	28	12	13
Ferronickel	277	221	219	247
Other	20	17	18	13
Total	2,499	2,358	2,213	1,983
Korea, North: Furnace and alloy type undistributed[e]	110	110	110	110
Korea, Republic of: Electric furnace:				
Ferromanganese	--	--	--	28
Ferrosilicon	38	23	38	30
Total	38	23	38	58
Mexico: Electric furnace:				
Ferromanganese	54	71	60	110
Silicomanganese	16	18	19	30
Ferrosilicon	22	20	20	25
Ferrochromium	--	--	4	3
Other	(5)	(5)	(5)	(5)
Total	92	109	103	168
New Caledonia: Electric furnace ferronickel	205	230	173	128
Norway: Electric furnace:				
Ferromanganese	370	[r]373	413	276
Silicomanganese	207	180	186	151
Ferrosilicon	342	325	306	260
Ferrochromium	34	30	35	26
Ferrochromium-silicon	1	1	1	(5)
Other	10	[r]34	34	20
Total	964	943	975	733
Peru: Electric furnace, ferrosilicon	1	1	(5)	[e]1
Poland:				
Blast furnace:				
Spiegeleisen	9	10	9	12
Ferromanganese	138	153	128	136
Electric furnace, undistributed	173	183	180	193
Total	320	346	317	341
Portugal:				
Blast furnace, undistributed	1	--	--	--
Electric furnace, undistributed	12	10	13	18
Total	13	10	13	18
Rhodesia, Southern: Electric furnace, ferrochromium[e]	200	[r]200	205	110
South Africa, Republic of:				
Blast furnace and electric furnace undistributed:[15]				
Ferromanganese[e]	[r]391	[r]371	[r]386	441
Silicomanganese[e]	11	17	24	28
Ferrosilicon[e]	53	84	87	110
Ferrochromium[e]	[r]213	[r]329	[r]386	419
Ferrochromium-silicon[e]	32	23	24	32
Other[e 16]	[r]1	[r]1	[r]1	(5)
Total	701	[r]825	[r]908	1,030

See footnotes at end of table.

Table 9.—Ferroalloys: World production by furnace type, alloy type, and country —Continued

(Thousand short tons)

Country,[1] furnace type,[2] and alloy type[3]	1974	1975	1976	1977[p]
Spain: Electric furnace:				
Ferromanganese	124	[r]140	146	164
Silicomanganese	[r]88	[r]96	100	73
Ferrosilicon	60	61	63	74
Ferrochromium	[r]23	[r]17	21	21
Other	([5])	([5])	([5])	([5])
Total	295	314	330	332
Sweden: Electric furnace:				
Silicomanganese	11	10	8	--
Ferrosilicon	56	55	41	25
Ferrochromium	111	102	128	148
Ferrochromium-silicon	20	17	7	9
Other	3	3	3	2
Total	201	187	187	184
Switzerland: Electric furnace, ferrosilicon[e]	7	6	6	6
Taiwan: Electric furnace, ferrosilicon	30	26	17	17
Thailand: Electric furnace:				
Ferromanganese	2	1	2	--
Ferrosilicon	1	([5])	1	--
Total	3	1	3	--
Turkey: Electric furnace, ferrochromium[e]	10	10	28	39
U.S.S.R.:				
Blast furnace:				
Spiegeleisen	118	115	112	110
Ferromanganese	947	968	937	937
Other	29	30	31	28
Electric furnace:[17]				
Ferromanganese[e]	[r]99	90	99	104
Silicomanganese[e]	28	28	28	33
Ferrosilicon[e]	330	330	331	331
Ferrochromium[e]	203	227	231	232
Ferrochromium-silicon[e]	7	4	6	6
Other[e 13]	[r]198	180	193	198
Total	[r]1,959	1,972	1,968	1,979
United Kingdom: Blast furnace:[18]				
Spiegeleisen	9	([5])	--	--
Ferromanganese	91	94	134	107
Total	100	94	134	107
United States: Blast furnace and electric furnace:[19]				
Ferromanganese	544	576	483	334
Silicomanganese	196	143	129	120
Ferrosilicon	932	791	861	895
Ferrochromium	337	197	215	217
Ferrochromium-silicon	99	52	54	53
Other[13 20]	176	167	168	135
Total	2,284	1,926	1,910	1,754
Uruguay: Electric furnace, ferrosilicon	([5])	([5])	([5])	([5])
Venezuela: Electric furnace, ferrosilicon	2	3	3	[e]3
Yugoslavia: Electric furnace:				
Ferromanganese	25	34	24	60
Silicomanganese	19	16	29	10
Ferrosilicon	115	92	109	61
Ferrochromium	43	59	47	40
Ferrochromium-silicon	5	11	8	6
Other[13]	2	3	4	2
Total	209	215	221	179

See footnotes at end of table.

Table 9.—Ferroalloys: World production by furnace type, alloy type, and country —Continued

(Thousand short tons)

Country,[1] furnace type,[2] and alloy type[3]	1974	1975	1976	1977[p]
Grand total	r14,703	r13,923	14,067	13,480
Of which:				
Blast furnace:				
Spiegeleisen[21]	154	r141	124	139
Ferromanganese[21]	r2,184	r1,980	1,915	1,832
Other[22]	r159	r133	100	91
Unspecified	38	31	33	33
Total blast furnace	2,535	r2,285	2,172	2,095
Electric furnace:				
Ferromanganese[23]	r1,951	r1,942	2,034	1,927
Silicomanganese[23 24]	r1,197	r1,107	1,083	985
Ferrosilicon	r2,966	r2,722	2,817	2,777
Ferrochromium[25 26]	r2,053	r1,981	2,102	1,979
Ferrochromium-silicon[25 26]	r184	r142	125	127
Ferronickel[26 27]	642	590	545	504
Other[27]	r546	r527	572	539
Unspecified[26]	r924	r910	918	892
Total electric furnace	r10,463	r9,921	10,196	9,730
Furnace type unspecified:				
Ferromanganese	r935	r947	869	775
Unspecified	770	770	830	880
Total furnace type unspecified	r1,705	r1,717	1,699	1,655

eEstimate. pPreliminary. rRevised.

[1]In addition to the countries listed, Romania is known to produce electric furnace ferroalloys, but output is not reported and no basis is available for estimation.

[2]To the extent possible, ferroalloy production of each country has been separated according to the furnace type from which production is obtained; production derived from metallothermic operations is included with electric furnace production.

[3]To the extent possible, ferroalloy production of each country has been separated so as to show individually the following major types of ferroalloys: Spiegeleisen, ferromanganese, silicomanganese, ferrosilicon, ferrochromium, ferrochromium-silicon and ferronickel. Ferroalloys other than those listed that have been identified specifically in sources, as well as those ferroalloys not identified specifically but which definitely exclude those listed previously in this footnote have been reported as 'Other'. For countries for which one or more of the individual ferroalloys listed separately in this footnote have been inseparable from some other ferroalloys owing to the nation's reporting system, such deviations are indicated by individual footnote. In instances where ferroalloy production has not been subdivided in sources, and where no basis is available for estimation of individual component ferroalloys, the entry has been reported as 'Undistributed'.

[4]Data for year ending November 30 of that stated.

[5]Less than 1/2 unit.

[6]Electric furnace output, if any, is not reported, and no basis is available for estimation.

[7]Includes spiegeleisen.

[8]Includes silicomanganese.

[9]Includes ferrochromium (1974 only), ferrochromium-silicon (if any) and ferronickel.

[10]All ferrosilicon.

[11]Includes silicospiegeleisen.

[12]Includes ferrochromium-silicon, if any was produced.

[13]Includes ferronickel, if any was produced.

[14]Included with other, if any was produced.

[15]In addition to the ferroalloys individually identified, ferronickel is also produced but output is not reported and no basis is available for estimation.

[16]Ferrovanadium only.

[17]Soviet production of electric furnace ferroalloys is not reported; estimates provided are based on crude source material production and availability for consumption (including estimates), and upon reported ferroalloy exports.

[18]In addition to blast furnace ferroalloy production reported, electric furnace ferroalloys are known to be produced, but data are not published and no basis is available for estimates.

[19]U.S. production of ferromanganese cannot be separated by furnace type in order to conceal corporate proprietary information. Similarly, spiegeleisen and ferronickel production cannot be reported separately. All U.S. ferroalloy production except a portion of the ferromanganese output is from electric furnaces or by metallothermic operations.

[20]Includes spiegeleisen and ferronickel.

[21]Spiegeleisen for the Federal Republic of Germany included with ferromanganese.

[22]Includes the following quantities specifically identified as ferrosilicon, in thousand short tons: 1974—130; 1975—103; 1976—r91; 1977—96. The differences between the foregoing figures and the listed totals are not identified in anyway except that they are neither spiegeleisen nor ferromanganese.

[23]Silicomanganese for Canada included with ferromanganese.

[24]Includes silicospiegeleisen for France.

[25]Ferrochromium-silicon for France included with ferrochromium.

[26]Canada's production of ferrochromium (1974 only), ferrochromium-silicon (if any), and ferronickel included with unspecified.

[27]Ferronickel (if any) for France, India, Norway, the U.S.S.R., the United States and Yugoslavia included with "Other".

TECHNOLOGY

Bureau of Mines recycling research on the pelletization and smelting of stainless steel wastes, which had previously been conducted using induction furnaces, was extended to the use of electric-arc furnaces. Trials in heat sizes of up to 1 ton continued to indicate that the process could be expected to be profitable. Application of the process could recover thousands of tons of valuable alloying elements, particularly chromium and nickel, which are now lost in fumes, mill scale, and grinding swarf.[2] The Bureau, in a cooperative project, also used electric-arc furnaces to confirm the feasibility of producing ferronickel from prereduced nickel concentrate from the Yugoslavian Feni project. Test results indicated that similar technology would be applicable to the limited number of domestic nickel ores. It was shown that ferronickel containing 15% to 20% nickel as typically produced in the test program could be upgraded by selective oxidation to a nickel content of over 50%.[3]

A shell design for submerged-arc furnaces has been developed, by Elkem-Spigerverket A/S of Norway, which it is hoped will permit smelting of ferrosilicon and silicon metal in completely closed furnaces. In this design the furnace body is divided into two independently rotatable parts. The upper part is a ring whose interior cross section has the shape of a regular polygon typically with nine sides. Smelting tests in laboratory and small-scale industrial furnaces have shown that with this design an even distribution of the charge and off-gasses can be achieved with a closed top. This contrasts with a conventional furnace in which free access for stoking at the furnace top is required to achieve satisfactory operation.[4] [5]

The Republic of South Africa's National Institute for Metallurgy (NIM) participated in two developments in technology for smelting ferrochromium in submerged-arc furnaces. One was the devising of a computerized monitoring system that was reported to have contributed to a near doubling of furnace productivity.[6] The other was determination of a method for pelletizing fines from friable Transvaal chromium ores as a means of extending the South African chromium resource base. It was found that satisfactory pellets could be produced using a bentonite binder and induration at about 1,000° C. These pellets, in amounts up to 60% of the chromium units in the furnace charge, were reportedly suitable for production of high-carbon ferrochromium.[7]

Plasma technology for metallurgical processing and especially for ferroalloy production was reviewed at the Republic of South Africa's NIM. It was concluded that use of plasma furnaces for making ferroalloys should be seriously evaluated, as in production of ferrochromium from chromium ore fines.[8]

An "Extended Arc Flash Reactor" (EAFR) which makes use of a plasma and has potential for ferroalloy production has been developed by a Canadian company, Tibur Metals, Ltd. A key component of the EAFR is a hollow electrode through which argon or another gas passes and is ionized to form a plasma giving rise to an extended arc. An outgrowth of previous work on electric-arc furnaces for steel production, the EAFR appears to be particularly applicable to reduction of fine iron-bearing oxide dusts from steel plant operations. However, its use for smelting such ferroalloys as ferrochromium, ferromolybdenum, and ferrovanadium is also visualized.[9] [10]

Laboratory investigation of a process aimed at making molybdenum-iron compacts that could be used in place of conventional ferromolybdenum was reported by Kennecott Copper Corp. A process proposed on the basis of the investigation consisted of forming briquets from technical-grade molybdenum oxide and iron oxide; reducing these briquets to metal in a cracked ammonia atmosphere in two stages, first at 600° C and then at 900° C; and crushing and rebriquetting the product to obtain adequate mechanical strength and high enough density to penetrate a steelmaking slag. The two-stage reduction process was developed to maximize usage of hydrogen from the gas atmosphere.[11]

---

[1]Physical scientist, Division of Ferrous Metals.

[2]Barnard, P. G., W. M. Dressel, and M. M. Fine. Arc Furnace Recycling of Chromium-Nickel From Stainless Steel Wastes. BuMines RI 8218, 1977, 10 pp.

[3]Paulson, D. L., and W. E. Anable. Smelting Prereduced Nickel Concentrate in an Electric-Arc Furnace. BuMines RI 8196, 1977, 16 pp.

[4]Krogsrud, H., N. E. Bugge, and K. Piene. Recent Achievements in the Development of the Modern Ferrosilicon Furnace—the Elkem Split Furnace Body. Proc. 35th Electric Furnace Conf., ISS-AIME, Chicago, Ill., Dec. 6-9, 1977. American Institute of Mining, Metallurgical, and Petroleum Engineers, New York, 1978, pp. 15-18.

[5]Krogsrud, H. (assigned to Elkem-Spigerverket A/S, Oslo, Norway). Rotatable Furnace for Smelting Furnaces. U.S. Pat. 3,975,575, Aug. 17, 1976.

[6]Metals Week. Computer Helping Boost South African Alloys. V. 48, No. 21, May 23, 1977, p. 7.

[7]McRae, L. B., and S. S. Selmer-Olsen. An Investigation Into the Pelletizing and Prereduction of Transvaal Chromites. Ch. 20 in Agglomeration 77, Proc. 2d Internat. Symp. on Agglomeration. Atlanta, Ga., Mar. 6-10, 1977. V. 1, ed. by K. V. S. Sastry. American Institute of Mining, Metallurgical, and Petroleum Engineers, New York, 1977, pp. 356-377.

[8]Hamblyn, S. M. L. A Review of Applications of Plasma Technology With Particular Reference to Ferro-Alloy Production. National Institute for Metallurgy (Randburg, South Africa), Report No. 1895, Apr. 14, 1977, 34 pp.

[9]Canadian Chemical Processing. New Unit Smelts Oxide Dusts & Ores. V. 61, No. 4, April 1977, pp. 32-34.

[10]Segsworth, R. S., and C. B. Alcock (assigned to Tibur Metals, Ltd., Toronto, Canada). Extended Arc Furnace and Process for Melting Particulate Charge Therein. U.S. Pat. 4,006,284, Feb. 1, 1977.

[11]Crimes, P. B., N. F. Neumann, and P. R. Ammann. The Production of Molybdenum-Iron Composites as a Ferromolybdenum Substitute. Pres. at 16th Ann. Conf. of Metallurgists, The Metallurgical Soc. of CIM, Vancouver, B.C., Canada, Aug. 23, 1977, 24 pp.

Fluorspar

By Stanley K. Haines[1]

Domestic shipments of fluorspar decreased 10% to about 170,000 tons in 1977; of this total, 41% was metallurgical fluorspar. Imports for consumption increased 9% to 971,300 tons with 59% coming from Mexico. Net import reliance was 81%. Reported consumption dropped 9% to 1,162,000 tons. The principal end uses were hydrofluoric acid (HF), 51%; basic oxygen furnace (steel) 32%; open hearth furnaces (steel) 7%; and electric furnaces, 7%. Domestic mine stocks of crude fluorspar increased from 89,000 tons in 1976 to 204,000 tons in 1977. Fluosilicic acid (H_2SiF_6) production as a byproduct from phosphoric acid plants decreased 9% to 64,000 tons. Imports of 70% HF were up 5% to 90,000 tons in 1977.

The average value per ton of domestic shipments and of imports was $97.23 and $79.38, respectively. Quoted prices were stable during the year with the exception of a $3 to $5 per ton drop in price for European and South African fluorspar. A bill to remove duties on fluorspar imports for a 2-year period was reintroduced into Congress. However, by yearend it had not cleared the Ways and Means Committee.

World production of fluorspar increased 4% to 5,148,081 tons in 1977.

Table 1.—Salient fluorspar statistics[1]

	1973	1974	1975	1976	1977
United States:					
Production:					
Mine production short tons	561,149	447,253	376,601	611,133	613,000
Material beneficiated do	663,361	409,005	401,477	574,678	538,000
Material recovered do	232,891	207,816	132,060	182,582	164,600
Finished (shipments) do	248,601	201,116	139,913	188,270	169,489
Value f.o.b. mine thousands	$17,381	r$17,297	r$14,888	$17,927	$16,479
Exports short tons	2,428	5,847	1,384	4,923	6,642
Value thousands	$171	$316	$234	$764	$975
Imports for consumption short tons	1,212,347	1,336,389	1,050,448	895,254	971,355
Value[2] thousands	$52,620	$60,988	$66,899	$64,881	$69,457
Consumption (reported) short tons	1,351,705	1,524,532	1,244,938	r1,273,498	1,162,336
Consumption (apparent)[3] do	1,508,759	1,428,719	1,300,067	1,120,970	1,191,000
Stocks Dec. 31:					
Domestic mines:					
Crude do	57,901	44,196	57,833	88,905	204,466
Finished do	8,675	13,668	11,386	14,870	12,243
Consumer do	327,703	430,642	319,552	277,783	226,320
World: Production do	5,043,737	5,355,079	r4,985,568	r4,932,084	5,148,081

rRevised.
[1]Does not include fluosilicic acid and imports of hydrofluoric acid and cryolite.
[2]F.o.b. foreign port in 1973-74; c.i.f. U.S. port, in 1975-77.
[3]Apparent consumption includes finished shipments plus imports, minus exports, minus consumer stock increase.

Legislation and Government Programs.—Government stockpiles of strategic and critical materials contained 890,000 tons of acid-grade and 412,000 tons of metallurgical-grade fluorspar at yearend. No withdrawals were made during the year. Stockpile goals for these grades were 1,594,000 tons for acid-grade fluorspar and 1,914,000 tons, for metallurgical-grade fluorspar.

The bill to suspend the duty on fluorspar for 2 years was reintroduced into Congress in March. Although it had not cleared the committee by yearend, it was expected to be acted upon in 1978.

Bureau of Mines research continued to develop methods for preparing synthetic or substitute fluorspar from fluosilicic acid for use by the steel industry.

DOMESTIC PRODUCTION

Domestic shipments of all grades of fluorspar decreased 10% to 170,000 tons. Shipments from the Illinois-Kentucky district represented 85% of the total volume; the balance came from Arizona, Montana, Nevada, and Texas. Two companies operating in Illinois accounted for most of the total output. Smaller, some intermittent, operations or only shipments from inventory in Illinois, Kentucky, and the Western States provided the remainder of domestic shipments. Names and locations of these facilities were as follows:

State	Company	Mines	Type of mills
Arizona	Tonto Mining and Milling Co	Bluebird	Flotation.[1]
	Western Fluorspar Co	Turkey	None.
Illinois	Allied Chemical Corp	Spivey, Gaskin, Deardorf and Minerva No. 1.	Heavy-medium and flotation.
	Ozark-Mahoning Co	Barnett, Knight, Oxford and H-M shaft.	Heavy-medium, flotation and briquetting.
	Hastie Mining Co	Spar Mountain	Heavy-medium.
Kentucky	Frontier Spar Corp	Babb-Barnes	Heavy-medium and flotation.
Montana	Roberts Mining Co	Crystal Mountain	Heavy-medium.[2]
Nevada	J. Irving Crowell, Jr. & Sons	Daisy	None.
Texas	D & F Minerals Co	Paisano	Do.

[1]Processed crude ore from Bluebird and Turkey mines.
[2]Shipments from inventory only.

Total shipments of acid-grade fluorspar were 101,000 tons valued at $10.76 million, compared with 116,000 tons valued at $12.47 million in 1976. Production of metallurgical-grade fluorspar also declined, dropping from 72,000 tons in 1976 to 69,000 tons in 1977.

Kenspar Corp., a joint venture of Minerals Exploration Co. and Armco Steel Corp., ceased production in September after amassing a large stockpile of crude ore.

Ozark-Mahoning Co., a subsidiary of Pennwalt Corp., and Allied Chemical Corp. continued as the largest domestic producers of fluorspar, with operations in Hardin County in southern Illinois. Output by Ozark-Mahoning consisted of acid- and metallurgical-grade fluorspar, including briquets, while Allied Chemical Corp.'s output comprised acid and ceramic grades. Both operators also recovered various amounts of lead, zinc, and barite concentrates as byproducts from their flotation circuits.

U.S. Borax and Chemical Co. continued its drilling and exploration activities in the Sweetwater, Tenn., area. Plans for 1978 included the sinking of a test shaft.

Frontier Spar Corp., a wholly owned subsidiary of Marathon Oil Co., broke ground for its Lasher-Robinson mine north of Salem, Ky. The ore was to be treated at the company's facility at its Babb-Barnes mine near Salem, Ky.[2]

Eight processors, operating at 44% of estimated annual capacity, supplied the steel industry with 241,000 tons of fluorspar briquets averaging 68% CaF_2 and valued at $19 million. These shipments represented a decrease of 17% in volume and 21% in value, compared with those of 1976. Cametco, Inc., opened a new briquetting plant in 1977 near steel mills in the Chicago area. Location of fluorspar briquetting plants operating in 1977 are as follows:

Processor	Location
Cametco, Inc	Chicago, Ill.
Do	Duquesne, Pa.
Delhi Foundry Sand Co	Brownsville, Tex.
Mercier Corp	Dearborn, Mich.
National Briquet Corp	East Chicago, Ind.
Oglebay Norton and Co	Brownsville, Tex.
Ozark-Mahoning Co	Rosiclare, Ill.
Do	Brownsville, Tex.

Fluosilicic acid, recovered from the wet-process manufacture of phosphoric acid from fluorapatite, continued to be an important domestic source of fluorine for use by the chemical and aluminum industries. Eleven phosphoric acid plants processing about 8 million tons of phosphate rock, recovered about 64,000 tons of fluosilicic acid in 1977, a decrease of 9% below 1976 levels. About 43,000 tons of this acid was shipped to consumers. A list of domestic phosphoric acid plants reporting fluorine recovery in 1977 follows:

Processor	Location
Agrico Chemical Co	Pierce, Fla.
Borden Chemical Co	Norfolk, Va.
Central Phosphates, Inc	Plant City, Fla.
Farmland Industries	Bartow, Fla.
Gardinier (SOPAG), Inc	Tampa, Fla.
Mississippi Chemical Corp	Pascagoula, Miss.
Stauffer Chemical Co	Salt Lake City, Utah
U.S.S. Agri-Chemicals	Bartow, Fla.
Do	Wilmington, N.C.
Do	Nashville, Tenn.
W. R. Grace & Co	Bartow, Fla.

Table 2.—Shipments of finished fluorspar, by State

State	1976			1977		
	Quantity (short tons)	Value: Total (thousands)	Value: Average per ton	Quantity (short tons)	Value: Total (thousands)	Value: Average per ton
Illinois	142,666	$14,563	$102.08	131,218	$13,941	$106.24
Other States[1]	45,604	3,364	73.77	38,271	2,538	66.32
Total	188,270	17,927	95.22	169,489	16,479	97.23

[1]Includes Arizona, Kentucky, Montana, Nevada, Texas, and Utah.

Table 3.—Shipments and mine stocks of finished fluorspar in the United States, by grade

Grade	1976				1977			
	Short tons	Value[1] (thousands)	Value per ton	Yearend stocks	Short tons	Value[1] (thousands)	Value per ton	Yearend stocks
Acid	[2]116,300	$12,470	$107.23	9,063	[2]100,605	$10,755	$106.90	4,070
Metallurgical	71,970	5,457	75.82	5,807	68,884	5,724	83.10	8,173
Total	188,270	17,927	95.22	14,870	169,489	16,479	97.23	12,243

[1]Total value as reported by mine production.
[2]Includes No. 1 ceramic grade.

CONSUMPTION AND USES

Acid-grade fluorspar, containing more than 97% CaF_2, is feedstock for the manufacture of hydrofluoric acid, a key chemical used in the manufacture of aluminum and fluorochemicals. Ceramic-grade, containing between 85% and 97% CaF_2, is used in the ceramics industry for the production of glass and enamel. Metallurgical-grade fluorspar, containing between 60% and 85% CaF_2, is used almost exclusively in the iron and steel industries. Traditionally, fluorspar containing a minimum of 70% effective CaF_2 has been used in steel furnaces, but in recent times lower grade material, including briquets, has gained widespread usage.

Major U.S. steel mills consumed 535,000 tons of fluorspar, a decrease of 12% from the 1976 figure. Of this, basic oxygen furnaces consumed 69%; open hearth furnaces, 16%; and electric furnaces, 15%. Domestic production of raw steel decreased 2% to about 125 million tons according to the American Iron and Steel Institute. The steel industry consumed 8.6 pounds of fluorspar per ton of steel produced. On the basis of furnace type, the average fluorspar consumption per ton of raw steel was as follows:

Type of furnace	Fluorspar cosumption pounds per ton	
	1976	1977
Open hearth	7.9	8.5
Basic oxygen	10.6	9.5
Electric	7.3	5.9

Acid-grade consumption by 12 domestic hydrofluoric acid plants amounted to 592,000 tons, a decrease of 6% from that of 1976. Part of the decline was due to the closing of Allied Chemical's plant at Claymont, Del., in April 1977. A yearend list of domestic hydrofluoric acid plants follows:

Producer	Plant location	Estimated capacity tons per year
Aluminum Company of America	Point Comfort, Tex	55,000
Allied Chemical Corp	Baton Rouge, La Geismar, La Nitro, W.Va Port Chicago, Calif	90,000
DuPont Company	Strang, Tex	75,000
Essex Chemical Corp	Paulsboro, N.J	11,000
Harshaw Chemical Co	Cleveland, Ohio	18,000
Kaiser Aluminum & Chemical Corp.	Gramercy, La	50,000
Pennwalt Corp	Calvert City, Ky	25,000
Stauffer Chemical Co	Houston, Tex	6,000
Total		330,000

Source: Chemical Marketing Reporter.

Hydrofluoric acid produced and sold totaled 179,000 tons in 1977, compared with 182,000 tons in 1976. An additional 90,000 tons, valued at $45 million, was available from imports, principally from Mexico and Canada. Major end uses of hydrofluoric acid were fluorocarbon production, aluminum production, petroleum alkylation, uranium enrichment, stainless steel pickling, the production of fluorine compounds other than fluorocarbons, and miscellaneous uses.

Production of fluorocarbons F11 and F12, decreased 13% to 272,000 tons according to the U.S. International Trade Commission. Data on production of other fluorocarbons were unavailable. The five most common fluorocarbons are listed below:

Fluorocarbon No.	Chemical name	Molecular formula
F11	Trichlorofluoromethane	CCl_3F
F12	Dichlorodifluoromethane	CCl_2F_2
F22	Chlorodifluoromethane	$CHClF_2$
F113	Trichlorotrifluoroethane	$CCl_2F\text{-}CClF_2$
F114	Dichlorotetrafluoroethane	$CClF_2\text{-}CClF_2$

Fluorocarbon production was halted by Union Carbide Corp. at its Institute, W. Va., plant due to economic considerations.[3] The following table presents the leading producers of fluorocarbons and their estimated capacities:

Producer	Plant location	Capacity tons per year
Allied Chemical Corp	Baton Rouge, La Denville, Ill Elizabeth, N.J El Segundo, Calif	185,000
DuPont Company	Antioch, Calif Deepwater, N.J Louisville, Ky Montage, Mich Corpus Christi, Tex	250,000
Kaiser Aluminum & Chemical Corp.	Gramercy, La	40,000
Pennwalt Corp	Calvert City, Ky	45,000
Racon Corp	Wichita, Kans	23,000
Total		543,000

Sources: Chemical Marketing Reporter and Arthur D. Little, Inc.

Using a revised model, the National Center for Atmospheric Research estimated that the amounts of fluorocarbons in the atmosphere would destroy 1.2% of the ozone. The revised model decreased the estimated damage of high-flying aircraft on the ozone and increased the effect of fluorocarbons.[4]

The Consumer Product Safety Commission and the Food and Drug Administration (FDA) issued rules dealing with labeling and data submission requirements for products making use of chlorofluorocarbons as propellants. FDA also announced its intent to prohibit use of chlorofluorocarbon propellants in all products subject to the Federal Food, Drug, and Cosmetic Act.[5] Oregon became the first State to ban the sale of aerosols containing chlorofluorocarbons exempting propellants for medical products. Twenty other States were considering similar bans.[6]

DuPont announced a 50% increase in capacity for manufacturing facilities for fluoroplastics. The new facility would be at Parkersburg, W. Va. Two of the products directly affected were Teflon PFA fluorocarbon resin and Tefzel fluoropolymer.[7]

Six major companies—Aluminum Co. of America, Allied Chemical Corp., Kaiser Aluminum & Chemical Corp., Olin Corp., Stauffer Chemical Co., and Reynolds Metals Co.—accounted for most of the domestic production, from hydrofluoric acid, of aluminum fluoride and synthetic cryolite. Domestic production of primary aluminum in 1977 was 4,539,000 tons. An estimated 56 pounds of hydrofluoric acid was consumed for each ton of aluminum produced. This amounted to about 127,000 tons of HF.

An estimated 15,600 tons of uranium oxide, U_3O_8, (contained in ore) was converted to uranium hexafluoride in 1977. This conversion required an estimated 17,200 tons of hydrofluoric acid. This relatively minor demand should continue to grow in parallel with the growth of nuclear power.

In summary, reported domestic fluorspar consumption decreased 9% to 1,162,000 tons in 1977. About 60% of this consumption was acid-grade; the remainder was metallurgical-grade. Raw steel production accounted for 46% of total fluorspar consumed; hydrofluoric acid production required 51%. The remaining 3% was used in stainless steel pickling, uranium enrichment, glass, pottery, and other end uses.

Supplementing the domestic supply of fluorine was byproduct fluosilicic acid recovered from wet-process phosphoric acid plants. In 1977, about 43,000 tons of fluosilicic acid was shipped. Almost 72% of the total shipments went to producers of synthetic cryolite and aluminum fluoride for aluminum production. The remainder went to manufacturers of other fluorine compounds including those used in water fluoridation plants.

Table 4.—Reported domestic consumption of fluorspar in 1977, by end use and grade

(Short tons)

End use or product	Containing more than 97% CaF_2	Containing not more than 97% CaF_2	Total
Hydrofluoric acid	592,229	W	592,229
Glass and fiber glass	5,702	3,972	9,674
Enamel and pottery	W	1,234	1,234
Welding rod coatings	686	1,948	2,634
Primary aluminum and magnesium	333	161	494
Iron and steel castings	--	15,357	15,357
Open hearth furnaces	--	84,980	84,980
Basic oxygen furnaces	--	369,217	369,217
Electric furnaces	3,813	77,114	80,927
Other uses or products	688	4,902	5,590
Total	603,451	558,885	1,162,336
Stocks, Dec. 31, 1977	74,252	152,068	226,320
Stocks, Dec. 31, 1976	66,641	211,142	277,783

W Withheld to avoid disclosing company proprietary data; included with "Other uses or products."

STOCKS

Yearend stocks of U.S. producers totaled 12,300 tons of finished fluorspar. Acid-grade fluorspar totaled 4,100 tons, a 55% decrease from the 1976 figure. Metallurgical-grade material increased 41% to 8,200 tons. Yearend domestic consumer stocks decreased by 19% to 226,000 tons. The General Services Administration Government stockpile inventory remained at 896,000 tons of acid-spar, 295,000 tons of metallurgical-grade fluorspar and 117,000 tons of non-stockpile-grade metallurgical fluorspar.

PRICES

Domestic fluorspar prices, f.o.b. Illinois-Kentucky, as reported in Engineering and Mining Journal, remained level during the year. The only change from 1976 occurred in quotations on offshore-imported acid-grade fluorspar which dropped to $97-$102 per ton from $102.50-$105.00, c.i.f. U.S. port.

DuPont announced an increase in prices for fluorocarbon refrigerants sold to original equipment manufacturers. The yearend prices of bulk Freon 11 and 12 were 39 cents and 43 cents per pound, respectively. Other yearend Freon prices, in cents per pound, were Freon 22, 61; Freon 113, 56; Freon 114, 62; Freon 500, 67; and Freon 502, 124.[8]

Table 5.—Prices of domestic and imported fluorspar

(Dollars per short ton)

	1976	1977
Domestic, f.o.b. Illinois-Kentucky:		
Metallurgical: 70% effective CaF_2 briquets	83- 91	83- 91
Ceramic, variable calcite and silica:		
88% to 90% CaF_2	90-100	90-100
95% to 96% CaF_2	95-106	95-106
97% CaF_2	100-115	100-115
Acid, dry basis, 97% CaF_2:		
Carloads	95-115	95-115
88% effective CaF_2 briquets	111	111
European and South African:[1] Acid, term contracts	102.50-105.00	97-102
Mexican:[2]		
Metallurgical:		
70% effective CaF_2, f.o.b. vessel, Tampico	65.52	65.52
70% effective CaF_2, f.o.b. cars, Mexican border	62.92	62.92
Acid, bulk: 97%+, Mexican border	79.38	79.38

[1]C.i.f. east coast, Great Lakes, and Gulf ports.
[2]U.S. import duty, insurance, and freight not included.

Source: Engineering and Mining Journal, December 1976 and 1977.

FOREIGN TRADE

A total of about 7,000 tons of fluorspar was exported in 1977, mainly to Canada.

U.S. imports of fluorspar increased 9% to 971,300 tons in 1977. Mexico supplied 59% of the total, followed by the Republic of South Africa with 20% and Spain with 11%. Of the total, 61% was acid-grade and the remainder was metallurgical-grade. U.S. imports of cryolite increased 4% to 12,000 tons valued at $5 million. Japan and Denmark supplied 66% and 20%, respectively. Imports of 70% hydrofluoric acid increased 5% to 90,000 tons valued at $45 million. Mexico and Canada were the leading source countries.

Table 6.—U.S. exports of fluorspar

Year and country	Quantity (short tons)	Value
1974	5,847	$315,852
1975	1,384	233,602
1976	4,923	763,757
1977:		
Argentina	8	3,425
Brazil	23	19,349
Canada	5,691	759,926
Dominican Republic	229	37,899
Mexico	311	31,653
South Africa, Republic of	21	3,506
United Kingdom	16	50,850
Venezuela	343	68,827
Total	6,642	975,435

Table 7.—U.S. imports for consumption of fluorspar, by country and customs district

Country and customs district	1976 Quantity (short tons)	1976 Value (thousands) Customs	1976 Value (thousands) C.i.f.	1977 Quantity (short tons)	1977 Value (thousands) Customs	1977 Value (thousands) C.i.f.
CONTAINING MORE THAN 97% CALCIUM FLUORIDE						
Canada: Galveston	77	$6	$6	--	--	--
France: Cleveland	7,720	556	734	--	--	--
Italy:						
Galveston	49,510	3,765	4,194	54,323	$4,208	$4,745
New Orleans	7,854	635	714	--	--	--
Total	57,364	4,400	4,908	54,323	4,208	4,745
Kenya:						
Detroit	15,056	656	918	18,708	1,092	1,393
Houston	6,366	398	495	--	--	--
Total	21,422	1,054	1,413	18,708	1,092	1,393
Mexico:						
El Paso	88,910	4,947	7,429	91,756	5,219	7,671
Galveston	--	--	--	46	3	3
Laredo	212,310	15,358	15,703	192,154	14,180	14,700
New Orleans	4,334	339	372	--	--	--
Total	305,554	20,644	23,504	283,956	19,402	22,374
Morocco: Philadelphia	--	--	--	5,952	486	545
South Africa, Republic of:						
Detroit	8,489	567	723	--	--	--
Laredo	4,874	283	366	20,613	1,171	1,851
New Orleans	74,918	4,544	5,454	118,918	7,541	9,268
Philadelphia	--	--	--	1,982	122	167
Total	88,281	5,394	6,543	141,513	8,834	11,286
Spain:						
Cleveland	21,108	1,511	2,005	46,141	3,275	4,207
Houston	28,505	2,157	3,014	17,769	1,343	1,564
New Orleans	9,941	836	1,031	--	--	--
Philadelphia	16,354	1,407	1,611	16,105	1,693	1,768
Total	75,908	5,911	7,661	80,015	6,311	7,539
Taiwan: Houston	6,943	515	520	--	--	--
Thailand: New Orleans	27,945	1,330	1,771	9,271	515	727
Grand total	591,214	39,810	47,060	593,738	40,848	48,609
CONTAINING NOT MORE THAN 97% CALCIUM FLUORIDE						
Brazil: New York	2	1	1	--	--	--
Canada: Detroit	43	4	2	--	--	--
Colombia: Laredo	--	--	--	455	29	29
Mexico:						
Baltimore	--	--	--	4,653	305	366
Buffalo	20,366	1,248	1,425	25,525	1,417	1,736
El Paso	14,270	505	504	36,880	1,123	1,122
Laredo	196,583	9,945	10,029	222,865	10,784	10,789
New Orleans	--	--	--	57	4	4
Philadelphia	7,986	729	868	3,866	256	297
Total	239,205	12,427	12,826	293,846	13,889	14,314
South Africa, Republic of: New Orleans	34,020	1,804	2,334	53,792	3,249	4,046
Spain:						
Baltimore	23,330	1,894	2,007	23,632	1,853	1,973
Philadelphia	7,440	640	651	5,892	428	486
Total	30,770	2,534	2,658	29,524	2,283	2,459
Grand total	304,040	16,770	17,821	377,617	19,450	20,848

Table 8.—U. S. imports for consumption of 70% hydrofluoric acid

Country	1976			1977		
	Quantity (short tons)	Value (thousands)		Quantity (short tons)	Value (thousands)	
		Customs	C.i.f.		Customs	C.i.f.
Canada	36,675	$17,041	$17,170	30,793	$15,336	$15,225
Germany, Federal Republic of	--	--	--	(1)	(1)	(1)
Japan	105	49	63	--	--	--
Mexico	48,672	23,712	23,724	58,846	29,249	29,303
United Kingdom	78	33	43	416	192	275
Total	85,530	40,835	41,000	90,055	44,777	44,803

[1] Less than 1/2 unit.

Table 9.—U.S. imports for consumption of cryolite[1]

Year and country	Quantity (short tons)	Value (thousands)	
		Customs	C.i.f.
1974	21,216	$6,969	$8,209
1975	22,120	9,058	10,555
1976	11,325	4,329	5,136
1977:			
Canada	508	218	232
China, People's Republic of	220	68	91
Denmark	2,308	1,020	1,168
Germany, Federal Republic of	83	36	43
Greenland	31	20	24
Hong Kong	276	140	85
Italy	601	228	241
Japan	7,727	2,538	3,111
Mexico	3	1	1
Netherlands	16	9	10
Taiwan	3	1	1
Total	11,776	4,279	5,007

[1]Only the material from Denmark is natural cryolite. All other material is synthetic.

WORLD REVIEW

World production of fluorspar was 5,148,081 tons, an increase of 4%. Mexico remained the leading producer with 20% of world production, followed by the U.S.S.R., Spain, France, and the Republic of South Africa in order of volume.

Canada.—Alcan Smelters and Chemicals Ltd. closed its fluorspar mining operations near St. Lawrence, Newfoundland, in the fall of 1977. The company, which had mined fluorspar in this area for 35 years, claimed that changing world fluorspar market conditions caused the operations to be uneconomical.[9]

The Canadian Department of the Environment decided to gradually phase out the use of F11 and F12 fluorocarbons for all nonessential uses. The aerosol industry agreed to cut its fluorocarbon use in half by the end of 1977.[10]

Mexico.—Pennwalt Corp. notified the Mexican Government that it intends to close its Villa de Zaragoza fluorite mine. Mining operations had weakened the hill in which the mine was located. Cracks appeared around the mouth of the mine causing a safety hazard.[11]

Pakistan.—The Baluchistan Development Authority completed a report on fluorite deposits at Dilband in the Kalat District. The metallurgical-grade fluorspar could feed the Karachi steel mills at a rate of about 4,000 tons per year. Plans also called for exports of about 1,000 tons per year.[12]

South Africa, Republic of.—The fluorspar industry experienced a substantial increase in production. Local sales dropped for all grades of fluorspar. Exports increased 25% to 285,000 tons with acid and metallurgical grades experiencing gains of 30% and 180%, respectively, over those of the preceding year. These gains were partially offset by a 58% decrease in exports of ceramic-grade material. Fluorspar reserves were estimated to be 118 million tons with an average grade of 25% CaF_2.[13]

Thailand.—A decline in exports and increased production costs have forced about 200 Thai fluorspar mines to close. The U.S.S.R. stopped purchasing Thai fluorspar because Thai exporters would not accept the requirement that they buy Soviet goods in return. Sales to Japan decreased.[14]

The largest fluorspar producer is Universal Mining Co. Ltd. It had several mines, mainly in the northern regions of the country, and operated a heavy-media separation plant at Ban Pa Plu, Laurphun Province, with a capacity of 60,000 tons per year of metallurgical-grade fluorspar.[15]

United Kingdom.—The British Steel Corporation let a contract for the construction of a fluorspar-processing plant at Weardale, County Durham. The plant was to produce 90% CaF_2 briquets at a rate of 14 tons per hour. The plant was due onstream by mid-1979. Ore would be furnished by British Steel's fluorspar mines in Weardale, and the products would be consumed in its various steelmaking plants.[16]

Dresser Minerals International Div., Dresser Industries, Inc. purchased the Hopton Works fluorspar-processing plant. The beneficiation plant was renamed the Ryder Point plant and has a capacity of 80,000 tons per year of acid-grade fluorspar filter cake. Byproduct barite was to be used in drilling muds. Dresser is undertaking an exploration and development program aimed at securing more captive sources of high-grade ore.[17]

Table 10.—Fluorspar: World production, by country

(Short tons)

Country[1] and grade[2]	1975	1976	1977[p]
North America:			
Canada, acid grade[3]	[r]70,500	66,100	44,100
Mexico:[4]			
Acid grade	720,128	320,134	460,344
Ceramic grade	--	28,107	36,124
Metallurgical grade	480,085	411,798	496,483
Unspecified	--	346,297	59,826
Total	1,200,213	1,106,336	1,052,777
United States (shipments):			
Acid grade	56,944	116,300	100,605
Metallurgical grade	82,969	71,970	68,884
Total	139,913	188,270	169,489
South America:			
Argentina:			
Acid grade[e]	12,566	13,253	14,707
Metallurgical grade[e]	29,321	30,924	34,316
Total	41,887	44,177	49,023
Brazil, grade unspecified:[5]			
Direct shipping ore (sales)	67	[r]61	[e]33,000
Beneficiated product (output)	70,459	34,287	
Total	70,526	34,348	[e]33,000
Uruguay, grade unspecified	72	55	[e]55
Europe:			
Czechoslovakia:[e 3]			
Acid grade	50,000	50,000	50,000
Metallurgical grade	50,000	50,000	50,000
Total	100,000	100,000	100,000
France:[6]			
Acid and ceramic grades	[e]194,000	[e]212,000	407,855
Metallurgical grade	[e]157,000	[e]179,000	
Total	[e]351,000	[e]391,000	407,855
German Democratic Republic:[r 3]			
Acid grade	25,000	25,000	27,600
Metallurgical grade	75,000	75,000	82,400
Total	100,000	100,000	110,000
Germany, Federal Republic of (marketable):[3]			
Acid grade[e]	74,051	63,701	67,488
Metallurgical grade[e]	8,228	7,078	7,499
Total	82,279	70,779	74,987
Greece, grade unspecified	1,102	[e]1,100	551
Italy:			
Acid grade	227,280	192,222	158,000
Ceramic grade	--	9,205	14,544
Metallurgical grade	27,633	29,983	32,209
Total	254,913	231,410	204,753
Romania, metallurgical grade[e 3]	17,000	17,000	22,000
Spain:			
Acid grade	[r]270,713	244,687	231,305
Metallurgical grade	[r]67,496	70,191	208,488
Total	[r]338,209	314,878	439,793
Sweden:[3]			
Acid grade[e]	2,065	2,015	1,213
Metallurgical grade	1,689	1,649	992
Total	3,754	3,664	2,205

See footnotes at end of table.

Table 10.—Fluorspar: World production, by country —Continued

(Short tons)

Country[1] and grade[2]	1975	1976	1977[p]
Europe —Continued			
U.S.S.R.:[e 3]			
Acid grade	250,000	260,000	265,000
Metallurgical grade	270,000	280,000	287,000
Total	520,000	540,000	552,000
United Kingdom:[7]			
Acid grade	140,000	148,000	
Metallurgical and ceramic grades	[r]35,270	36,380	220,000
Unspecified	[r]83,776	55,100	
Total	[r]259,046	239,480	220,000
Africa:			
Egypt, grade unspecified	2,607	1,716	1,548
Kenya:			
Acid grade	[3]--		116,575
		82,703	
Metallurgical grade	[r 3]54,193		20,112
Total	[r]54,193	82,703	136,687
Morocco, grade unspecified	52,273	56,714	44,100
Rhodesia, Southern, metallurgical grade[e 3]	200	220	220
South Africa, Republic of:			
Acid grade	189,895	232,449	258,656
Ceramic grade	11,347	43,543	72,378
Metallurgical grade	22,067	44,469	55,523
Total	223,309	320,461	386,557
Tunisia, acid grade	37,387	38,030	31,809
Zambia, grade unspecified	[e]110	3	[e]10
Asia:			
China, People's Republic of, metallurgical grade[e 3]	385,000	385,000	385,000
India:			
Acid grade	5,469	10,712	[e]9,920
Metallurgical grade	5,794	4,708	[e]7,500
Total	11,263	15,420	[e]17,420
Korea, North, metallurgical grade[e 3]	33,000	33,000	44,000
Korea, Republic of, metallurgical grade	31,191	22,344	14,309
Mongolia, metallurgical grade[e 3]	333,000	333,000	352,700
Pakistan, grade unspecified	12	11	[e]22
Thailand:[8]			
Acid grade	[r]77,246	49,886	32,286
Metallurgical grade	192,814	141,679	213,093
Total	[r]270,060	191,565	245,379
Turkey, metallurgical grade	1,549	[r e]3,300	5,732
Grand total	[r]4,985,568	4,932,084	5,148,081

[e]Estimate. [p]Preliminary. [r]Revised. NA Not available.

[1]In addition to the countries listed, Bulgaria is believed to have produced fluorspar, but production is not officially reported, and available information is inadequate for the formulation of reliable output-level estimates.

[2]An effort has been made to subdivide production of all countries by grade (acid, ceramic, and/or metallurgical). Where the subdivision is available in offical reports of the subject country, the data have been entered without qualifying notes; where a secondary source has been used to subdivide production by grade, the source of the information for this subdivision has been identified by footnote. Where no basis for subdivision is available, the country entry has been identified with the notation "grade unspecified."

[3]Information on grade obtained from Bundesanstalt Für Bodenforschung Hannover and Deutsches Institut Für Wirtschaftsforschung Berlin. Untersuchungen über Angebot und Nachfrage Mineralischer Rohstoffe IV. Flusspat, March 1974, p. 39.

[4]Totals for all years are reported production for all grades of fluorspar; acid-grade and metallurgical-grade output for 1975 also represent output as reported. Data by grade for 1976 and 1977 are exports and local sales as listed by Instituto Mexicano de la Fluorita (Mexican Fluorspar Institute). Metallurgical-grade fluorspar includes material listed as submetallurgical in nature, while unspecified material represents the difference between reported exports and production, and as such, is presumably indicative of additions to or deletions from stocks.

[5]Official Brazilian sources list crude ore mined as follows in short tons: 1975—120,346; 1976—54,540; 1977—NA.

[6]Data for 1975 and 1976 are marketed production estimated from domestic consumption and trade data; it does not take into account changes in stocks. Total run-of-mine production (direct-shipping ore plus ore destined for concentration) was as follows in short tons: 1975—805,000; 1976—744,000; and 1977—NA.

[7]Includes material recovered from lead-zinc mine dumps.

[8]Acid-grade material listed for Thailand is beneficiated product resulting from processing of reported low-grade material; metallurgical-grade material is run-of-mine material reported under the term "high-grade." Recorded production of low-grade material was as follows, in short tons: 1975—122,611; 1976—79,184; 1977—51,246.

Table 11.—Fluorspar: World trade[1] by source and destination, 1976

(Short tons)

Source	Destination: Australia[2]	Austria	Belgium-Luxembourg	Canada	France	Germany, Federal Republic of	Italy	Japan	Netherlands[3]
Argentina	NA	--	--	--	--	--	--	--	--
Austria[4]	NA	XX	--	--	--	--	--	--	--
Belgium-Luxembourg[4]	NA	--	XX	--	--	--	--	--	--
Brazil	NA	--	--	--	--	--	--	--	--
Canada	--	--	--	XX	--	--	--	--	--
China, People's Republic of	NA	--	5,526	--	105	--	2,152	129,097	--
France	NA	768	7,636	--	XX	2,771	5,804	--	647
German Democratic Republic	NA	9,209	3,207	--	--	--	--	--	--
Germany, Federal Republic of	NA	5,550	--	--	1,343	XX	--	--	313
Italy	NA	406	--	--	276	31,801	XX	--	1
Kenya	NA	--	--	--	--	7,870	--	42,392	--
Korea, North	NA	--	--	--	--	--	--	662	--
Korea, Republic of	NA	--	--	--	--	--	--	6,801	--
Mexico	NA	--	--	68,555	--	--	18,522	--	--
Mongolia	NA	--	--	--	--	--	--	--	--
Morocco	NA	--	--	10,010	--	11,043	6,063	--	--
Mozambique	NA	--	--	--	--	--	--	--	--
Netherlands[4]	NA	--	--	--	--	--	--	--	XX
South Africa, Republic of	NA	--	--	--	--	6,617	--	109,607	--
Spain	NA	--	--	58,357	--	34,513	4,716	--	--
Sweden	NA	--	--	--	--	--	--	--	--
Switzerland[4]	NA	165	--	--	--	--	--	--	--
Thailand	NA	--	--	--	--	--	--	134,055	--
Tunisia	NA	--	--	--	--	--	9,061	--	--
Turkey	NA	--	--	--	--	--	--	--	--
United Kingdom	NA	--	584	2,301	355	12,777	--	--	--
United States	NA	--	--	12,135	--	--	--	--	--
Unspecified and other	e33,000	6	908	--	293	125,272	84	--	28,200
Total	e33,000	16,104	17,861	151,358	2,372	232,664	46,402	422,614	29,161

Source	Destination: Norway	Poland	Sweden	U.S.S.R.	United States	Yugoslavia	Other[5]	Total receipts by listed countries	Total recorded exports
Argentina	--	--	--	NA	--	--	--	--	NA
Austria[4]	--	--	--	NA	--	191	--	191	--
Belgium-Luxembourg[4]	--	--	--	NA	--	--	--	--	926
Brazil	--	--	--	NA	2	--	--	2	224
Canada	--	--	--	NA	120	--	--	120	--
China, People's Republic of	556	6,004	6,142	NA	--	--	72	149,654	e155,000
France	--	--	7,754	NA	7,719	662	2,993	36,754	101,841
German Democratic Republic	855	21,835	2,249	NA	--	3,237	463	41,055	e41,000
Germany, Federal Republic of	8,921	--	22	NA	--	2,013	1,107	19,269	15,959
Italy	3,114	--	33	NA	57,364	88	4,623	97,706	115,312
Kenya	--	--	--	NA	21,422	--	--	71,684	[6]99,720
Korea, North	--	--	--	NA	--	--	--	662	e660
Korea, Republic of	--	--	--	NA	--	--	301	7,102	7,283
Mexico	--	--	--	NA	544,758	--	--	631,835	e635,000
Mongolia	--	--	--	NA	--	--	--	NA	NA
Morocco	2,687	--	--	NA	--	--	--	29,803	30,366
Mozambique	--	--	--	NA	--	--	--	NA	NA
Netherlands	--	--	--	NA	--	--	1,155	1,155	399
South Africa, Republic of	--	--	80	NA	122,301	--	--	238,605	e245,000
Spain	5,744	--	--	NA	106,678	--	6,081	216,089	249,315
Sweden	--	--	XX	NA	--	--	582	582	718
Switzerland[4]	--	--	--	NA	--	--	--	165	e220
Thailand	--	11,602	--	NA	27,945	--	13,780	187,382	313,372
Tunisia	--	--	--	NA	--	--	--	9,061	[6]18,376
Turkey	--	--	--	NA	--	--	--	NA	NA
United Kingdom	20,346	--	220	NA	--	--	1,383	37,966	38,084

See footnotes at end of table.

Table 11.—Fluorspar: World trade[1] by source and destination, 1976 —Continued

(Short tons)

Source	Destination: Norway	Poland	Sweden	U.S.S.R.	United States	Yugoslavia	Other[5]	Total receipts by listed countries	Total recorded exports
United States	--	--	--	NA	XX	--	380	12,515	4,923
Unspecified and other	1	14,074	94	[e]550,000	6,942	1	4,765	763,640	NA
Total	42,224	53,515	16,594	[e]550,000	895,251	6,192	37,685	2,552,997	2,073,698

[e]Estimate. NA Not available. XX Not applicable.

[1]Compiled from official import data of listed countries of destination except where otherwise specified by footnote; figures in total receipts by listed countries column are simply summations of reported imports for all listed destinations, in contrast to figures in total recorded exports column which are either (1) actual reported exports of listed source countries or (2) estimates of total exports. Differences between these two columns are attributed to (1) time lag between date of shipment and date of receipt, (2) concealment policies of some countries, and (3) reshipment of material by intermediate countries which may be credited as the origin in the trade returns of the final destination countries.

[2]Official import statistics not available but assumed to be similar to previous years' level.

[3]Excludes imports from Belgium-Luxembourg.

[4]No recorded production of fluorspar; exports are generally derived from imported materials.

[5]Data compiled from official import statistics of 10 nations and export statistics of 6 significant producing nations, the latter to determine apparent imports for 13 other countries for which official fluorspar import figures are not available. Nations reporting imports and total recorded imports for each are as follows in short tons: Algeria—130; Denmark—4,375; Finland—4,161; India—4,478; Ireland—33; Spain—63; Thailand—125; the United Kingdom—22. Nations for which apparent imports have been derived and apparent imports for each are as follows in short tons: Brazil—36; Czechoslovakia—2,286; Greece—1,928; Hungary—672; Indonesia—198; Korea (Republic of)—8,598; Malaysia—438; Mexico—332; Philippines—779; Portugal—1,268; Romania—3,591; Taiwan—4,068; Venezuela—53; Zaire—39.

[6]Includes fluorspar as well as any feldspar, nepheline and/or nepheline syenite exported.

TECHNOLOGY

Power Reactor and Nuclear Fuel Development Corp. developed a process to produce UF_4 from uranium ore using a simple wet-processing technique. The UF_4 could be obtained by electrolytic reduction and hydrofluorination of the ore through the following steps: (1) ore, (2) pregnant liquor, (3) solvent extraction, (4) chloride conversion, (5) electrolytic reduction, (6) hydrofluorination and precipitation, and (7) drying and dehydration. Conventional fluorination techniques could then be used to upgrade the UF_4 to UF_6. The process has the advantage of eliminating intermediate products such as yellow cake. The production of the UF_4 could be carried out under relatively low-temperature and pressure conditions. Costs should be lower since the equipment is operated at low temperature and the overall process is simplified.[18]

A new thermoplastic fluorocarbon coating that remains unharmed at 500° F was announced by DuPont. The coatings, produced by a powder called Teflon P, are inert to almost all chemicals.[19] Fluoroplastics had become a growing sector of the plastics market. Fluoroplastics are well suited for applications where thermal, chemical, and electrical resistance must be coupled with high strength. These plastics were finding their way into many new areas such as automobile gaskets, vascular grafts, and as separators in fuel cells. Fluorocarbon coatings have been shown to provide increased protection against corrosion in SO_2 scrubbers and power plant chimneys. A 3-year study in the United Kingdom showed that a coating called CXL2000 from Colebrand, Ltd., in London protected against the corrosive effects of sulfuric acid. The North American licenser for CXL2000 is Pullman Kellogg Co.[20]

---

[1]Physical scientist, Division of Nonmetallic Minerals.

[2]Skillings' Mining Review. Frontier Breaks Ground for Fluorspar-Zinc Mine. V. 66, No. 29, July 16, 1977, p. 6.

[3]Chemical & Engineering News. Business Concentrates. V. 55, No. 33, Aug. 15, 1977, p. 8.

[4]Science News. Prediction of Ozone Loss Down, and Up. V. 111, No. 24, June 24, 1977, p. 18.

[5]Federal Register. V. 42, No. 83, Apr. 29, 1977, part IV, pp. 22018-22033.

Federal Register. V. 42, No. 164, Aug. 24, 1977, part IV, pp. 42780-42784.

[6]Environmental Science & Technology. Currents. V. 11, No. 5, May 1977, p. 433.

[7]Chemical Marketing Reporter. Fluoroplastics Expansion is the Biggest for DuPont. V. 211, No. 5, June 31, 1977, pp. 3, 42.

[8]Chemical Week. Market Newsletter. V. 121, No. 24, Dec. 14, 1977, p. 38.

[9]Northern Miner. Newfoundland Fluorspar Mines Will Close Next Year. V. 63, No. 20, July 28, 1977, p. 18.

[10]European Chemical News. Technology. V. 30, No. 273, Feb. 11, 1977, p. 27.
[11]Industrial Minerals. Company News and Mineral Notes. No. 118, July 1977, p. 58.
[12]Mining Journal. Kalot Fluorite Development. V. 289, No. 7402, July 1, 1977, p. 12.
[13]U.S. Embassy, Johannesburg. State Department Airgram A-05, Jan. 27, 1978, p. 34.
[14]Industrial Minerals. Company News and Mineral Notes. No. 112, January 1977, p. 44.
[15]Industrial Minerals. The Industrial Minerals of Thailand. No. 117, June 1977, pp. 22-25.
[16]Industrial Minerals. New Fluorspar Plant for Weardale. No. 120, September 1977, p. 12.
[17]Industrial Minerals. Ryder Point (ex. Hopton) Fluorspar. No. 122, November 1977, p. 13.
[18]Asia Mining. New Uranium Ore Refining Technology. V. 10, No. 2, February 1977, pp. 55-57.
[19]Materials Engineering. Fluorocarbon Coating Stays Tough at 500° F. V. 85, No. 4, p. 30.
[20]Chemical & Engineering News. Concentrates. V. 55, No. 12, Mar. 21, 1977, p. 20.

Gallium

By Benjamin Petkof[1]

The domestic gallium industry continued to provide the major portion of U.S. demand for the metal as imports declined greatly in 1977. Data on world production and consumption were not available. Gallium was consumed for the production of various gallium compounds used to produce electronic devices.

Table 1.—Salient gallium statistics in the United States

(Kilograms)

	1974	1975	1976	1977
Production	W	W	W	NA
Imports for consumption	6,536	6,830	4,920	2,884
Consumption	6,939	7,493	8,880	8,789
Price per kilogram	$750	$750-$800	$750-$800	$500-$600

NA Not available. W Withheld to avoid disclosing individual company confidential data.

DOMESTIC PRODUCTION

The Aluminum Co. of America, using proprietary technology at its Bauxite, Ark., alumina plant, recovered gallium as a coproduct from residues of its alumina production process. Eagle-Picher Industries, Inc., produced gallium metal, oxide, and trichloride from zinc production residues at its Quapaw, Okla., facility. Production data are not available. Based on consumption and imports data, output was about the same as in 1975 and 1976.

CONSUMPTION

Total domestic gallium consumption decreased 1% from that of 1976. The quantity consumed for electronics decreased 3%, and that for research and development increased 25%. The quantity used for dental alloys increased slightly; unspecified uses remained unchanged. Most of the gallium was used to manufacture electronic devices that required high-purity gallium metal. Intermetallic gallium compounds such as arsenide, phosphide, and arsenide-phosphide were also used to manufacture semiconductor devices. Gallium oxide was used for the preparation of phosphors.

Table 2.—Consumption of gallium, by end use

(Kilograms)

End use	1976	1977
Alloys[1]	4	4
Electronics[2]	8,210	7,965
Research and development	609	763
Unspecified uses	57	57
Total	8,880	8,789

[1]Specialty alloys.
[2]Light-emitting diodes, semiconductors, and other electronic devices.

Table 3.—Stocks, receipts, and consumption of gallium

(Kilograms)

Purity	Beginning stocks[1]	Receipts	Consumption	Ending stocks[1]
1976:				
97.0%-99.9%	9	3	6	6
99.99%	3	1	1	[2]2
99.999%	3	68	60	11
99.9999%-99.99999%	912	9,575	8,813	1,674
Total	927	9,647	8,880	[3]1,694
1977:				
97.0%-99.9%	6	6	4	8
99.99%	[2]3	7	2	9
99.999%	11	62	61	13
99.9999%-99.99999%	1,674	8,563	8,722	1,515
Total	1,694	[3]8,639	8,789	1,545

[1]Consumers only.
[2]Ending stocks for 1976 do not equal 1977 beginning stocks because of reported beginning stock adjustments.
[3]Data do not add to total shown because of independent rounding.

General acceptance by the public of various electronic devices using gallium-based components helped sustain gallium demand. Continued interest in the development of gallium-based direct solar energy conversion cells for the production of electricity and further development of fiber-optic light transmission cables that are actuated by gallium-based light-emitting diodes may stimulate demand for gallium and gallium compounds in the near future.

STOCKS

Consumer stocks of gallium metal at yearend 1977, both commercial and high-purity grades, shown in table 3, decreased 9% from beginning stocks.

PRICES

Gallium prices are not formally reported and are subject to negotiation between buyer and seller. At the beginning of the year the American Metal Market quoted metal of 99.999% purity at $750 to $800 per kilo in 100-kilogram lots and reduced its price quotation to $500 to $600 per kilo during the year.

FOREIGN TRADE

Data on the export of gallium metal and compounds are not reported separately but are included in the category "base metals and alloys, not elsewhere classified, wrought or unwrought, waste and scrap." Significant quantities of gallium and gallium compounds are exported as parts of manufactured gallium-based electronic and electrical components and equipment.

Total U.S. gallium imports declined 41% in quantity and 47% in value from those of 1976. Sources of gallium imports were Switzerland (51%), the Federal Republic of Germany (27%), Italy (12%), and Canada (10%). The average value of imports decreased from $473 per kilo in 1976 to $431 per kilo in 1977.

Table 4.—U.S. imports for consumption of gallium (unwrought, waste and scrap), by country

Country	1976		1977	
	Kilograms	Value	Kilograms	Value
Canada	214	$100,706	276	$119,613
China, People's Republic of	50	19,633	--	--
Germany, Federal Republic of	2,391	1,103,652	774	352,350
Hungary	199	66,890	--	--
Italy	75	27,210	349	121,610
Japan	50	70,115	--	--
Netherlands	40	21,078	--	--
Switzerland	1,799	873,854	1,485	648,017
United Kingdom	90	40,319	--	--
U.S.S.R	12	2,719	--	--
Total	4,920	2,326,176	2,884	1,241,590

WORLD REVIEW

Data on world consumption and production of gallium are not available. However, significant quantities of gallium metal and compounds are probably consumed by countries with large well-developed electronic and electrical industries. Based on 1977 U.S. imports of gallium, it is thought that the rest of world gallium production decreased.

TECHNOLOGY

The proceedings of two international symposia on gallium arsenide and related compounds were published in 1977. A wide range of research on gallium compounds was reported.[2 3]

Gallium was removed from scrubber dust formed during the electrolytic production of aluminum. The scrubber dust was mixed with sodium carbonate, sintered in air at 500- to 800°C, and the resulting sinter was leached with water. Gallium was precipitated by treating the leach solution with iron filings to recover the gallium.[4]

---

[1]Physical scientist, Division of Nonferrous Metals.

[2]Eastman, L. F. Gallium Arsenide and Related Compounds. Proc. Sixth Internat. Symp. on Gallium Arsenide and and Related Compounds, St. Louis Conf., Sept. 26-29, 1976. Institute of Physics, Bristol and London, 355 pp. (Conf. Serv. No. 33b), 1977.

[3]Hilsum, C. Gallium Arsenide and Related Compounds. Proc. Sixth Intern. Symp. on Gallium Arsenide and Related Compounds, Edinburgh Conf., Sept. 20-22, 1976. Institute of Physics, Bristol and London, 436 pp. (Conf. Serv. No. 33a), 1977.

[4]MacGregor, J. J. (assigned to Johnson Matthey and Co., Ltd.). Extraction of Gallium from Scrubber Dust. U.S. Pat. 3,969,108, July 13, 1977.

Gem Stones

By W. Timothy Adams[1]

The value of gem stones and mineral specimens produced in the United States during 1977 was estimated to be $8.9 million, the same as that of 1976. Production in the domestic commercial mining industry decreased, with the shutdown of many turquoise mines and the sapphire mine in Montana. Amateur collectors accounted for much of the activity in many States. Commercial operators sold mainly to wholesale or retail outlets and also to jewelry manufacturers.

DOMESTIC PRODUCTION

Mines and collectors in 39 States produced gem materials estimated at $1,000 or more in value for each State. Nine States supplied 90% of the total value, as follows: Arizona, $4.5 million; Maine, $1 million; Nevada, $1 million; Oregon, $520,000; California, $230,000; Wyoming, $200,000; New Mexico, $170,000; Texas, $160,000; and Washington, $160,000.

Park authorities at the Crater of Diamonds Park in Arkansas reported 91,849 people visited the park and found 371 diamonds. The largest was a 4-carat, 25 point canary yellow stone, but no value was placed on the stone. A campground for visitors with 60 class A campsites with utility hookups is scheduled for completion this year.[2]

A 2,400-pound boulder of Wyoming jade was displayed in the lobby of the First National Bank Building in Denver, Colo. The material came from a 1-mile-wide, 4-mile-long jade strain discovered in southwestern Wyoming. Much of the jade carved in Hong Kong is supplied from Wyoming and imported into this country as finely carved Oriental jewelry.[3]

The second largest ruby ever found in the Cowee Valley near Franklin, N.C., was discovered at the Gregory Ruby Mine, a dig-for-fee mine. The stone weighed 456 carats and is conservatively valued at $20,000. It is 3-inches in diameter, 1 inch thick, 85% ruby, and the value could exceed $100,000 if a star is formed when the stone is cut.[4]

The Maine Tourmaline Necklace was donated to the State of Maine by the Maine Retail Jewelers' Association on May 25, 1977. Two years in the making, the necklace is made of Maine native gold and 24 pink and green Maine tourmalines with the center drop stone weighing 24.58 carats. The necklace will be available for the First Lady of Maine to wear at official functions.[5]

Peridot was produced by about 200 individuals of the San Carlos Apache Tribe at Peridot, Ariz. Twenty tons of crude materials valued at $17,000 was reported for 1977. Of this, it is estimated that 7% remains as salable material after processing into faceted and tumble-polished gem stones. The major portions of the finished stones are in the lower priced tumble-polished category. A report was completed on the olivine resources on Peridot Mesa at the request of the San Carlos Apache Tribe.[6]

The production of turquoise of all grades and quantities reported was 44 tons and was principally from Arizona, Nevada, and Colorado. About 10% of the turquoise produced was gem-grade material, which sold for $10 to $100 per carat and averaged about $200 per pound. Lower grade turquoise suitable for stabilizing treatment sold for about $35 per pound of rough material. The value for all types and grades of turquoise in 1977 was estimated at $4.5 million. The market for turquoise seems to be decreasing somewhat in the face of high prices and suspicion as to whether the material offered is a synthetic made of other material and colored to look like turquoise.

CONSUMPTION

Domestic gem stone output went to amateur and commercial rock, mineral, and gem stone collections, objects of art, and jewelry. Apparent consumption of gem stones (domestic production plus imports minus exports and reexports) was $1,044.7 million, 48% more than that of 1976.

PRICES

Typical costs to retail jewelers in December 1977 for representative better quality gem stones as reported by colored-stone dealers in various U.S. cities were as follows:[7]

Gem stone	Carat weight	Price range per carat	Median prices per carat	
			Early December	Early November
Amethyst	10	$17.50- $36	$30	$30
Aquamarine	5	110- 500	150	150
Cat's eye	5	1,000- 2,400	1,600	1,600
Citrine	10	8- 30	16	16
Emerald:				
Medium to better	1	1,500-16,000	5,000	5,000
Commercial	1	250- 7,000	1,500	1,500
Garnet, green	1	700- 1,400	1,026	1,026
Opal, black	3	500- 1,200	766	766
Opal, white	5	120- 220	150	150
Peridot	5	76- 120	90	90
Ruby:				
Medium to better	1	700- 9,000	2,000	2,000
Commercial	1	250- 3,500	700	700
Sapphire:				
Medium to better	1	450- 3,600	1,000	1,000
Commercial	1	100- 1,600	326	326
Star sapphire:				
Sky-blue		160- 1,600	600	600
Grey		46- 330	190	190
Tanzanite	5	500- 600	550	550
Topaz	5	220- 440	360	360
Tourmaline, green	5	60- 130	90	90
Tourmaline, pink	5	50- 160	125	125

Typical costs to retail jewelers in December 1977 for representative diamonds as reported by diamond dealers in various U.S. cities were as follows:[8]

Carat weight	Description, color[1]	Clarity[2] (GIA terms)	Price range per carat	Medium price per carat	
				Early December	Early November
0.04-0.08	G-1	VS_1	$630-$1,088	$824	$744
.04- .08	G-1	SI_1	550- 832	730	634
.09- .16	G-1	VS_1	660- 1,198	940	850
.09- .16	G-1	SI_1	604- 954	800	708
.17- .22	G-1	VS_1	816- 1,246	1,050	1,000
.17- .22	G-1	SI_1	680- 1,016	902	864
.23- .28	G-1	VS_1	848- 1,418	1,206	1,150
.23- .28	G-1	SI_1	794- 1,292	1,000	952
.29- .35	G-1	VS_1	1,132- 1,618	1,312	1,304
.29- .35	G-1	SI_1	906- 1,546	1,100	1,028
.46- .55	G-1	VS_1	1,486- 2,536	2,090	1,940
.46- .55	G-1	SI_1	1,100- 2,000	1,680	1,528
.69- .79	G-1	VS_1	1,738- 3,826	2,852	2,616
.69- .79	G-1	SI_1	1,338- 2,650	2,234	2,104
.95-1.15	G-1	VS_1	2,420- 6,244	4,410	4,410
.95-1.15	G-1	SI_1	1,984- 5,632	3,410	3,232
1.00	D	FL	17,000-21,000	20,000	16,000

[1]Gemological Institute of America color grades: D—colorless; G-1—traces of color.
[2]Clarity: FL—no blemishes; VS_1—very slightly included; SI_1—slightly included.

FOREIGN TRADE

Exports of all gem materials amounted to $356.6 million, and reexports to $245.7 million. Diamond accounted for 94% of the value of exports and 95% of the reexports. Exports of diamond totaled 316,160 carats valued at $336.0 million. Of this total, diamond cut but unset, suitable for gem stones not over 0.5 carat, was 63,968 carats valued at $26.4 million; and cut, but unset, over 0.5 carat was 246,351 carats valued at $308.3 million.

Reexports of diamond amounted to 1,240,469 carats, valued at $232.9 million, in categories as follows: Rough or uncut, suitable for gem stones, not classified by weight, 1,113,988 carats valued at $146.0 million; cut but unset, not over 0.5 carat, 49,679 carats valued at $15.5 million; cut but unset, over 0.5 carat, 76,802 carats, valued at $71.4 million.

The 11 leading recipients of diamond exports accounted for 97% of both the carats and the value and were as follows: Hong Kong, 107,902 carats valued at $131.6 million; Belgium, 32,664 carats valued at $45.2 million; Switzerland, 25,452 carats valued at $41.8 million; Japan, 33,190 carats valued at $35.8 million; the Netherlands, 24,327 carats valued at $32.1 million; France, 6,011 carats valued at $18.8 million; the United Kingdom, 9,809 carats valued at $7.2 million; Israel, 18,360 carats valued at $7.0 million; Canada, 11,789 carats valued at $5.8 million; India, 31,758 carats valued at $0.4 million; and Austria, 4,381 carats valued at $0.3 million.

The nine leading recipients of diamond reexports accounted for 99% of the carats and 98% of the value and were as follows: Israel, 466,101 carats valued at $73.6 million; Belgium, 395,545 carats valued at $69.0 million; the Netherlands, 185,544 carats valued at $30.6 million; Switzerland, 9,111 carats valued at $13.3 million; the United Kingdom, 40,444 carats valued at $12.2 million; France, 14,288 carats valued at $10.6 million; Japan, 15,981 carats valued at $8.9 million; Hong Kong, 12,408 carats valued at $7.9 million; and India, 84,874 carats valued at $2.0 million.

Exports of all other gem materials amounted to $20.6 million. Of this total, pearls, natural and cultured, not set or strung, were valued at $0.5 million. Natural precious and semiprecious stones, unset, were valued at $18.2 million; and synthetic or reconstructed stones, unset, were valued at $1.9 million. Reexports of all other gem materials amounted to $12.8 million in categories as follows: Pearls, $1.1 million; natural precious and semiprecious stones, unset, $11.6 million; synthetic or reconstructed stones, unset, $0.1 million.

Imports of gem materials increased 39% in value over those of 1976. Diamond accounted for 88% of the total value of gem material imports.

Although rough and uncut diamond imports were reported from 28 countries, 99% of the value was from 7 countries as follows: The Republic of South Africa, 1,096,493 carats, $315.8 million; the United Kingdom, 1,280,769 carats, $238.6 million; Sierra Leone, 185,869 carats, $40.5 million; the Netherlands, 29,152 carats, $12.5 million; Israel, 56,567 carats, $11.2 million; Belgium, 22,348 carats, $7.6 million; and Venezuela, 154,814 carats, $5.4 million.

Cut but unset diamond, not over 1/2 carat, was imported from 33 countries; however, the imports of this category from 7 countries amounted to 98% of total carats and value as follows: Israel, 1,145,413 carats, $256.2 million; Belgium, 1,106,815 carats, $223.3 million; India, 765,432 carats, $129.3 million; the U.S.S.R., 35,207 carats, $9.8 million; the Netherlands, 46,784 carats, $9.0 million; the Republic of South Africa, 20,707 carats, $7.6 million; and the United Kingdom, 26,520 carats, $4.2 million. Cut but unset diamond, over 1/2 carat, was imported from 28 countries; the imports from 8 countries amounted to 99% of both the total carats and value as follows: Belgium, 150,059 carats, $84.5 million; Israel, 115,087 carats, $48.1 million; the Republic of South Africa, 12,900 carats, $9.3 million; the U.S.S.R., 9,239 carats, $4.2 million; the Netherlands, 7,608 carats, $3.5 million; the United Kingdom, 4,479 carats, $2.8 million; Switzerland, 766 carats, $1.6 million; and India, 3,905 carats, $1.2 million.

Emerald imports increased 34% in quantity and 16% in value. Emerald was imported from 34 countries; the imports from 10 countries amounted to 98% of the carats and 95% of the value as follows: Colombia, 73,948 carats, $25.1 million; India, 968,937 carats, $12.5 million; Switzerland, 26,198 carats, $7.3 million; Israel, 68,644 carats,

$3.6 million; Hong Kong, 68,717 carats, $3.1 million; the United Kingdom, 57,877 carats, $2.9 million; Brazil, 212,974 carats, $2.4 million; the Federal Republic of Germany, 30,318 carats, $1.9 million; France, 5,368 carats, $1.4 million; and Belgium, 12,706 carats, $0.8 million. Imports of ruby and sapphire were imported from 32 countries; the imports from 10 countries amounted to 96% of the value as follows: Thailand, $22.5 million; Switzerland, $2.0 million; Sri Lanka, $1.9 million; Hong Kong, $1.6 million; India, $1.6 million; Belgium, $0.5 million; Burma, $0.5 million; Israel, $0.5 million; the United Kingdom, $0.5 million; and Canada, $0.4 million. Natural pearls and parts from 12 countries decreased 28% in value of imports; 5 countries accounted for 92% of the value as follows: India, $369,000; Burma, $36,000; Japan, $35,000; Italy, $33,000; and Hong Kong, $27,000. Imports of cultured pearls increased 65% in value, and were received from 17 countries; Japan, at $17.6 million, accounted for 96% of the value. Imports of imitation pearls increased 39% in value; Japan, at $748,000, accounted for 79% of the value. Coral, cut but unset, and cameos suitable for use in jewelry decreased 32% in value of imports, which were received from 15 countries; 3 countries accounted for 95% of the value as follows: Italy, $1.8 million; Taiwan, $1.8 million; and Japan, $0.6 million.

Imports of other precious and semiprecious stones, rough and uncut, increased 26% in value and came from 43 countries, 7 of which accounted for 80% of the value as follows: Brazil, $3.9 million; Australia, $1.5 million; Colombia, $0.8 million; Kenya, $0.7 million; Switzerland, $0.7 million; Zaire, $0.4 million; and Israel, $0.3 million. Other precious and semiprecious stones, cut but unset, increased 1% in value and were imported from 65 countries, of which 5 countries accounted for 84% of the value as follows: Hong Kong, $17.8 million; Brazil, $4.2 million; the Federal Republic of Germany, $3.9 million; Australia, $2.7 million; and Taiwan, $1.2 million. Synthetic gem stones, cut but unset, increased 3% in value and came from 17 countries, 6 of which accounted for 94% of the value as follows: The Federal Republic of Germany, $6.4 million; Japan, $1.1 million; Switzerland, $1.1 million; France, $0.7 million; Austria, $0.3 million; and Israel, $0.2 million. Imitation gem stones increased 19% in value and came from 22 countries, of which 5 countries accounted for 94% of the value as follows: Austria, $6.0 million; the Federal Republic of Germany, $2.8 million; Czechoslovakia, $0.7 million; Japan, $0.3 million; and the United Kingdom $0.3 million.

Table 1.—U.S. imports for consumption of precious and semiprecious gem stones

(Thousand carats and thousand dollars)

Stones	1976 Quantity	1976 Value	1977 Quantity	1977 Value
Diamonds:				
Rough or uncut	2,464	462,657	2,909	638,205
Cut but unset	3,087	549,182	3,502	806,332
Emeralds: Cut but unset	1,165	55,286	1,563	64,375
Coral, cut but unset, and cameos suitable for use in jewelry	NA	6,497	NA	4,410
Rubies and sapphires: Cut but unset	NA	27,165	NA	33,544
Marcasites	NA	20	NA	58
Pearls:				
Natural	NA	755	NA	544
Cultured	NA	11,062	NA	18,260
Imitation	NA	680	NA	942
Other precious and semiprecious stones:				
Rough and uncut	NA	8,266	NA	10,448
Cut but unset	NA	35,278	NA	35,617
Other n.s.p.f	NA	2,565	NA	3,273
Synthetic:				
Cut but unset number	18,705	10,115	15,753	10,391
Other	NA	766	NA	864
Imitation gem stones	NA	9,072	NA	10,841
Total	NA	1,179,366	NA	1,638,104

NA Not available.

Table 2.—U.S. imports for consumption of diamond (exclusive of industrial diamond), by country

(Thousand carats and thousand dollars)

Country	1975				1976				1977			
	Rough or uncut		Cut but unset		Rough or uncut		Cut but unset		Rough or uncut		Cut but unset	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Belgium-Luxembourg	31	8,250	849	153,276	38	6,651	1,168	223,858	22	7,592	1,257	307,766
Bolivia	--	--	--	--	5	99	--	--	--	--	--	--
Brazil	5	982	3	491	1	79	4	690	(1)	91	4	860
Canada	--	--	1	156	(1)	6	(1)	90	(1)	49	1	704
Central African Empire	134	5,298	--	--	36	2,204	--	--	51	3,539	--	--
France	7	231	18	2,195	6	643	9	1,957	8	683	9	1,577
Germany, Federal Republic of	--	--	1	281	(1)	(1)	4	1,214	(1)	8	4	906
Ghana	2	58	--	--	(1)	16	--	--	8	64	--	--
Hong Kong	--	--	5	847	1	825	10	1,962	1	98	9	1,741
India	--	--	300	37,211	--	--	502	65,432	(1)	1	769	130,501
Ireland	--	--	(1)	64	--	--	--	--	1	413	2	305
Israel	33	5,523	902	147,114	39	8,239	1,203	211,146	57	11,177	1,260	304,263
Italy	--	--	1	219	1	82	2	292	--	--	2	641
Japan	1	77	2	428	1	51	6	1,001	(1)	27	1	286
Liberia	4	4,981	--	--	3	2,871	--	--	1	228	--	--
Mauritania	--	--	--	--	--	--	(1)	47	5	45	(1)	23
Netherlands	36	13,643	58	9,860	50	20,524	78	12,849	29	12,465	54	12,489
Portugal	5	570	2	473	--	--	--	--	--	--	--	--
Sierra Leone	272	32,696	(1)	83	331	42,861	1	129	186	40,467	4	881
South Africa, Republic of	927	189,885	21	7,777	1,194	257,249	22	9,674	1,096	315,790	33	16,905
Switzerland	(1)	42	4	1,087	1	29	14	2,796	6	811	8	3,003
Tunisia	--	--	--	--	--	--	--	--	--	--	3	548
U.S.S.R	--	--	43	9,215	--	--	43	10,607	--	--	44	14,089
United Kingdom	451	69,959	17	2,576	495	113,756	14	3,630	1,281	238,608	32	7,073
Venezuela	389	8,204	(1)	5	260	5,987	(1)	79	155	5,381	--	--
Western Africa, n.e.c	36	6,568	--	--	(1)	172	--	--	(1)	23	--	--
Other	r8	r915	r9	r879	r2	r313	r7	r1,729	2	645	6	1,771
Total	2,341	347,882	2,236	374,237	2,464	462,657	3,087	549,182	2,909	638,205	3,502	806,332

r Revised.
1 Less than 1/2 unit.

WORLD REVIEW

Angola.—The Government of Angola increased its holdings in Compania de Diamantes de Angola (Diamang) from 200,000 shares to over 1.5 million shares. This gave the Government a 60.85% majority interest. Foreign companies with interests in Diamang will not be affected by the takeover.[9]

Australia.—Subject to obtaining the necessary government approval, Conzinc Riotinto of Australia (CRA) Exploration Pty. was attempting to increase its 35% interest in venture prospecting for diamonds in the Kimberley's, Western Australia.[10] Promising diamond finds in the Kimberley region of West Australia led to a confrontation between Western Australia's State Government and the Federal Government's Director of Aboriginal Affairs. Exploration permits issued by the State to CRA Exploration Pty., DeBeers Consolidated Ltd., and Broken Hill Pty. Ltd. were rejected by the Director under his authority over aboriginal lands. It is believed that diamondiferous kimberlite pipe has been discovered.[11]

Botswana.—Agreement has been reached between the Government of Botswana and DeBeers Consolidated Mines Ltd. on the basic final arrangements for the development and operation of the large diamond mine at Jwaneng. Development of the mine and infrastructure is expected to take about 4 years.[12]

Central African Empire.—Diamond output increased to 301,000 carats. In 1976, total diamond production was 286,000 carats, half of the 524,000 carats mined as recently as 1972. Exports totaled 269,000 carats valued at $14.4 million. Exports maintained their value, reflecting the emphasis on gem-quality stones. Part of the decline in production was due to legal difficulties between the leading alluvial diamond mining company, Société Centrafricaine d' Exploitation Diamantifere (SCED), and the Central African Empire Government. Questions relating to SCED status under the nation's investment and tax code led to a temporary suspension of mining.[13]

Colombia.—Colombia supplies 90% of the world's emeralds. Legal production is estimated at $25 million, which represents about 10% of the nation's total exports. Fewer than 1% of the emeralds found are judged to be of top quality.[14]

Greenland.—Fiscanex Ltd., Willowdale, Ontario, Canada, marketed ruby corundum as individual crystals or dots of crystals in a variety of rock matrix types. These stones have exceptionally good color and fluoresce strongly under longwave ultravioletlight but somewhat less under shortwave ultravioletlight. The firm anticipates entering the reconstituted ruby material market since the quality of the material is suitable for recrystallized laser applications.

Israel.—Exports of cut diamonds for the first 9 months of 1977 increased 42%. The diamonds were valued at $708 million with the expectation that exports will total more than $1,000 million in 1977.[15]

Pakistan.—Rich deposits of rubies occur in the Hunza area of northern Pakistan. In order to properly explore the occurrences, Pakistan Mineral Development Corp. took responsibility for the Hunza ruby project in 1974. The main marble formation having ruby mineralization was reported to have a stratigraphic thickness of 2,500 feet and was traced for an uninterrupted strike length of more than 12 miles. Average weight of individual ruby crystals being produced is slightly less than a carat. Crystals up to 2 carats are not uncommon. Color of the stones ranges from dull red or brownish, pink, purple to red, bright red, and dark pigeon-blood red.[16]

South Africa, Republic of.—Preliminary data on diamond production for 1977 showed an increase of 14%. The total for 1977 was 8,033,000 carats; 4,171,000 carats of industrial diamond and 3,862,000 carats of gem stones. The upward trend in sales has prompted DeBeers Consolidated Mines Ltd. to expand its exploration program and accelerate mine development at ongoing operations. The Finsch open pit in northern Cape Province is being expanded to increase production from 2.0 million to 3.0 million carats per year by 1979. The Langhoogle underground mine, Cape Province, is being reopened and is expected to supply 60,000 carats per year beginning in July 1978. The Koingnaas mine on the Cape Province coast was scheduled to begin production in July 1978 and produce 500,000 carats per year.[17] Expansion was also scheduled for the Kimberley District mines, however, the Dutoitspan and Bultfontein mines were temporarily closed by flooding. Mine personnel were transferred to the two other mines in the district. Production is expected to be maintained at the 1976 level of over 1 million carats.[18]

Demand for the smaller sized gem stones increased rapidly in 1977. The Central Selling Organization announced price increases of 15% and 17% during 1977 for a compound increase of nearly 35% for the year. Increased prices and demand provided Central Selling Organization sales of approximately $2.1 billion in 1977, a 33% increase over 1976.[19]

South-West Africa, Territory of.—A new diamond deposit was claimed in the Hunsberge area, east of the Restricted Diamond Area No. 1.[20]

Zaire.—Société Minière de Bakwanga (Miba), Zaire's principal producer of low-grade industrial diamond, is operated by the Zairian Government. Miba has an export quota of 13.5 million carats per year, which is set by Zaire—British Diamond Distributors, Ltd., an affiliate of the Central Selling Organization. Miba has suffered from supply problems along with a cash squeeze that prevented it from making normal reinvestments to upgrade and maintain capital equipment to overcome a substantial shortage of exports below that allowed by the quota.[21]

Zambia.—The Kafubu emerald mine is to be developed on a commercial scale. Recent geological surveys have shown that the emerald deposits south of Kalulushi may be more extensive and of much greater value than originally anticipated. The mine has been clandestinely operated by small workers.[22]

Table 3.—Diamond (natural): World production, by country[1]

(Thousand carats)

Country	1975			1976			1977[p]		
	Gem	Industrial	Total	Gem	Industrial	Total	Gem	Industrial	Total
Africa:									
Angola	743	248	991	255	85	340	265	88	353
Botswana	359	2,038	2,397	358	2,026	2,384	404	2,287	2,691
Central African Empire	220	119	339	172	114	286	182	119	301
Ghana	233	2,095	2,328	228	2,055	2,283	230	2,070	[e]2,300
Guinea[e]	25	55	80	25	55	80	25	55	80
Ivory Coast	84	125	209	24	36	60	26	39	[e]65
Lesotho	[2]1	[2]2	[2]3	[2]1	[2]4	[2]5	6	22	[e]28
Liberia	[3]244	[3]162	[3]406	[3]176	[3]144	[3]320	163	163	326
Sierra Leone	293	439	732	192	289	481	180	270	[e]450
South Africa, Republic of:									
Premier mine	509	1,527	2,036	458	1,375	1,833	502	1,508	2,010
Other De Beers properties[4]	2,518	2,061	4,579	2,549	2,086	4,635	2,796	2,287	5,083
Other	408	272	680	333	222	555	564	376	940
Total	3,435	3,860	7,295	3,340	3,683	7,023	3,862	4,171	8,033
South-West Africa, Territory of	1,660	[r]88	[r]1,748	1,609	85	1,694	1,901	100	2,001
Tanzania	224	224	448	219	219	438	187	188	[e]375
Zaire	[r]395	12,415	12,810	591	11,230	11,821	561	10,652	11,213
Other areas:									
Brazil	131	131	262	38	38	76	100	100	[e]200
Guyana	8	13	21	6	8	14	7	10	17
India	17	3	20	17	3	20	19	3	[e]22
Indonesia[e]	[r]3	[r]12	15	3	12	15	3	12	15
U.S.S.R.	1,950	7,750	9,700	2,000	7,900	9,900	2,100	8,200	10,300
Venezuela	239	821	1,060	190	643	833	160	540	700
World total	[r]10,264	[r]30,600	[r]40,864	9,444	28,629	38,073	10,381	29,089	39,470

[e]Estimate. [p]Preliminary. [r]Revised.

[1]Total (gem plus industrial) diamond output for each country is actually reported except where indicated to be an estimate by footnote. In contrast, the detailed separate reporting of gem diamond and industrial diamond represents Bureau of Mines estimates in the case of every country except Lesotho (1975-76), Liberia (1977), Venezuela (1975 and 1976), and Zaire (1975), where sources give both total output and detail. The estimated distribution of total output between gem and industrial diamond is conjectural in the case of a number of countries, based on unofficial information of varying reliability.

[2]Exports of diamond originating in Lesotho; excludes stone imported for cutting and subsequently reexported.

[3]Exports.

[4]All company output from the Republic of South Africa except for that credited to the Premier mine; also excludes company output from the Territory of South-West Africa and Botswana.

TECHNOLOGY

Grading and demonstrating cut diamonds is said to be fast and accurate when using the Gem Proportionscope. When the diamond is placed in the optical field of the instrument, any deviation from ideal proportions is said to be clearly visible. Comparisons can be easily made for establishing the grade of a diamond's cut.[23]

Six isolated and totally enclosed inclusions were recovered from an Arkansas diamond by burning in air at 850°C. They are identified as (a) three euhedral crystals of chromian diopside, (b) a euhedral bicrystal of chromian diopside plus orthopyroxene with minor included matter, (c) anhedral olivine plus a small amount of attached unidentified glassy silicate rich in silicon and aluminum with minor iron, titanium, zinc, and potassium, (d) finely polycrystalline periclase plus minor magnetite. X-ray diffraction, and chemical and morphological data are given. The periclase may have existed in the diamond as magnesite; if so, the observed inclusions bear resemblance to equilibrium phases recently reported for silicate plus carbonate reactions under mantle-like conditions. Interpretation of pressure-temperature equilibrium conditions for the diamond inclusion system based on the silicate-carbonate reaction and the two-pyroxene geothermometer suggests $5x10^4$ kbars and 1,300°C, but the olivine plus vitreous-like phase inclusion may indicate a pressure well below $5x10^4$ kbars.[24]

When does a science come of age? When it grows so fast and in so many parts of the world that its members need abstracts. These data will be useful in two types of laboratories: (1) The research laboratory where the goal is new syntheses through flame, flux, and pressure; and (2) the testing laboratory, which is under constant challenge to identify manmade materials and treatments. More than 1,750 entries are arranged in the alphabetical order of mineral species. However, garnet-type synthetics such as yttium-aluminum garnet (YAG) and gadolinium-gallium garnet (GGG) are grouped together, as are double, triplets, and information about synthesis in general. Treatments such as irradiation, staining, coating, and heating are also covered. Each entry gives the color, type, manufacturer, identification data, and the name and date of the publication or patent describing it. The abstracted journals and monographs are worldwide and date from the 1880's.[25]

For many years it was said that opal could not be synthesized. However, synthetics are now available from several sources. When the synthetics first came on the market, gemologists had to develop methods of differentiating them from natural opals. One of the first indications was that synthetic opals were too perfect as compared with most natural opals, but better methods were necessary. A series of tests was devised and are presented to assist in the identification of synthetic opal.[26]

Faceting may be described as the technique of cutting a gem stone with a number of flat polished surfaces arranged in a given pattern and at predetermined angles. The main reason for faceting a stone is that this style of cutting takes advantage of the inherent brilliance of the material being cut. The amount of brilliance a gem shows depends on the quantity of light reflected from its surface and, even more important, the amount of internal reflection. Faceted gems are usually cut from transparent materials to take advantage of their property of reflecting light. Even though stones are faceted primarily for their brilliance, many of the more valuable stones are cut for their color. If color is the main feature, even if a stone has just a little potential brilliance, it will look better faceted. The potential brilliance of a gem is very important in determining the style of cut that will help the stone achieve its potential brilliance. There are two basic styles of cuts—the brilliant and the step (or emerald) cut. Brilliant cuts are preferred for stones having a high refractive index and a high dispersion; the step cut is effective for colored gems having a low to medium refractive index. The evaluation of equipment, materials, methodology, and techniques were discussed in a recent publication.[27]

---

[1]Physical scientist, Division of Nonmetallic Minerals.

[2]Arkansas Gazette (Little Rock, Ark.). One in Every 248 Finds Mufreesboro Diamond. Jan 28, 1978, p. 1.

[3]Rocky Mountain News (Denver, Colo.). The Art and Utilitarian Use of Wyoming Jade. Dec. 14, 1977, p. 68.

[4]The News and Observer (Raleigh, N.C.). Gravel Yields "Pretty" Stone. June 16, 1977, p. 45.

[5]Stevens, J. P. The Maine Tourmaline Necklace. Lapidary J., v. 31, No. 5, August 1977, pp. 1092, 1094, 1110, 1112, 1114.

[6]Vuich, J. S., and R. T. Moore. Olivine Resources on San Carlos Apache Reservation. Summer 1977 Fieldnotes, v. 7, No. 2, pp. 1, 6-10; available from the Arizona Bureau of Geology and Mineral Technology, Phoenix, Ariz.

[7]Jewelers' Circular-Keystone. JC-K Colored Stone Price Index. V. 148, No. 1, January 1978, p. 141.

[8]Jewelers' Circular-Keystone. JC-K Diamond Index. V. 148, No. 1, January 1978, p. 141.

[9]Mining Journal. Diamang Takeover. V. 289, No. 7412, Sept. 9, 1977, p. 203.

[10]Mining Journal. Industry in Action. V. 288, No. 7395, May 23, 1977, p. 369.

[11]Engineering and Mining Journal. Exploration Roundup. V. 178, No. 12, December 1977, p. 148.

[12]U.S. Embassy, Gaborone, Botswana. State Department Telegram Gaboro 03323, Dec. 31, 1977, 1 p.

[13]Mining Magazine. Panorama. V. 136, No. 5, May 1977, p. 335.

[14]New York Times. Hazards Abundant in Emerald Trade. Oct. 31, 1977, sec. A, p. 38.

[15]Mining Journal. Diamond Exports Sparkle. V. 289, No. 7417, Oct. 14, 1977, p. 318.

[16]Faruqi, S. H. Evaluating Rich Ruby Deposits of Northern Pakistan. World Min., v. 30, No. 13, December 1977, pp. 60-61.

[17]U.S. Consulate, Johannesburg, South Africa. State Department Airgram A-05, Jan. 27, 1978, encl. 1, pp. 31-33.

[18]Industrial Minerals. Company News and Mineral Notes. No. 119, August 1977, p. 54.

[19]Mining Journal. Mining Annual Review, 1978, Gem stones and Abrasives. V. 290, Nov. 11, 1977, p. 125, 127, 128.

[20]Engineering and Mining Journal. Exploration Roundup. V. 178, No. 4, April 1977, p. 174.

[21]U.S. Bureau of Mines. Region of Kasai: Zaire. Mineral Trade Notes, v. 74, No. 4, July 1977, p. 17.

[22]World Mining. What's Going on in World Mining? V. 30, No. 13, December 1977, p. 90.

[23]Gems and Minerals. What's New? No. 476, June 1977, p. 77. Gem Proportionscope.

[24]Newton, M. G., C. E. Melton, and A. A. Giardini. Mineral Inclusions in an Arkansas Diamond. Am. Mineralogist, v. 62, No. 5-6, May-June 1977, pp. 583-586.

[25]O'Donoghue, M. Synthetic Gem Materials. The Worshipful Company of Goldsmiths, London, 1976, 215 pp.

[26]Jobbins, E. A., P. M. Statham, and K. Scarratt. Internal Structures and Identification of Gilson Opal. Gems and Minerals, No. 459, January 1977, pp. 15, 26, 28-30, 38-42.

[27]Hemrich, G. I. Faceting for Beginners. Gems and Miner.—Part I. No. 475, May 1977, pp. 28-29.

—.Faceting for Beginners. Gems and Miner.—Part II. No. 476, June 1977, pp. 36-37.

—.Faceting for Beginners. Gems and Miner.—Part III. No. 478, August 1977, pp. 28-30, 93.

—.Faceting for Beginners. Gems and Miner.—Part IV. No. 479, September 1977, pp. 28, 30, 31.

—.Faceting for Beginners. Gems and Miner.—Part V. No 480, October 1977, pp. 62-63.

—.Faceting for Beginners. Gems and Miner.—Part VI. No. 481. November 1977, pp. 12-14.

—.Faceting for Beginners. Gems and Miner.—Part VII. No. 482. December 1977, pp. 56-61.

Gold

By W. C. Butterman[1]

The production of gold from domestic mines increased 5% in 1977, to 1.1 million ounces,[2] but production of secondary gold from scrap fell 2%, to 2.45 million ounces. The mined gold came from 13 States, and 76% came from 3 of them - Nevada, South Dakota, and Utah. Higher prices for gold caused considerable interest in the exploitation of low-grade deposits and the reworking of mine dumps in the Western United States. Several operations using cyanide heap leaching came onstream or were being readied in 1977. World gold production was essentially unchanged at 39.0 million ounces, of which the Republic of South Africa accounted for 58% and the U.S.S.R. 20%.

Consumption of refined bullion by domestic industry and the arts rose 5%, to 4.9 million ounces. As in past years, more than half of the bullion consumed went into the manufacture of jewelry. According to estimates by Consolidated Gold Fields, Limited., consumption by arts and industries in the market economy countries rose 1%, to 44.6 million ounces, and purchases of bullion for investment purposes took another 7.1 million ounces.

The price of gold in the United States increased from a low of about $130 per ounce in January to $148 in mid-September and, to $168 in November. The average for the year (as quoted by Engelhard Industries) was $148.31 per ounce. London prices were generally 45 to 75 cents per ounce lower than New York prices.

The U.S. gold market expanded in 1977, and the expansion was accompanied by an increased flow of gold into the market from imports and bullion sales, and by increased exports and larger stocks. Imports of gold coins were estimated at 1.6 million ounces, while imports of all other forms totaled 4.5 million ounces. Net deliveries to the market from earmarked foreign bullion stocks totaled 6.4 million ounces, and deliveries from International Monetary Fund (IMF) auctions totaled 4.5 million ounces. Exports were 8.7 million ounces, including 1.7 million ounces of monetary gold. Commercial stocks of bullion tripled, ending the year at 3.8 million ounces.

Trading in gold bullion futures on U.S. commodity markets in the first 9 months of 1977 was at about twice the level of the same period in 1976, averaging 5.7 million ounces per month on the Commodity Exchange, Inc. (COMEX) in New York and 5.1 million ounces per month on the International Monetary Market (IMM) in Chicago. In the fourth quarter, trading grew rapidly, the November volume reaching 18.5 million ounces on COMEX and 17.3 million ounces on IMM. Volume declined somewhat in December.

Stocks of monetary gold held by the market economy countries and their international monetary agencies declined 6.6 million ounces to 1,157 million ounces. U.S. Treasury stocks rose 2.9 million ounces to 277.5 million ounces, valued at $11,718 million.

Legislation and Government Programs.—Legislation signed by the President in October in effect nullified the part of the joint congressional resolution of June 5, 1933, that provided that no business contract could be enforced if it required payment in gold or in dollar amounts indexed to the price of gold. In the late 1930's, the Supreme Court interpreted the resolution to extend to contracts requiring payment in a foreign currency or in the dollar equivalent of a foreign currency at a fixed rate of exchange. The new 'gold clause' legislation, an amendment to H.R. 5675, thus legalized multiple-currency contracts and contracts specifying payment in gold.

The Commodity Futures Trading Commission continued to study the question of whether to permit trading in gold market options but had not ruled on the matter by yearend.

The Federal Trade Commission on June 6 proposed amending the Trade Practice Rules for the jewelry industry to allow jewelry items of less than 10-karat gold content to be labeled "gold". By yearend, the Commission had not ruled on the proposal.

The IMF sold 6 million ounces of bullion at 11 public auctions during the year; 4.5 million ounces, the amount sold at 8 of the auctions, was delivered in New York, and the rest was delivered in London and Paris. After the first auction, of 780,000 ounces in January, the auctions were conducted on a monthly basis, and 525,000 ounces was offered each month, beginning in March. The IMF also began its planned 4-year restitution of 25 million ounces of bullion to member countries, returning a total of 6 million ounces to 112 member countries in the first 2 months of the year.

Table 1.—Salient gold statistics

	1973	1974	1975	1976	1977
United States:					
Mine production ___ thousand troy ounces__	1,176	1,127	1,052	1,048	1,100
Value ____________ thousands__	$115,000	$180,009	$169,928	$131,340	$163,192
Ore (dry and siliceous) produced:					
Gold ore ______thousand short tons__	4,715	4,598	5,722	3,063	5,806
Gold-silver ore ___________ do____	124	65	137	1,027	481
Silver ore ____________ do____	370	560	672	651	800
Percentage of gold derived from:					
Dry and siliceous ores ____________	52	58	62	61	60
Base-metal ores ______________	47	41	36	36	38
Placers ____________________	1	1	2	3	2
Refinery production:					
From domestic ores[1] thousand troy ounces__	1,210	1,021	1,093	954	956
Secondary _____________ do____	1,779	1,926	2,696	2,504	2,454
Exports:[2]					
Commercial _____________ do____	601	570	2,689	2,879	7,011
Government ____________ do____	2,384	3,293	807	652	1,660
Total ________________ do____	2,985	3,863	3,496	3,531	8,671
Imports, general[2] ___________ do____	3,845	2,651	2,662	2,656	4,454
Gold contained in imported coins___ do____	--	3,090	1,673	1,333	1,614
Sales from foreign stocks in Federal Reserve Bank ______________ do____	1,704	2,144	577	2,125	6,573
Stocks, Dec. 31:					
Monetary[3] ____________ millions__	$11,652	$11,652	$11,599	$11,598	$11,718
Industrial[4] ___thousand troy ounces__	4,498	5,670	788	928	1,976
Consumption in industry and the arts ___________________ do____	6,729	4,651	3,993	4,648	4,859
Price:[5] Average per troy ounce _________	$97.81	$159.74	$161.49	$125.32	$148.31
World:					
Production ______thousand troy ounces__	43,297	40,124	r38,476	r39,089	38,966
Official reserves[6] __________ millions__	r$49,658	r$49,609	r$49,574	r$49,142	$48,862

rRevised.
[1]Sources: 1973-74, Office of Domestic Gold and Silver Operations, U.S. Department of the Treasury; 1975-77, Bureau of Mines, U.S. Department of the Interior.
[2]Excludes coins.
[3]Gold valued at $42.22 per troy ounce. Includes gold in Exchange Stabilization Fund.
[4]Gold content of all products in stocks held by manufacturers and refiners in 1973-74; gold content of bullion only in 1975-77 (excludes trading stocks). Stocks at beginning of 1975 amounted to 1,896,000 ounces of bullion.
[5]Engelhard Industries quotations.
[6]Held by market-economy-country central banks and Governments; gold valued at $42.22 per ounce. Source: International Monetary Fund.

DOMESTIC PRODUCTION

Refinery production of 995 fine, or better, gold totaled 3.47 million ounces in 1977. Of the total, 1.02 million ounces was refined from ores and concentrates, 1.04 million ounces from old scrap, and 1.41 million ounces from new (manufacturers') scrap. Six percent of the ores and concentrates and an estimated 10% to 12% of the scrap were imported.

Mine production rose 5% in 1977, to 1.10 million ounces. Production came from 12 Western States; the 3 leading States, in

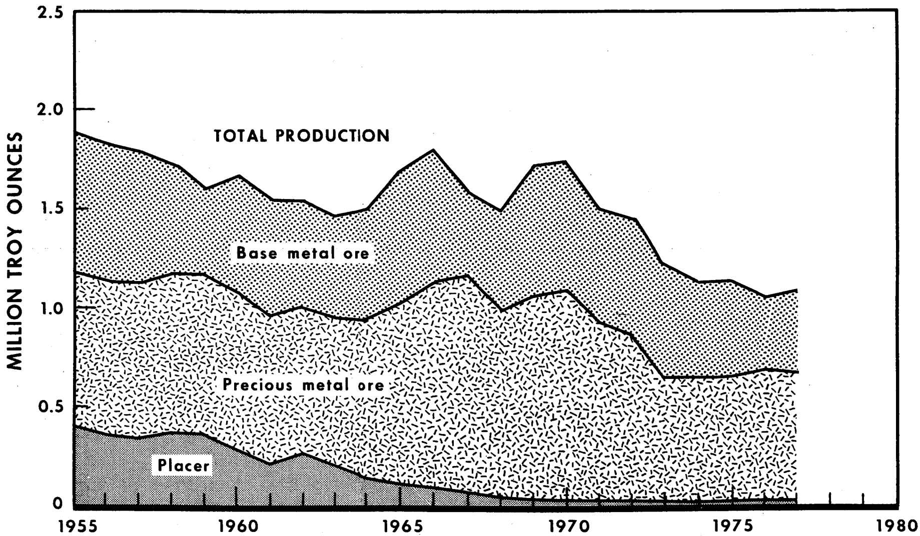


Figure 1.—Gold production in the United States, by sources.

order of output, were Nevada, South Dakota, and Utah, and together they accounted for 76% of domestic mine production. Gold production was reported by 169 mines, of which 133 were lode mines and 36 were placer mines. Placer mines produced only 2% of the gold, mostly in Alaska. Placer production in California and Colorado was a byproduct of sand and gravel quarrying. Thirty-nine percent of the gold from lode mines, or 38% from all mines including placer mines, was derived as a byproduct of base metal ores. Of the gold from lode mines, 56% was recovered by cyanidation, 42% by smelting, and 2% by amalgamation.

As in past years, most domestic gold was mined at relatively few mines. The top 25 producers (table 5) accounted for 96% of the gold, and three of these - Homestake, Utah Copper, and Carlin - accounted for about 65%.[3]

In Nevada, the principal mines (all surface mines) were the Carlin, Round Mountain, Bootstrap, Copper Canyon, Atlanta, Ruth Pit, Windfall, and Gooseberry. The Carlin Gold Mining Co. produced, from the Carlin and Bootstrap pits, 215,100 ounces of gold from 803,000 tons of ore, recovering on the average 0.268 ounce per ton. Revenue from bullion sales was $33 million; the average price for gold was $154 per ounce. Ore reserves at the end of 1977 were 6.2 million tons grading 0.202 ounce per ton, compared with 5.3 million tons averaging 0.208 ounce per ton in 1976. Testing of a new double-oxidation cyanide process developed to handle high-carbon ores was completed, and full-scale equipment was installed late in the year. The new process allowed a considerable tonnage of high-carbon ore in the deep easterly extension of the main pit to be counted as reserves.

The Round Mountain mine (Smoky Valley Mining Corp.), north of Tonopah, started its heap-leaching operation in early 1977 and progressed rapidly toward a scheduled production rate of 55,000 to 60,000 ounces per year.[4] Late in the year, Duval Corp. was engaged in converting its Battle Mountain mine and mill from copper to gold production, a reflection of the relative shift in market value of the two metals. Startup was scheduled for 1978. Freeport Minerals Co., in a joint venture with FMC Corp., explored the Jerritt Creek area, 55 miles north of Elko. The partners later announced (April 1978) that drilling had outlined a possible 5 million tons of carbonaceous gold ore, averaging better than 0.3 ounce per ton, and had located several other promising areas in their 42 square miles of claims. Tentative plans called for a 1,500-ton-per-day open pit operation by 1982, which would make the mine one of the largest in the United States. Argus Resources, Inc., acquired the White Caps mine near Manhattan and planned to renovate the mine and build a mill to extract gold and antimony from the old tailings pile. Silver King Mines Inc. studied the feasibility of processing gold-silver ore from its East Robinson properties at a cyanide-leach plant to be built at its Taylor silver property. Several companies, including Homestake Mining Co., were reported to be exploring for gold in the Flowery Mountains, northeast of Virginia City.

In South Dakota, the Homestake mine accounted for essentially all gold produced. Homestake produced 304,769 ounces in 1977 (318,487 ounces in 1976) from 1,578,000 tons of ore, with an average recovery grade of 0.193 ounce per ton. Gold bullion sales totaled $44.9 million; the average price realized was $147.47 per ounce. Ore reserves at yearend 1977 totaled 14.87 million tons averaging 0.224 ounce per ton, compared with 14.25 million tons averaging 0.229 ounce per ton a year earlier. The Grizzly Gulch tailings dam and associated pollution control facilities were substantially completed in 1977.

The large quantities of gold produced in Utah and Arizona were almost entirely byproducts of copper mining, even though several mines in the two States produced modest quantities of gold from other ores.

At Republic, Wash., production from the Knob Hill mine decreased as the mine approached depletion. Mining was suspended at the end of February 1978, and subsequently Day Mines Inc. acquired the property and plant of Knob Hill Mines Inc. and started exploration for new reserves.

In Idaho, the DeLamar silver mine (Earth Resources Co. and Superior Oil Co.), located in the southwestern corner of the State, poured its first silver-gold dore bars in April 1977; gold production was expected to be about 40,000 ounces annually.

Alaska Gold Co. operated two bucket line dredges at Nome in 1977. Seasonal operations ceased for the winter the first week in November, somewhat earlier than anticipated; however, the company expected substantially increased output in 1978.

CONSUMPTION AND USES

Domestic gold consumption, as measured by conversion of bullion into primary products, totaled 4.86 million ounces in 1977, 5% higher than in 1976. Consumption was distributed among end uses as follows, in thousand ounces (with 1976 figures in parentheses): Jewelry and arts, 2,658 (2,562); dental, 728 (694); various industrial uses, mainly electronic, 1,205 (1,233); investment products, 268 (159). Jewelry and arts accounted for 55% of consumption, dental for 15%, industrial for 25%, and investment products for 5%. An estimated 68% of the gold consumed went into karat gold alloys, 14% was used in electroplated products, and the rest went into gold-filled articles, rolled gold, and other products.

In addition to the 4.86 million ounces of refined gold consumed, an estimated 4 million ounces of bullion and bullion coins were believed to have been purchased for investment purposes in 1977. Of this, 1.6 million ounces was in imported coins, few of which had numismatic value. Another 2.7 million ounces was in the apparent domestic supply surplus, most of which probably reflected absorption of bullion into private, unreported stocks.

With gold prices rising through the year, industry continued its efforts to use less gold per manufactured item and to substitute other metals for gold. In general, the efforts were a continuation of past trends, such as expansion of selected-area plating in the manufacture of electronic components and the substitution of palladium for gold wherever possible. Part of the jewelry trade wanted to be allowed to label as gold, jewelry containing less than 10-karat gold, and approached the Federal Trade Commission (FTC) about the matter. The FTC on June 6 published proposed amendments to its Trade Practice Rules for the Jewelry Industry, to allow such labelling, but had not ruled on the proposal by yearend.

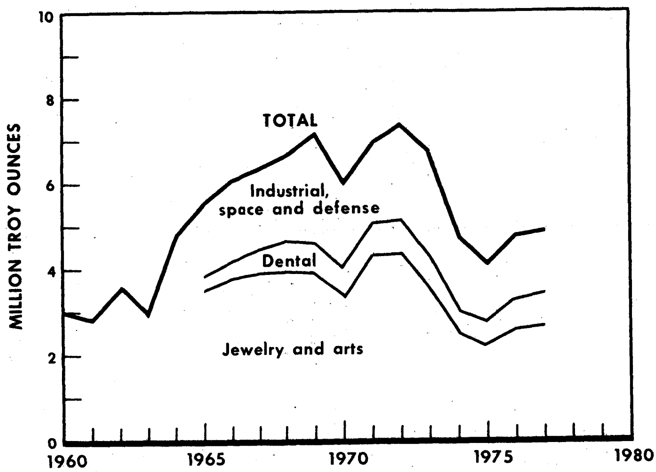


Figure 2.—Gold consumption in the United States.

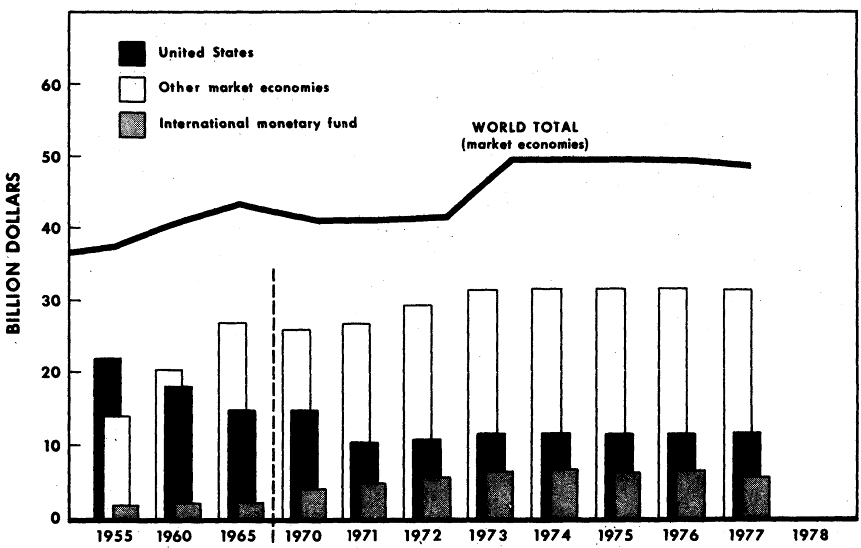


Figure 3.—World monetary gold stocks.

STOCKS

Monetary.—U.S. Treasury gold stocks at yearend 1977 were 277.57 million ounces and were worth $11,718 million, at the official valuation price of $42.22 per ounce. No domestic monetary gold was bought or sold during the year. Earmarked gold held at the New York Federal Reserve Bank for foreign and international official accounts amounted to 372.88 million ounces, a decrease of 15.89 million ounces during the year. Official gold reserves of the market economy countries, including stocks held by the IMF and the Bank for International Settlements, totaled 1,157 million ounces at yearend. IMF stocks, 137.41 million ounces, had decreased 12 million ounces during the year because of IMF's public auction of 6 million ounces and the restitution of another 6 million ounces to member countries.

Commercial Stocks.—Industrial stocks of 995 fine or better gold held by refiners, fabricators, and dealers at yearend totaled 1.98 million ounces, a nearly six-fold increase over the yearend 1976 figure.

PRICES

The price for unfabricated gold, quoted daily by Engelhard Industries, began the year at $136.10 per ounce, declined to the year's low of $130.25 per ounce on January 11, climbed to $154.05 on March 25, fell to $137.60 on June 14, and then increased to about $148 in mid-September; thereafter it rose rapidly to the year's high of $168.45 on November 11 and ended the year at $165.45. The average price for the year was $148.31. London final prices generally were 45 to 75 cents per ounce lower than U.S. prices and averaged $147.72 for the year. Most central banks in the market economy countries continued to value gold at an official price of $42.22 per ounce. The official IMF price was 35 Special Drawing Rights (SDR) per ounce; at the yearend exchange rate of $1.21471 per SDR, this was equivalent to an average of $42.51 per ounce for 1977.

Table 2.—U.S. monthly gold selling prices in 1977, per troy ounce

Month	Average	Low	High
January	$132.92	$130.25	$136.20
February	136.74	132.60	143.25
March	148.73	141.90	154.05
April	149.68	146.10	152.70
May	147.23	143.45	148.85
June	141.51	137.60	144.35
July	144.02	141.05	146.90
August	145.50	143.80	147.25
September	150.10	145.93	154.55
October	159.36	154.45	163.75
November	162.84	156.65	168.45
December	161.14	158.10	166.50
Year	148.31	130.25	168.45

Source: Englehard Industries.

FOREIGN TRADE

U.S. exports of nonmonetary gold in 1977 totaled 7.0 million ounces, valued at $985 million. Of this, 0.4 million ounces was contained in ore, base bullion, and scrap, which went mainly to the United Kingdom (36%) and Belgium-Luxembourg (36%). The remaining 6.6 million ounces was refined bullion, which went mainly to the United Kingdom (51%) and Switzerland (41%). In addition, 1.66 million ounces of monetary bullion was exported, 1.5 million ounces going to Switzerland and 0.16 million ounces to Mexico.

Imports of gold, all nonmonetary, totaled 4.45 million ounces, valued at $674 million. Of this, 0.24 million ounces was contained in ore, base bullion, and scrap derived from 29 countries. The rest, 4.21 million ounces, was refined bullion and came mainly from Canada (40%), the U.S.S.R. (33%), and

Switzerland (15%). The average valuation of refined bullion imports was $151.54 per ounce. In addition to conventional imports, the gold market was supplied with net deliveries of 6.41 million ounces of bullion from foreign and international stocks held at the New York Federal Reserve Bank, and 4.45 million ounces of bullion delivered in New York from IMF auctions. Another 1.61 million ounces was imported in the form of gold coins, mostly the so-called bullion coins.

The net inflow of gold to U.S. markets, exclusive of the movement of coins and monetary bullion but including deliveries from foreign and international stocks, was 8.31 million ounces in 1977, compared with 4.99 million ounces in 1976, 0.55 million ounces in 1975, and 4.23 million ounces in 1974.

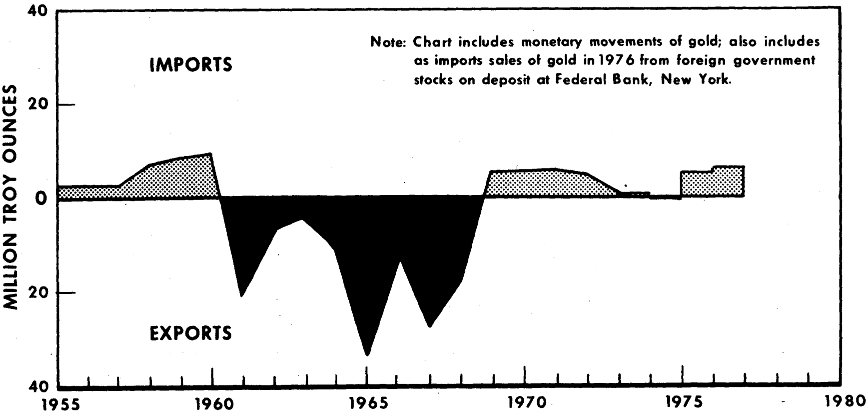


Figure 4.—Net exports or imports of gold.

WORLD REVIEW

World gold production in 1977, at 39 million ounces, was essentially unchanged from that of 1976. A decrease of 434,000 ounces in the Republic of South Africa production was offset by increases in production in the U.S.S.R., Australia, Papua New Guinea, the Philippines, and Canada.

Consolidated Gold Fields Limited, in its annual review, Gold 1978, puts 1977 world production at 45.9 million ounces and estimates that the supply of gold available to private purchasers in market economy countries increased 11%, to 51.7 million ounces. Of the total supplies, 25% came from central economy countries and 15% from "official" sales, mainly the IMF auctions. Eighty-six percent of the gold was fabricated, and 14% was purchased as bullion. Developed countries took 56% of the fabricated gold. Overall, in the market economy countries, 70% of the fabricated gold went into jewelry, 10% into official coins, 6% into dental uses, 5% into electronics, 5% into miscellaneous industrial and decorative uses, and 4% into medals, medallions, and fake coins.

A brief review by countries follows:

Australia.—Gold production increased 23% in 1977, to 620,605 ounces. The Telfer mine (70% owned by Newmont Pty., Ltd.) in the Paterson Range, Western Australia, came onstream in March and was building toward full production in the following months. Reserves were increased during the year by 0.4 million tons, to 3.9 million tons averaging 0.26 ounce per ton.

A $3.1 million rejuvenation and expansion program was begun at the Mt. Charlotte mine; by yearend, the new flotation plant had been commissioned, and work continued on the mill and crushing plant. It was expected that the changes, when completed, would reduce production costs by $A10 per ounce.

The Central Norseman mine increased production 32% to 24,500 ounces, by processing 9% more ore. Revenues benefited from the rising market price for gold as well as from increased production.

The Blue Spec antimony-gold mine in the Pilbara region of Western Australia, which had been reopened in April 1976, lost $1.8 million in the year ended June 30, 1977. The grade had run 25% below expectation, and costs soared. Because further exploration failed to increase reserves and losses continued, the mine closed January 12, 1978.

Australia's largest antimony mine, the Hillgrove mine in New South Wales, installed equipment for the recovery of gold from antimony concentrates. The Jabiluka uranium mining project in the Northern Territory was reported to have reserves of gold ore of 585,000 short tons, grading about 0.5 ounce per ton. It was expected that gold could be produced for at least 4 years of the estimated 30-year life of the uranium mine.

Bolivia.—Gold production fell 41% in 1977, to 24,293 ounces, primarily due to flooding of gold-producing areas on the Tipuani and Kaka Rivers early in the year. The South American Placers Inc. dredge was shut down 3 months during the year, and this, along with the depletion of the ground worked by the gold cooperatives on the Tipuani River, contributed to the decline in production. Exploration continued in 1977 for economic alluvial gold deposits along the Tipuani, Illica, Murmuntani, Mapiri, and Kaka Rivers.

Brazil.—With the improving gold price in 1977, output by individual panners, or alluvial miners, called garimpeiros, increased. It was estimated that about 4,000 garimpeiros, in 30 to 40 camps, were recovering alluvial gold, mostly along the Tapajos and adjacent rivers in the upper Amazon basin. The garimpeiros accounted for about 30% of the production reported to the Government, but it was believed that most garimpeiro production goes unreported.[5] Most of the rest of Brazilian gold comes from the Morro Velho mine in Minas Gerais. A 49% interest in Morro Velho was purchased in 1976 by Anglo American Corp. of South Africa.

The Anglo American Group looked for gold ore by surface drilling and underground exploration at the Jacobina deposit in Bahia. In the region south of the Carajas Hills in Para, the State mining company, Cia. Vale do Rio Doce (CVRD), discovered extensive gold mineralization over a 3,000-square-mile area while drilling for zinc and nickel. The company moved to establish a pilot operation in the area immediately, but said that 2 years of further exploration would be required to delineate the gold-bearing areas.

Canada.—Canadian production, 1,717,000 ounces, came from 21 mines, and was about 1% higher than in 1976. All of the gold produced in the Atlantic Provinces, and nearly all of the gold produced in the Prairie Provinces and British Columbia, was a byproduct of base metal mining. Among the Provinces, Ontario was the largest producer with 43% of national production, followed by Quebec with 27% and British Columbia with 11%; the Northwest Territories accounted for another 11% of national production. Details of the operation of individual mines were published in the Canadian Minerals Yearbook.

Colombia.—Gold output dropped 14% in 1977, to 257,138 ounces. To increase production in 1978 from small mines working alluvial deposits, the Government established an 8% export subsidy and raised the price it pays miners for gold. Mineros de Colombia (the national mining company), which added six new dredges and expanded it operations, reported a 15% increase in production. Frontino Gold Mines, Ltd., the last foreign-owned gold mining company in Colombia, went bankrupt and made plans to settle debts and liquidate assests.

Costa Rica.—Production from the San Martin and Tres Hermanos mines, the only active gold mines in Costa Rica, increased 28% to 12,249 ounces in 1977. United Hearne Resources of Canada, in a 70 to 30 joint venture with Canadian Barranco Corp., continued exploratory drilling of the Santa Clara property. By early 1978 they had proven about 7 million tons of ore grading 0.07 ounce per ton and were planning milling-cyanide leaching facilities. Silver Eureka Corp. began exploration for gold and base metals on the Sacrafamilia and Compania properties under an option agreement with the owner, Aguacate Consolidated Mines, Inc.

Dominican Republic.—Output of the Pueblo Viejo mine fell 16% to 348,473 ounces, as the grade of ore declined. The quantity of ore processed increased slightly in spite of problems with hard siliceous ores. The company reportedly expected grade to drop further and began installation of a primary crusher and an additional ball mill to raise ore throughput by 20%. Also begun was a new program of drill exploration of the underlying sulfide deposit, which is estimated to contain 2.4 million ounces of gold, grading 0.115 ounce per ton. At yearend, the disposition of the Los Cacaos deposit, adjacent to the Pueblo Viejo deposit, had not been agreed upon between the Dominican Government and Rosario Dominicana.

Fiji.—Output of the sole producer, Emperor Gold Mines, declined 25% in 1977 to 49,067 ounces. The mine continued to operate at a loss and was receiving financial assistance from the Government until November. In January 1978 the mine reduced its labor force and cut back its mining volume in an effort to increase profitability. The future of the mine was in doubt, but there was a possibility that the Government would acquire it and keep it in operation.

Mexico.—Gold output rose 31% in 1977, to 212,709 ounces. The modernization of the Tayoltita mine, operated by Minas de San Luis, S.A., was described.[6] The described changes increased production 25%, to 32,000 ounces of gold and 55,000 ounces of silver per year. Toward yearend, Blythwood Mining Co. was attempting to raise capital for exploration of a gold-cobalt-silver deposit in Sonora, and the Mexican Government announced that a new gold mine reported to be at Pinzan Moredo, in Guerrero, with a capacity of 1 metric ton (32,000 ounces) of gold mine per year would come onstream in May 1978.

New Zealand.—At yearend, the future of the large dredge operated by Kanieri Gold Dredging, Ltd., was in doubt. The dredge had accounted for nearly all gold production of the past several years in New Zealand, but had incurred a sizable operating loss in 1977, mostly because of low gold recovery.

Nicaragua.—The average grade of ore mined by Empresa Minera de el Sententrion (operated by Noranda Mines Inc.) fell in 1977, because an important area of good-grade ore was flooded in 1976. The company began work on a pumping shaft, by which it hoped to reclaim the desired ores. The Rosario Mining Co. of Nicaragua converted part of its La Rosita copper mill to a 500-ton-per-day gold cyanidation mill and was readying the Riscos de Oro and Blag mines to feed the mill.

Papua New Guinea.—By yearend 1977, about 65,000 feet of drilling had been completed at the Ok Tedi gold-bearing copper orebody in the Star Mountains of northwest Papua and a tunnel was being driven into the gold-enriched material above the main orebody. The deposit was considered to have considerable potential as a gold producer. Expansion of capacity at Bougainville Copper Ltd., which produces virtually all of Papua New Guinea's gold, helped raise gold production above the 1976 level.

Peru.—Approximately 45% of Peru's gold production in 1977 was placer gold, nearly all won from alluvial gravels on the eastern slopes of the Andes by individual miners. Another 40% was byproduct gold. The only straight lode gold mine now operating in the country, Minas Ocoña S.A., contributed the remaining 15% of Peruvian production. The Government of Peru actively encouraged gold mining in 1977. Exploration funded by its Banco Minero located several prospects, of which the two most important were alluvial deposits in the Department of Madre de Dios in southeastern Peru. The Alto Laberinto deposit was estimated to have potential reserves of 3.5 million ounces; an estimate of reserves in the Huaypetue deposit was not available. The Government also invited the private sector to participate in reactivating the old placer deposit of San Antonio de Poto, in the Department of Puno, which had been last worked by dredge from 1961 to 1972.

Saudi Arabia.—Consolidated Gold Fields conducted a drilling exploration program in 1977 at the Mahd adh Dhahab mine, thought to be the site of King Solomon's legendary mine. The first stage of the drilling program indicated a relatively small deposit that was of sufficient interest to justify further exploration.

South Africa, Republic of.—Gold production declined 2% to 22.5 million ounces in 1977. The 38 member mines of the Chamber of Mines accounted for 99.5% of South African output. Figures published by the chamber showed that member mines milled 82.2 million short tons of ore, averaging 0.27 ounce of gold per ton. Working costs averaged R75.92 per ounce ($87.31), and ranged from R33.47 per ounce ($38.49) at the East Driefontein mine to R163.51 per ounce ($188.04) at Free State Saaiplass. Production by the seven major mining groups follows, in million ounces: Anglo American Corp. of South Africa, Ltd., 8.4; Gold Fields of South Africa Ltd., 5.1; Rand Mines, Ltd., 2.3; Union Corp., 2.1; General Mining and Finance Corp., 1.6; Anglo Transvaal Consolidated Investment Co. Ltd., 1.3; and Johannsesburg Consolidated Investment Corp., 1.3. The largest gold mines, in terms of output, were Vaal Reefs (2.06 million ounces), followed by West Driefontein (1.70 million ounces) and East Driefontein (1.57 million ounces). Ten gold mines also produced uranium in 1977; total production was 3,926 short tons of U_3O_8 (not counting 345 tons reclaimed from tailings). Vaal Reefs was the largest uranium producer, with a yield of 1,121 tons of U_3O_8. South African proven gold reserves at end of the third quarter of 1977 were 164 million short tons, grading 0.44 ounce per ton.

Three major mines were under development in 1977—the Unisel mine of Union Corp., the Deelkraal mine of Gold Fields of South Africa, and the Elandsrand mine of Anglo American Corp. The Unisel mine is south of Welkom in Orange Free State, and the Deelkraal and Elandsrand are adjoining mines in the Far West Rand field, south of Carletonville, in Transvaal. At Unisel, the shaft had been sunk to its final depth of 6,500 feet, and surface construction progressed satisfactorily, but underground development lagged, partly because of difficult ground conditions. Startup was rescheduled for the first quarter of 1979, and it was estimated that full production, about 75,000 tons per month, would be reached by November of that year. Development work at the Deelkraal mine was concentrated on sinking the twin shafts; No. 2 shaft reached its final depth of 5,835 feet, and work was continuing on the No. 1 subvertical shaft at yearend. The mine was expected to go into production in 1979, starting at about 60,000 tons per month and increasing to about 120,000 tons per month by yearend. At Elandsrand, innovative development techniques moved the estimated startup date forward to mid-1979. Production at startup was expected to be 60,000 tons per month, building to 135,000 tons by mid-1980, and to 180,000 tons by 1983.

Anglo American Corp.'s "Joint Metallurgical Scheme" in the Orange Free State, designed to recover gold, uranium, and sulfur from tailings at six mines, encountered problems which kept gold production down to about 10,000 ounces, less than one-tenth of design production. Startup of the Corporation's East Rand Gold and Uranium Co. (ERGO) operation took place in December. ERGO's production of the first gold from tailings piles in the Johannesburg area was scheduled for the first quarter of 1978; annual production was expected to be 225,000 ounces at design capacity.

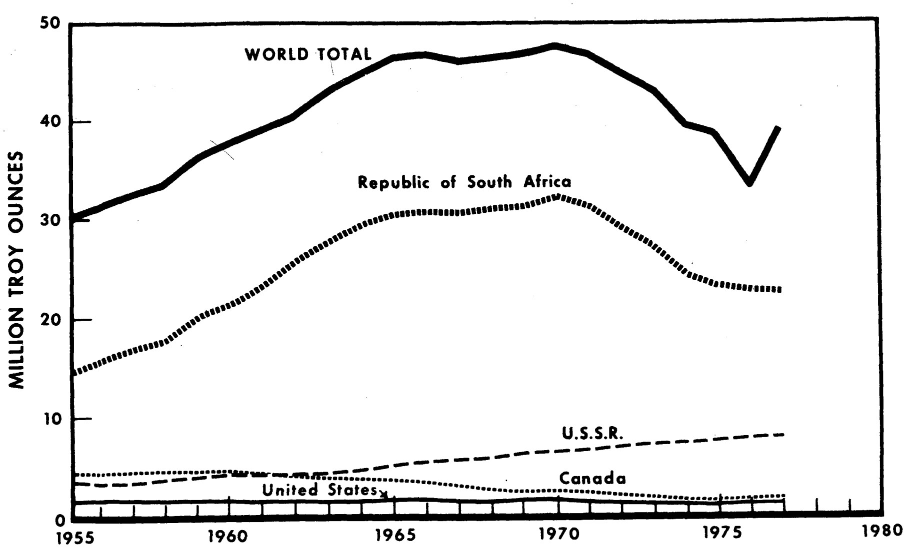


Figure 5.—World production of gold.

TECHNOLOGY

Interest continued in heap leaching with dilute cyanide solutions as a means of processing low-grade gold ores. The technology and economics of the process, including safe handling and disposal of cyanide, were summarized in a Bureau of Mines information circular.[7] The Bureau continued work on methods of improving the flow of cyanide solution through heaps of ore and old mine tailings having clayey constituents. One promising technique involved agglomerating the fines by adjusting the moisture content of the ore and mixing it with lime, in amounts normally required for protective alkalinity during cyanidation. The key to improved percolation rates was found to be proper aging of the agglomerates, so as to develop sufficient green strength to withstand prolonged leaching. The addition of flocculants further enhanced agglomeration in some circumstances.

The addition of alcohols to the hot alkali solution used to strip gold from pregnant gold cyanide solution had been shown by Bureau of Mines research to cut stripping time drastically, and several domestic companies adopted this innovation. Further study was begun in 1977 to determine the feasibility of substituting a high-boiling alcohol for methanol or ethanol, in order to cut evaporation losses and avoid the possibility of forming toxic concentrations of alcohol in the air. Initial tests with ethylene glycol were promising.

After several absorption and stripping cycles, the loading efficiency of activated carbon used in cyanide-carbon systems drops markedly. Studies were begun on regeneration of the carbon by distillation of adsorbed alcohol and by treatment with superheated steam.

Research was begun on the development of simpler means of processing Merrill-Crowe gold precipitates that would be suitable for small operations.

Sand and gravel are quarried in huge quantities, and in some areas, such as central California, they contain gold and other heavy minerals. Gold is recovered at a number of pits, but usually the remaining heavy minerals, or black sands, are discarded. The recovery of the platinum-group metals and other black sand constituents could affect the economic feasibility of gold-saving operations at some of the pits. The Bureau of Mines continued research into developing ways of separating and concentrating the individual minerals in black sands. Depending upon the composition of the black sand, various combinations of gravity concentration with separation by magnetic, electrostatic, heavy-media, and flotation methods were being investigated.

The feasibility of recovering precious metals from electronics scrap was examined by the Bureau of Mines. A large sample of scrapped military electronic gear, disassembled by hand to allow measurement of the metals content, contained about the same amounts of gold and silver as do typical ores of these metals.

A new dental restoration, combining dental porcelain and an improved white gold alloy, was reported. The gold base alloy contains 4.5% to 8% combined tin and indium.[8]

Three new types of gold epoxy, for use in electronics circuitry, were introduced. Each contains 88% gold and is reported to have high electrical conductivity and high bond strength.[9]

Gold thick-film conductors are commonly attached to other circuit elements by ultrasonically bonded aluminum wire or by indium-lead solders. Storage at elevated temperatures tends to degrade bond or joint integrity. The changes in performance of aged interconnections when alloying elements are added to the gold compositions were investigated and reported.[10]

The concept of using gold to encapsulate nuclear wastes was developed further. It was proposed to limit gold encapsulation to the most dangerous part of the high-level waste, the transuranic elements, produced at a rate of about 2 liters per reactor per year. The transuranics would be encased in small stainless steel cylinders lined with cadmium and lead and coated in turn with 1-millimeter-thick electrodeposited gold, a thick layer of copper, and a thick layer of asphalt. The cylinders would be buried at great depth in the ground.[11]

The Gold Bulletin, a quarterly journal of the Chamber of Mines of South Africa, contained a variety of articles on new gold uses and technology.[12]

---

[1]Physical scientist, Division of Nonferrous Metals.
[2]Ounce means troy ounce.
[3]American Bureau of Metal Statistics Inc. Nonferrous Metal Data 1977. Pp. 110-112.
[4]White, L. Heap Leaching Will Produce 85,000 Ounces/Year of Dore Bullion for Smoky Valley Mining. Eng. & Min. J., v. 178, No. 7, July 1977, pp. 70-72.
[5]Work cited in footnote 3.

[6]Haptonstall, J. C. Modernization of the Tayoltita Mine, One of Mexico's Major Silver and Gold Operations. Min. Eng., v. 30, No. 2, February 1978, pp. 171-176.
[7]Heinen, H. J., D. G. Peterson, and R. E. Lindstrom. Processing Gold Ores Using Heap Leach-Carbon Adsorption Methods. BuMines IC 8770, 1978, 21 pp.
[8]Tin International. V. 50, No. 10, October 1977, pp. 374.
[9]New Electronics. Gold Conductive Epoxies. Sept. 20, 1977.
[10]Horowits, S. J., D. J. Gerry, and R. E. Cote. Alloy Element Additions to Gold Thick Film Conductors: Effects on Indium/Lead Soldering and Ultrasonic Aluminum Wire Bonding. Solid State Technol., v. 21, No. 1, January 1978, pp. 47-54.
[11]Gold-Plated Waste. Eng., August 1977.
[12]Chamber of Mines of South Africa Research Organization (Johannesburg). Gold Bulletin. V. 10, Nos. 1-4, 1977 issues (quarterly publication).

Table 3.—Mine production of recoverable gold in the United States, by State

(Troy ounces)

State	1973	1974	1975	1976	1977
Alaska	7,107	9,146	14,980	22,887	18,962
Arizona	102,848	90,586	85,790	102,062	90,167
California	3,647	5,049	9,606	10,392	5,704
Colorado	63,422	52,083	55,483	50,764	72,668
Idaho	2,696	2,898	2,529	2,755	12,894
Montana	27,806	28,268	17,259	24,075	22,348
Nevada	260,437	298,754	332,814	287,962	324,003
New Mexico	13,864	15,427	15,049	15,198	13,560
Oregon	W	W	W	28	675
South Dakota	357,575	343,723	304,935	318,511	304,846
Tennessee	68	18	W	W	13
Utah	307,080	254,909	189,620	187,318	210,501
Washington	W	W	W	W	24,006
Other States	29,200	26,025	24,187	26,085	--
Total	1,175,750	1,126,886	1,052,252	1,048,037	1,100,347

W Withheld to avoid disclosing company proprietary data; included in "Other States."

Table 4.—Mine production of recoverable gold in the United States, by month

(Troy ounces)

Month	1976	1977
January	91,121	90,768
February	82,215	81,705
March	88,096	93,498
April	91,488	87,294
May	93,317	94,166
June	87,760	86,924
July	83,776	82,238
August	84,971	93,690
September	88,727	85,855
October	93,195	99,402
November	81,377	101,034
December	81,994	103,773
Total	1,048,037	1,100,347

Table 5.—Twenty-five leading gold-producing mines in the United States in 1977, in order of output

Rank	Mine	County and State	Operator	Source of gold
1	Homestake	Lawrence, S. Dak	Homestake Mining Co	Gold ore.
2	Utah Copper	Salt Lake, Utah	Kennecott Copper Corp	Copper ore.
3	Carlin	Eureka, Nev	Carlin Gold Mining Co	Gold ore.
4	Sunnyside	San Juan, Colo	Standard Metals Corp	Lead-zinc ore.
5	Round Mountain	Nye, Nev	Smokey Valley Mining Corp	Gold ore.
6	Bootstrap	Elko, Nev	Carlin Gold Mining Co	Do.
7	Copper Canyon	Lander, Nev	Duval Corp	Copper ore.
8	Knob Hill	Ferry, Wash	Knob Hill Mines, Inc	Gold ore.
9	Trixie	Utah, Utah	Kennecott Copper Corp	Gold-silver ore.
10	San Manuel	Pinal, Ariz	Magma Copper Co	Copper ore.
11	Magma	do	do	Do.
12	Berkeley Pit	Silver Bow, Mont	The Anaconda Company	Do.
13	New Cornelia	Pima, Ariz	Phelps Dodge Corp	Do.
14	Leadville Unit	Lake, Colo	ASARCO Incorporated	Lead-zinc ore.
15	Atlanta	Lincoln, Nev	Standard Slag Co	Gold ore.
16	Nome Unit	Seward Peninsula, Alaska	Alaska Gold Co	Placer.
17	Ruth Pit	White Pine, Nev	Kennecott Copper Corp	Copper ore.
18	Delamar	Owyhee, Idaho	Earth Resources Co	Gold-silver ore.
19	Windfall	Eureka, Nev	Idaho Mining Co	Gold ore.
20	Morenci	Greenlee, Ariz	Phelps Dodge Corp	Copper ore.
21	Idarado	Ouray and San Miguel, Colo	Idarado Mining Co	Copper-lead-zinc ore.
22	Continental	Grant, N. Mex	UV Industries, Inc	Copper ore.
23	Metcalf	Greenlee, Ariz	Phelps Dodge Corp	Do.
24	Pinto Valley	Gila, Ariz	Cities Service Co	Do.
25	Gooseberry	Storey, Nev	West Coast Oil & Gas Corp	Gold ore.

Table 6.—Production of gold in the United States in 1977, by State, type of mine, and class of ore, in terms of recoverable metal

State	Placer (troy ounces of gold)	Lode: Gold ore		Lode: Gold-silver ore		Lode: Silver ore	
		Short tons	Troy ounces of gold	Short tons	Troy ounces of gold	Short tons	Troy ounces of gold
Alaska	18,924	5	38	--	--	--	--
Arizona	--	--	--	--	--	W	W
California	3,210	521	1,642	W	W	--	--
Colorado	66	--	--	--	--	103,552	870
Idaho	--	W	W	W	W	571,875	1,159
Montana	--	3,658	314	3,059	223	61,068	622
Nevada	7	4,176,343	280,755	--	--	20,022	7
New Mexico	927	W	W	--	--	2,680	317
Oregon	--	2,978	675	--	--	--	--
South Dakota	80	1,578,413	304,766	--	--	--	--
Tennessee	--	--	--	--	--	--	--
Washington	--	39,750	23,992	--	--	W	W
Other States[1]	--	3,918	1,229	477,726	34,370	40,440	5,390
Total	23,214	5,805,586	613,411	480,785	34,593	799,637	8,365
Percent of total gold	2	XX	56	XX	3	XX	1

State	Lode: Copper ore		Lode: Lead ore		Lode: Zinc ore	
	Short tons	Troy ounces of gold	Short tons	Troy ounces of gold	Short tons	Troy ounces of gold
Alaska	--	--	--	--	--	--
Arizona	139,735,227	87,720	--	--	--	--
California	--	--	--	--	--	--
Colorado	--	--	1,204	147	159,861	423
Idaho	W	W	182,950	1,095	9,680	6
Montana	15,475,605	21,181	2,000	8	--	--
Nevada	W	W	100	9	W	W
New Mexico	24,266,264	10,985	150	3	W	W
Oregon	--	--	--	--	--	--
South Dakota	--	--	--	--	--	--
Tennessee	--	--	--	--	--	--
Washington	--	--	--	--	--	--
Other States[1]	38,685,234	225,848	--	--	138,455	111
Total	218,162,330	345,734	186,404	1,262	307,996	540
Percent of total gold	XX	31	XX	(2)	XX	(2)

State	Lode: Copper-lead, lead-zinc, copper-zinc, and copper-lead-zinc ores		Lode: Old tailings, etc.		Total[3]	
	Short tons	Troy ounces of gold	Short tons	Troy ounces of gold	Short tons	Troy ounces of gold
Alaska	--	--	--	--	5	18,962
Arizona	40,710	154	W	W	139,833,089	90,167
California	--	--	W	W	4,521	5,704
Colorado	783,687	71,161	1	1	1,048,305	72,668
Idaho	755,438	434	--	--	2,066,179	12,894
Montana	--	--	--	--	15,545,390	22,348
Nevada	104,679	38	--	--	10,253,898	324,003
New Mexico	--	--	--	--	24,411,047	13,560
Oregon	--	--	--	--	2,978	675
South Dakota	--	--	--	--	1,578,413	304,846
Tennessee	1,250,130	13	--	--	1,250,130	13
Washington	W	W	--	--	193,575	24,006
Other States[1]	493,233	1,058	39,741	[4]369	33,022,827	210,501
Total	3,427,877	72,858	39,742	370	229,210,357	1,100,347
Percent of total gold	XX	7	XX	(2)	XX	100

W Withheld to avoid disclosing company proprietary data; included in "Other States." XX Not applicable.
[1]Includes Utah and items indicated by symbol W.
[2]Less than 1/2 unit.
[3]Data may not add to State totals because of items withheld to avoid disclosing company proprietary data.
[4]Includes byproduct gold recovered from tungsten ore in California.

Table 7.—Gold produced in the United States from ore, old tailings, etc., in 1977, by State and method of recovery, in terms of recoverable metal

State	Total ore, old tailings, etc., treated[1] (thousand short tons)	Ore and old tailings to mills					Crude ore, old tailings, etc., to smelters[1]	
		Thousand short tons[1]	Recoverable in bullion		Concentrates smelted and recoverable metal			
			Amalgamation (troy ounces)	Cyanidation (troy ounces)	Concentrates (short tons)	Troy ounces	Thousand short tons	Troy ounces
Alaska	(2)	--	--	--	--	--	(2)	38
Arizona	[3]182,993	[3]182,686	--	1,900	8,377,614	87,842	307	425
California	[4]5	[4]5	1,198	22	2,144	973	(2)	301
Colorado	1,222	1,217	25,408	--	127,268	46,711	5	483
Idaho	2,078	2,075	--	10,184	139,928	2,705	3	5
Montana	15,562	15,485	9	--	325,271	21,710	77	629
Nevada	[3]18,451	[3]18,390	--	280,761	293,065	42,859	61	376
New Mexico	24,440	24,360	--	--	768,734	11,098	80	1,535
Oregon	3	--	--	--	--	--	3	675
South Dakota	1,578	1,578	--	304,766	--	--	--	--
Tennessee	4,995	4,995	--	--	205,462	13	--	--
Utah	33,054	32,910	--	--	739,252	183,405	144	27,096
Washington	194	194	--	--	12,242	24,004	(2)	2
Total	284,575	283,895	26,615	597,633	10,990,980	421,320	680	31,565

[1]Includes some non-gold-bearing ores not separable.
[2]Less than 1/2 unit.
[3]Includes tonnages from which gold was recovered by heap leaching.
[4]Excludes tonnage of tungsten ore from which gold was recovered as a byproduct.

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 recoverable from all sources (percent)			
	Amalgamation	Cyanidation	Amalgamation	Cyanidation	Smelting[1]	Placers
1973	15,381	583,311	1.3	49.6	48.1	1.0
1974	11,749	618,137	1.0	54.9	43.0	1.1
1975	13,783	617,330	1.3	58.7	38.1	1.9
1976	18,207	587,540	1.7	56.1	39.6	2.6
1977	26,615	597,633	2.4	54.3	41.2	2.1

[1]Crude ores and concentrates.

Table 9.—Gold production at placer mines in the United States, by method of recovery

Method and year	Mines producing	Washing plants	Material washed (thousand cubic yards)	Gold recoverable: Thousand troy ounces	Gold recoverable: Value (thousands)	Gold recoverable: Average value per cubic yard
Bucketline dredging:						
1975	4	5	[1]2,715	14	$2,314	$0.852
1976	3	4	[1]2,816	17	2,124	.754
1977	3	4	1,377	12	1,742	1.265
Dragline dredging:						
1975	6	6	210	3	469	2.229
1976	3	3	245	5	606	2.474
1977	7	7	[2]10	[3]2	311	[4]5.932
Hydraulicking:						
1975	16	17	131	1	171	1.302
1976	14	14	129	1	157	1.212
1977	12	13	273	5	754	2.762
Nonfloating washing plants:						
1975	11	11	([2])	[3]2	269	([4])
1976	25	26	[2]136	[3]4	560	[4]2.097
1977	7	7	[2]106	[3]3	477	[4]2.319
Underground placer, small-scale mechanical and hand methods, and suction dredge:						
1975	12	8	27	([5])	47	1.752
1976	4	4	2	([5])	15	8.881
1977	7	7	41	1	159	3.901
Total placers:						
1975	49	47	[1,2]3,083	[3]20	[6]3,269	[4].973
1976	49	51	[1,2]3,328	[3,6]28	3,462	[r,4].958
1977	36	38	[2]1,807	[3]23	3,443	[4]1.638

[r]Revised.
[1]Does not include platinum-bearing material from which byproduct gold was recovered.
[2]Excludes tonnage of material treated at commercial sand and gravel operations recovering byproduct gold.
[3]Includes gold recovered at commercial sand and gravel operations recovering byproduct gold.
[4]Gold recovered as a byproduct at sand and gravel operations not used in calculating average value per cubic yard.
[5]Less than 1/2 unit.
[6]Data do not add to total shown because of independent rounding.

Table 10.—U.S. refinery production of gold

(Thousand troy ounces)

<table>
<tr><th>Source</th><th>1973</th><th>1974</th><th>1975</th><th>1976</th><th>1977</th></tr>
<tr><td>Concentrates and ores:[1]</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Domestic</td><td>1,210</td><td>1,021</td><td>1,093</td><td>954</td><td>956</td></tr>
<tr><td>Foreign</td><td>112</td><td>185</td><td>250</td><td>123</td><td>62</td></tr>
<tr><td>Old scrap</td><td rowspan="2">1,779</td><td rowspan="2">1,926</td><td>1,122</td><td>1,068</td><td>1,040</td></tr>
<tr><td>New scrap</td><td>1,574</td><td>1,436</td><td>1,414</td></tr>
<tr><td>Total</td><td>3,101</td><td>3,132</td><td>4,039</td><td>3,581</td><td>3,472</td></tr>
</table>

[1]Includes other primary sources.

Sources: 1973-74, Office of Domestic Gold and Silver Operations, U.S. Department of the Treasury; 1975-77, Bureau of Mines, U.S. Department of the Interior.

Table 11.—U.S. consumption of gold, by end use

(Thousand troy ounces)

End use[1]	1973	1974	1975	1976	1977
Jewelry and arts:					
Karat gold	NA	NA	1,747	2,153	2,236
Fine gold for electroplating	NA	NA	31	29	37
Gold filled and other	NA	NA	302	380	385
Total	3,473	2,402	2,080	2,562	2,658
Dental	679	509	595	694	728
Industrial:					
Karat gold	NA	NA	39	56	60
Fine gold for electroplating	NA	NA	592	686	656
Gold filled and other	NA	NA	428	491	489
Total	2,577	1,740	1,059	1,233	1,205
Investment[2]	--	--	258	159	268
Total consumption	6,729	4,651	[3]3,993	4,648	4,859

NA Not available.
[1]As reported by converters of refined gold.
[2]Fabricated bars, medallions, coins, and other products primarily for investment.
[3]Data do not add to total shown because of independent rounding.

Sources: 1973-74, Office of Domestic Gold and Silver Operations, U.S. Department of the Treasury; 1975-77, Bureau of Mines, U.S. Department of the Interior.

Table 12.—U.S. exports of gold in 1977, by country[1]

Destination	Ore, base bullion, and scrap		Refined bullion	
	Troy ounces	Value (thousands)	Troy ounces	Value (thousands)
Belgium-Luxembourg	141,313	$20,798	2,535	$371
Brazil	3,213	502	46,394	7,000
Canada	21,797	3,095	222,603	35,455
France	87	10	--	--
Germany, Federal Republic of	5,899	863	33,543	4,615
Hong Kong	--	--	1,007	133
Italy	--	--	14,364	2,086
Japan	48,520	6,763	--	--
Mexico	--	--	265,826	22,684
Netherlands	1,380	197	102,430	15,000
Netherlands Antilles	--	--	386	56
Panama	--	--	9	1
Paraguay	--	--	192	28
Spain	1,760	241	--	--
Sweden	8,939	1,294	--	--
Switzerland	21,102	3,094	4,236,746	450,806
United Kingdom	141,750	20,619	3,340,857	515,859
Venezuela	--	--	8,203	1,140
Total	395,760	[2]57,477	8,275,095	1,055,234

[1]Includes monetary exports of 1.5 million ounces to Switzerland and 0.16 million ounces to Mexico.
[2]Data do not add to total shown because of independent rounding.

Table 13.—U.S. imports (general) of gold in 1977, by country

Country	Ore, base bullion, and scrap		Refined bullion	
	Troy ounces	Value (thousands)	Troy ounces	Value (thousands)
Argentina	--	--	83,225	$11,140
Australia	32,089	$4,725	--	--
Belgium-Luxembourg	--	--	37,567	5,738
Bermuda	2	(1)	--	--
Brazil	--	--	225	29
Cameroon	--	--	2,112	212
Canada	54,308	7,805	1,692,100	249,918
Chile	5,816	850	64,836	9,493
Colombia	319	48	--	--
Dominican Republic	3,621	523	--	--
France	--	--	1,032	151
Germany, Federal Republic of	9,065	1,357	117	19
Guatemala	241	35	--	--
Guyana	--	--	263	39
Honduras	947	128	50	7
Hong Kong	1,669	225	94	13
Israel	12	2	--	--
Japan	10	2	18,252	2,477
Korea, Republic of	2,825	387	--	--
Malaysia	15,270	2,145	--	--
Mexico	3,977	559	614	80
Netherlands	81	10	1,081	161
Netherlands Antilles	388	55	--	--
New Zealand	2	(1)	--	--
Nicaragua	18,089	2,618	6,026	833
Panama	255	40	287	43
Paraguay	--	--	1,479	185
Peru	13,003	1,886	48,112	6,927
Philippines	53,102	8,323	16	2
Portugal	10	1	--	--
Singapore	10,260	1,492	64	10
South Africa, Republic of	1,775	269	12,704	1,857
Switzerland	9,666	1,467	619,510	94,863
Taiwan	58	8	--	--
Trinidad and Tobago	61	9	--	--
U.S.S.R.	--	--	1,410,811	220,134
United Kingdom	2,523	348	137,642	23,131
Yugoslavia	--	--	76,437	11,244
Total[2]	239,444	35,319	4,214,656	638,707

[1]Less than 1/2 unit.
[2]Data may not add to totals shown because of independent rounding.

Table 14.—Value of gold exported from and imported into the United States

(Thousand dollars)

Year	Exports	Imports
1975	492,932	456,638
1976	375,048	331,018
1977	1,112,711	674,026

Table 15.—Gold: World production,[1] by country

(Troy ounces)

Country[2]	1975	1976	1977[p]
North America:			
Canada	1,653,611	1,691,806	1,717,008
Costa Rica	18,000	9,600	12,249
Dominican Republic	195,488	413,788	348,473
El Salvador	8,713	3,007	2,156
Honduras	2,520	2,280	2,481
Mexico	144,710	162,811	212,709
Nicaragua	70,281	75,855	65,764
United States	1,052,252	1,048,037	1,100,347

See footnotes at end of table.

Table 15.—Gold: World production,[1] by country —Continued

(Troy ounces)

Country[2]	1975	1976	1977[p]
South America:			
Argentina	11,867	[e]12,000	[e]12,000
Bolivia	[r]53,019	41,519	24,293
Brazil[3]	172,038	158,246	[e]170,000
Chile[3]	130,651	129,143	112,736
Colombia	308,864	297,861	257,138
Ecuador	8,157	11,615	7,649
French Guiana	2,443	2,797	[e]2,800
Guyana	18,067	15,651	11,899
Peru	78,796	80,730	96,227
Surinam	141	39	--
Venezuela	18,326	16,506	17,490
Europe:			
Finland	22,216	26,299	27,392
France	47,004	50,991	[e]50,000
Germany, Federal Republic of	2,116	2,456	[e]2,380
Hungary[e]	300	290	300
Portugal	11,446	10,036	8,694
Romania[e]	60,000	60,000	65,000
Spain	124,584	[e]270,000	[e]270,000
Sweden	63,176	62,179	[e]60,000
U.S.S.R.[e]	7,500,000	7,700,000	7,850,000
Yugoslavia	177,922	157,088	[e]160,000
Africa:			
Angola[e]	1,000	1,000	1,000
Burundi	368	426	[e]450
Cameroon	96	251	182
Central African Empire[e]	529	400	100
Congo	528	482	[e]400
Ethiopia	19,981	30,000	10,000
Gabon	4,207	3,086	2,572
Ghana	523,889	532,473	480,884
Kenya	[r]98	37	89
Liberia	4,500	[e]4,500	[e]4,500
Madagascar	158	[e]160	76
Mali[e]	30	3,500	3,500
Mauritania	[e]42,000	22,120	[e]20,000
Nigeria	8	[e]10	[e]10
Rhodesia, Southern[e]	[r]600,000	[r]600,000	[r]600,000
Rwanda	425	936	[e]1,000
South Africa, Republic of	22,937,820	22,935,988	22,501,857
Sudan[e]	300	300	300
Tanzania[4]	48	10	--
Zaire[3]	103,217	102,882	81,661
Zambia[5]	[e]8,500	10,955	7,845
Asia:			
China, People's Republic of[e]	50,000	50,000	60,000
Democratic Kampuchea[e]	500	1,000	1,000
India[4]	90,826	100,696	91,758
Indonesia[6]	74,954	85,690	64,466
Japan[7]	143,503	137,669	170,431
Korea, North[e]	160,000	160,000	180,000
Korea, Republic of[4]	13,343	18,744	21,380
Malaysia:			
Peninsular Malaysia	2,484	3,574	4,306
Sarawak	1,192	965	608
Philippines	[r]502,577	501,210	559,937
Taiwan	22,110	26,952	14,995
Oceania:			
Australia	526,821	502,741	620,605
British Solomon Islands	804	[e]600	372
Fiji	68,744	65,757	49,067
New Zealand	2,747	3,276	[e]3,500
Papua New Guinea	611,356	668,014	739,730
Total	[r]38,476,371	39,089,034	38,965,766

[e]Estimate. [p]Preliminary. [r]Revised.

[1]Unless otherwise indicated, production is on the basis of mine output.

[2]Gold is also produced in Bulgaria and Czechoslovakia, and probably small quantities are produced in Burma, the German Democratic Republic, Guinea, Thailand, and several other countries. However, available data are insufficient to make reliable output estimates. Data are lacking on clandestine activities.

[3]Excludes unreported production from small placer mines, estimated at 150,000 ounces per year.

[4]Figures are reported as refined metal.

[5]Chiefly in blister copper and refinery muds.

[6]Excludes production from so-called "people's" mines.

[7]Refinery production for Japan was as follows: 1975—[r]1,123,489 ounces; 1976—1,043,676 ounces; 1977—1,219,155 ounces.

Graphite

By W. Thomas Cocke[1]

Natural graphite became more plentiful in 1977. Domestic consumption decreased slightly according to a canvass of major consumers. Domestic production was slightly less than that of 1976. Although some known graphite deposits were investigated, there were no new mine openings and only one mine remained in operation. National stockpile goals were reaffirmed to correspond to 3-year totals, but no acquisitions have been made.

Imports of natural graphite increased 9%. Total exports increased 13%. Prices were down 3% for crystalline and down 8% for amorphous in 1977. Domestic prices generally follow those of imported materials.

World production of graphite increased in 1977, with nearly all producers showing some increase. Supplies of amorphous graphite remained adequate and premium grades of crystalline became more plentiful. Substitutes of lower grade materials appear to have fallen off.

Production of manufactured graphite increased 11% over that of 1976, owing primarily to increases in production of electrodes, electric motor brushes, and graphite shapes.

Legislation and Government Programs.—On October 1, 1977, the Federal Preparedness Agency of the General Services Administration (GSA) reaffirmed national stockpile goals for strategic graphite to reflect the 3-year requirement proposed in 1976. Stockpile totals and objectives for each type of graphite are shown in table 2. There were no acquisitions of strategic graphite to reach the new goals, although there has been a reevaluation of GSA purchase specifications for strategic graphite materials. Careful consideration will be given to market conditions before any purchases are attempted. A decision will be made in 1978 concerning the extension of the 3-year trial suspension on the import duty for crystalline flake graphite.

Table 1.—Salient natural graphite statistics

	1973	1974	1975	1976	1977
United States:					
Consumption[e] [1] ____ short tons__	[r]69,000	[r]69,000	[r]54,000	[r]65,000	71,000
Exports ____ do____	7,953	12,189	10,586	12,236	13,783
Value ____ thousands__	$992	$1,693	$1,890	$2,388	$2,662
Imports for consumption[2] ____ short tons__	77,431	82,636	65,663	79,098	87,556
Value ____ thousands__	$4,494	$5,677	$5,698	$6,753	$8,058
World: Production ____ short tons__	435,150	548,284	[r]497,500	[r]497,564	503,510

[e]Estimate. [r]Revised.

[1]Apparent consumption has been substituted for the consumption survey results appearing as the total of table 4, since the latter are incomplete.

[2]Includes some manufactured graphite; see table 6.

DOMESTIC PRODUCTION

In 1977, natural graphite production was from a single source, the Southwestern Graphite Co. mine near Burnet, Tex. Shipments from the mine were less than in 1976 and continued to account for only a small portion of domestic supply. Graphite deposits in Alabama, Idaho, Montana, New York, and Pennsylvania have received attention from investigators contemplating the development or redevelopment of additional mines. However, no mine openings occurred by yearend.

Plans for the development of flake graphite deposits in the Alabama flake graphite district by International Carbon and Minerals Corp. and in northern Saskatchewan by Superior Graphite Co. appear slowed by the relatively inexpensive flake graphite materials now plentiful in the world market.

Reported production of manufactured graphite increased 11% to 318,315 tons. Total value of production increased 26% to $474 million. Electrode production was up 7% over that of 1976 to an alltime high of 221,493 tons, while scrap and powder was down 6% to a new low of 22,485 tons. Production of high-modulus fibers was up 8% in quantity while the price decreased 17% to less than $42 per pound. This would put the price for composite materials at about $25 per pound.

Manufactured graphite was produced at 25 plants in 1977, with some additional production for in-house use likely. The following is a list of principal producers in 1977:

Company	Plant location
Airco, Inc., Speer Div	Niagara Falls, N.Y.
Do	Punxsutawney, Pa.
Do	St. Marys, Pa.
Avco Corp., Avco Systems Div	Lowell, Mass.
The Carborundum Co., Graphite Products Div	Hickman, Ky.
Do	Sanborn, N.Y.
Celanese Corp., Celanese Research Lab	Summit, N.J.
Fiber Materials, Inc	Graniteville, Mass.
Great Lakes Carbon Corp	Rosamond, Calif.
Do	Niagara Falls, N.Y.
Do	Morganton, N.C.
Hercules, Inc	Bacchus, Utah.
HITCO	Gardena, Calif.
Ohio Carbon Co	Cleveland, Ohio.
Pfizer, Inc., Minerals Pigments & Metals Div	Easton, Pa.
Poco Graphite, Inc	Decatur, Tex.
Polycarbon, Inc	North Hollywood, Calif.
Stackpole Carbon Co	Lowell, Mass.
Do	St. Marys, Pa.
Super Temp Co	Santa Fe Springs, Calif.
Superior Graphite Co	Chicago, Ill.
Union Carbide Corp	Niagara Falls, N.Y.
Do	Yabucoa, P.R.
Do	Columbia, Tenn.
Do	Clarksburg, W.Va.

The Carbon Products Div. of Union Carbide Corp. put a halt to construction of the proposed electrode plant at Clarksville, Tenn. There is the possibility of a 2- to 3-year hold on this project. Superior Graphite Co. of Chicago completed construction of a manufacturing facility in Hopkinsville, Ky.[2] The new facility is producing synthetic graphite and desulfurized petroleum coke.

Table 2.—Government yearend stocks of natural graphite

(Short tons)

Type of graphite	Goal	National stockpile inventory (Dec. 31, 1977)
Malagasy crystalline flake	20,472	17,939
Sri Lanka amorphous lump	6,271	5,499
Crystalline, other than Malagasy and Sri Lanka	34,798	1,933
Non-stockpile-grade	--	867

Source: General Services Administration. Stockpile Report to the Congress, October 1977-March 1978.

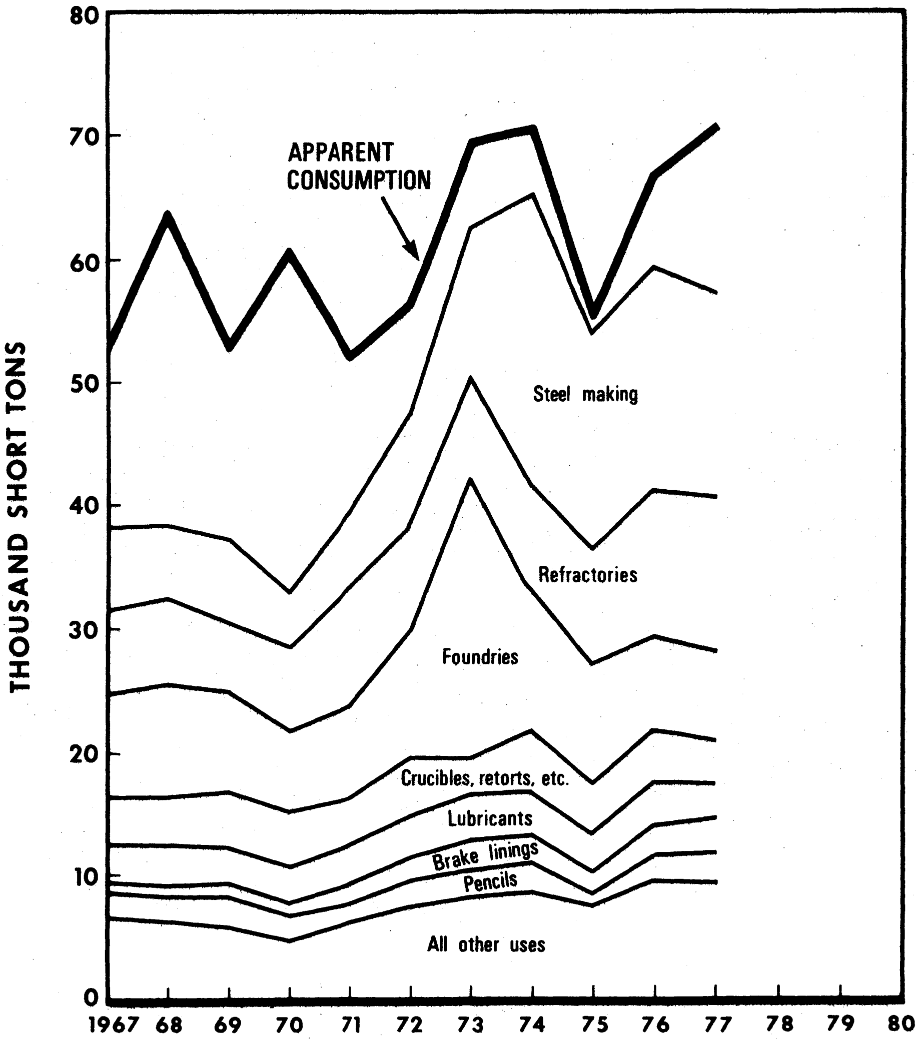


Figure 1.—Graphite end use patterns, 1967-77.

CONSUMPTION AND USES

Reported consumption of natural graphite in 1977 (table 4) decreased more than 3% to 57,303 tons. Consumption increased for batteries (33%), brake linings (23%), pencils (9%), powdered metals (43%), and refractories (5%). All other categories showed decreases. The decrease in manufacture of crucibles was due to Vesuvius Crucible Co. being on strike all of 1977. The three major uses, steelmaking, refractories, and foundries, accounted for 63% of reported consumption.

The actual amount of natural graphite consumed was greater than that shown in table 4, which reports only the results of a canvass of major known consumers. Estimated graphite consumption, based on apparent consumption, was 71,000 tons in 1977.

Figure 1 lists graphite end use statistics obtained from the consumption canvass. Although the canvass probably gives a good indication of consumption patterns, caution is advised in use of these data for absolute amounts owing to incomplete coverage and inconsistencies in company reporting.

Table 3.—Production of manufactured graphite in the United States in 1977, by use

Use	Quantity (short tons)	Value (thousands)
Synthetic graphite products:		
Anodes	20,116	$20,537
Electrodes	221,493	314,438
Crucibles and vessels	4,970	31,170
Refractories	W	W
Electric motor brushes and machined shapes	W	W
Unmachined graphite shapes	14,668	20,463
Cloth and fibers (low-modulus)	87	6,600
High-modulus fibers	53	4,450
Other	34,438	46,928
Total	295,825	444,586
Synthetic graphite powder and scrap	22,485	29,450
Grand total	318,310	474,036

W Withheld to avoid disclosing company proprietary data; included with "Other."

Table 4.—Consumption[1] of natural graphite in the United States in 1977, by use

Use	Crystalline		Amorphous[2]		Total	
	Quantity (short tons)	Value	Quantity (short tons)	Value	Quantity (short tons)	Value
Batteries	W	W	W	W	1,509	$1,513,720
Brake linings	801	$534,133	2,068	$1,219,769	2,869	1,753,902
Carbon products[3]	851	716,507	908	659,213	1,759	1,375,720
Crucibles, retorts, stoppers, sleeves, nozzles	W	W	W	W	3,597	1,486,228
Foundries	1,736	546,893	5,385	1,024,074	7,121	1,570,967
Lubricants[4]	758	677,514	1,944	743,915	2,702	1,421,429
Pencils	1,776	1,370,225	594	286,856	2,370	1,657,081
Powdered metals	665	802,512	126	137,005	791	939,517
Refractories	2,524	441,436	9,899	1,364,292	12,423	1,805,728
Rubber	W	W	W	W	359	182,065
Steelmaking	88	53,878	16,503	3,445,781	16,591	3,499,659
Other[5]	9,040	4,083,692	1,637	760,411	5,212	1,662,090
Total	18,239	9,226,790	39,064	9,641,316	57,303	18,868,106

W Withheld to avoid disclosing company proprietary data; included with "Other Crystalline" and "Other Amorphous."
[1]Consumption data incomplete. Small consumers excluded.
[2]Includes mixtures of natural and manufactured graphite.
[3]Includes bearings and carbon brushes.
[4]Includes ammunition, packings, and seed coating.
[5]Includes paints and polishes, antiknock and other compounds, drilling mud, electrical and electronic products, insulation, magnetic tape, small packages, and miscellaneous and proprietary uses.

PRICES

Average prices of graphite imports decreased in 1977. Prices were down 3% for crystalline and 8% for amorphous. Of the eight major sources of supply (98.5%), only materials from the Federal Republic of Germany, Norway, and the U.S.S.R. increased in price from 1976.

Actual prices are often negotiated between the buyer and seller, so price quotations represent the average of a range of prices. The source of information for imported graphite is the average value per ton computed from table 6; however, these data mainly represent shipments of unprocessed graphite.

The following tabulation[3] shows representative price ranges for several countries from which natural graphite is imported.

	Per short ton	
	1976	1977
Flake and crystalline graphite, bags:		
China, People's Republic of	--	$680- $998
Germany, Federal Republic of	$272-$1,270	227-1,089
Madagascar	136- 680	136- 431
Norway	150- 236	154- 254
Sri Lanka	163- 405	195- 603
Amorphous, nonflake, cryptocrystalline graphite (80% to 85% carbon):		
Korea, Republic of (bags)	36	36- 45
Mexico (bulk)	44- 50	32- 36

FOREIGN TRADE

The broad upward trend in exports of natural graphite continued in 1977. Exports increased 13% in 1977 to 13,783 tons. Poland became the principal buyer with 3,242 tons. Other major recipient countries were Canada (2,898 tons), the Federal Republic of Germany (2,796 tons), and the United Kingdom (1,361 tons). Graphite was also exported to 35 other countries.

Imports of natural graphite increased 8% to 84,369 tons in 1977, exceeding the previous high of 81,070 tons in 1974. A 5% increase in total imports of amorphous graphite from Mexico (54,927) and the Republic of Korea (12,696) and a 26% increase in imports of all other natural graphite brought the 1977 ratio of amorphous to crystalline down to 4:1. The ratio was nearly 5:1 in 1976. This is a result of the easily accessible supply of crystalline flake materials, imports of which were up 43% over that of 1976.

Table 5.—U.S. exports of natural graphite,[1] by country

Destination	1976		1977	
	Quantity (short tons)	Value	Quantity (short tons)	Value
Argentina	197	$45,553	106	$27,580
Australia	514	77,824	614	86,867
Austria	6	4,394	65	5,975
Belgium-Luxembourg	35	6,533	57	9,225
Brazil	137	44,861	42	9,595
Canada	3,394	773,893	2,898	624,187
Chile	11	4,685	23	13,320
Colombia	198	69,104	58	20,402
Denmark	76	10,941	54	8,754
Finland	26	3,243	8	1,516
France	435	122,829	99	23,260
Germany, Federal Republic of	1,638	326,999	2,796	481,265
India	41	5,316	51	6,656
Iran	17	6,250	21	4,230
Ireland	62	9,382	81	14,603
Israel	24	4,576	38	14,645
Italy	28	3,166	195	30,188
Japan	1,062	159,286	482	129,474
Kenya	--	--	53	4,703
Korea, Republic of	68	8,230	49	7,176
Malaysia	10	1,099	--	--
Mexico	451	65,269	540	150,492
Netherlands	500	78,293	21	8,368
New Zealand	72	9,784	60	4,993
Peru	48	9,346	1	590
Philippines	105	34,621	45	10,084
Poland	1,127	154,921	3,242	470,670
Singapore	29	13,020	47	6,162
South Africa, Republic of	181	19,373	--	--
Spain	352	34,114	--	--
Sweden	97	11,229	39	7,452
Switzerland	33	6,462	10	11,124
Taiwan	--	--	67	7,598
Thailand	37	4,131	--	--
United Kingdom	649	84,819	1,361	269,495
Venezuela	449	154,768	459	173,679
Other	r127	r20,132	101	17,379
Total	12,236	2,388,446	13,783	2,661,707

rRevised.
[1]Amorphous, crystalline flake, lump or chip, and natural, not elsewhere classified.

Table 6.—U.S. imports for consumption of natural and artificial graphite, by country

Year and country	Natural: Crystalline flake — Quantity (short tons)	Natural: Crystalline flake — Value (thousands)	Natural: Crystalline lump, chip or dust — Quantity (short tons)	Natural: Crystalline lump, chip or dust — Value (thousands)	Natural: Other natural crude and refined — Quantity (short tons)	Natural: Other natural crude and refined — Value (thousands)	Artificial[1] — Quantity (short tons)	Artificial[1] — Value (thousands)	Total — Quantity (short tons)	Total — Value (thousands)
1975	4,270	$1,118	250	$91	59,770	$4,149	1,373	$340	65,663	$5,698
1976:										
Austria	--	--	--	--	132	25	--	--	132	25
Canada	--	--	--	--	44	26	434	60	478	86
China, People's Republic of	120	32	--	--	2,479	669	55	19	2,654	720
France	--	--	10	3	61	27	1	1	72	31
Germany, Federal Republic of	259	125	--	--	1,180	399	317	89	1,756	613
India	--	--	--	--	17	15	--	--	17	15
Italy	--	--	5	7	--	--	([2])	1	5	8
Japan	--	--	20	7	60	21	354	135	434	163
Korea, Republic of	--	--	--	--	13,007	803	--	--	13,007	803
Madagascar	4,071	1,053	11	3	664	153	--	--	4,746	1,209
Mexico	--	--	--	--	51,398	1,600	--	--	51,398	1,600
Norway	143	35	--	--	411	73	--	--	554	108
Panama	--	--	--	--	221	190	--	--	221	190
Sri Lanka	57	14	255	104	1,444	528	--	--	1,756	646
Switzerland	--	--	--	--	20	15	239	188	259	203
Thailand	--	--	--	--	57	20	--	--	57	20
United Kingdom	37	13	--	--	71	15	--	--	108	28
U.S.S.R	--	--	--	--	1,360	263	--	--	1,360	263
Vietnam	--	--	84	22	--	--	--	--	84	22
Total	4,687	1,272	385	146	72,626	4,842	1,400	493	79,098	6,753
1977:										
Australia	--	--	--	--	--	--	([2])	2	([2])	2
Austria	--	--	--	--	21	5	--	--	21	5
Brazil	300	76	152	52	20	4	--	--	472	132
Canada	17	17	--	--	284	113	167	33	468	163
China, People's Republic of	33	12	--	--	2,531	651	--	--	2,564	663
Colombia	--	--	--	--	3	1	--	--	3	1
France	--	--	--	--	--	--	1	4	1	4
Germany, Federal Republic of	381	187	--	--	980	382	398	142	1,759	711
India	--	--	--	--	22	20	--	--	22	20
Italy	20	20	--	--	20	4	3	7	43	31
Japan	59	17	--	--	80	29	2,389	613	2,528	659
Korea, Republic of	--	--	--	--	12,696	655	--	--	12,696	655
Madagascar	4,523	1,058	--	--	456	119	--	--	4,979	1,177
Malaysia	--	--	--	--	68	16	--	--	68	16
Mexico	--	--	--	--	54,927	1,677	--	--	54,927	1,677
Norway	1,159	350	--	--	632	161	--	--	1,791	511
South Africa, Republic of	--	--	--	--	124	19	--	--	124	19
Sri Lanka	188	72	157	77	1,778	627	--	--	2,123	776
Sweden	1	1	--	--	20	28	--	--	21	29
Switzerland	--	--	--	--	--	--	229	194	229	194
Taiwan	--	--	--	--	88	38	--	--	88	38
U.S.S.R	--	--	--	--	2,629	574	--	--	2,629	574
United Kingdom	--	--	--	--	([2])	1	--	--	([2])	1
Total	6,681	1,810	309	129	77,379	5,124	3,187	995	87,556	8,058

[1]Includes only that received in raw material form; excludes products made of graphite.
[2]Less than 1/2 unit.

WORLD REVIEW

World production of natural graphite increased in 1977. Mexico and the Republic of Korea continue to be the main producers of amorphous graphite. Supplies of crystalline graphite were plentiful for the first time since 1974.

Canada.—Although a go/no go decision had been promised by 1977 on the $4 million Deep Bay Graphite deposit in Saskatchewan,[4] none was reached.

India.—Orissa State is the leading producer of graphite, accounting for 50% to

60% of annual production. Important deposits are located in the Bolangir, Sambalpur, Korapur, and Dhenkanal districts. Interest appears to be growing for establishing a domestic graphite-based manufacturing industry.[5]

Japan.—Production of natural graphite is restricted to about 350 tons per year by Amor Graphite Co.[6] As a result, substantial imports are required to meet the 60,000- to 80,000-ton annual demand.

Kenya.—The small graphite deposit being mined in the Machacos district, although still a promising deposit, was closed down.[7]

Pakistan.—High-quality crystalline graphite ore deposits were discovered in the Malakand area.[8] Initial reserves are estimated to be 10 to 20 million tons. Commercial quantities of cryptocrystalline graphite were outlined in the Azad Kashmir district.[9] Reserves of 1.2 million tons of 15% to 20% carbon were indicated.

Sri Lanka.—At present, graphite production is confined to two principal mines, Bogala in Kegalle district and the Kahategaha and Kolongaha (both linked underground) mines in Kurunegala district.[10] Two other mines, Rangala in Kegalle district and Ragedera in Kurunegala district, are under development. Geological investigations are being conducted at Siyambullapitiya in Kegalle district.

Thailand.—Graphite production to date has amounted to only the 30 tons produced at Chiang Rai in 1975.[11]

Table 7.—Graphite: World production, by country

(Short tons)

Country[1]	1975	1976	1977[p]
Argentina	44	60	[e]150
Austria	33,715	36,439	[e]38,600
Brazil (marketable)	[r]5,798	6,634	[e]6,700
Burma	96	(2)	--
China, People's Republic of[e]	55,000	55,000	55,000
Germany, Federal Republic of[3]	14,944	15,461	[e]15,900
India	[r]34,058	35,842	[e]36,400
Italy	[r]1,645	4,242	[e]2,700
Korea, North[e]	85,000	85,000	85,000
Korea, Republic of	52,064	45,955	[e]50,000
Madagascar	19,592	15,886	[e]16,500
Mexico	67,036	66,510	[e]66,100
Norway	[r]9,838	9,213	[e]8,800
Romania[e]	6,600	6,600	6,600
Sri Lanka	11,493	9,138	[e]9,400
South Africa, Republic of	577	584	[e]660
U.S.S.R.[e]	100,000	105,000	105,000
United States	W	W	W
Total	[r]497,500	497,564	503,510

[e]Estimate. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data.
[1]In addition to the countries listed, Czechoslovakia, Southern Rhodesia, and the Territory of South-West Africa (Namibia) are believed to produce graphite, but available information is inadequate for formulation of reliable estimates of output levels.
[2]Revised to zero.
[3]Data represent marketable production, including some produced from imported raw materials.

TECHNOLOGY

Research efforts continue to be concentrated on manufactured graphite, and there were few new developments pertaining to natural graphite.

The increased use of powder metal parts in the automotive industry has led to increased use of graphite both as a lubricant and as a carbon raiser in steel alloy powders.[12] Sintering processes involved in this fabrication technique diffuse the graphite uniformly in the alloy for applications such as bearing parts.[13]

Because of its outstanding high-temperature strength, graphite is also used as a mold material in ceramic applications.[14] There are various other foundry and refractory applications for which natural graphite is useful. It can be used as a water-based coating on metal, plastic, and ceramic surfaces and in crucibles for coreless induction furnaces.[15]

Graphite may no longer be added to externally applied cosmetics.[16] Use is being prohibited because graphite contains polynuclear aromatics, some of which, according to the Food and Drug Administration, are known carcinogens.

Atlantic Richfield Co. introduced a graphite-containing petroleum lubricant called Arco-graphite.[17] Tests show this new high-grade motor oil containing submicron-size graphite particles increases gas mileage and reduces engine wear. It is also marketed at a price below synthetic oils.

Graphite electrical discharge machine (EDM) electrodes have been machined into tiny rod diameters.[18] The material formulation is substantially different from other graphite materials. Extremely fine grain homogeneous structure plus controlled porosity and inherent high strength are characteristics especially adaptable for small EDM electrode sizes. Although graphite is the most widely used EDM material, a 75% tungsten-25% copper alloy reportedly outlasts graphite.[19] Time and cost savings in manufacture are reportedly 39% and 66%, respectively, compared with graphite electrodes.

A new high-temperature graphite tube furnace is designed to heat up quickly and maintain uniform temperatures up to 2,700° C under controlled atmosphere conditions.[20] The furnaces are electrically heated and contain a resistance-type graphite element. Reported uses for this furnace include graphitizing carbon, making graphite cloth, and producing carbon and graphite fibers.

A 20,000-pound-per-square-inch isostatic press capable of molding rectangular sections up to 12 by 26 by 72 inches is reported to be the largest presently in use by the graphite industry.[21] Another major advance in graphite molding technology is the development of large graphite parts for use in fuel cell plates.[22]

Uses of graphite fibers and composites continue to grow. In addition to numerous uses in aircraft and sporting goods applications,[23] automotive and other uses have developed.[24] Experiments in the past, utilizing graphite composites in automobile springs, drive shafts, bumpers, and engine push rods, have led to an experimental car with wholesale substitution of composite parts for steel in the body, chassis, and power train.[25] The intermediate-sized, six-passenger car will weigh 1,250 pounds less than its conventional counterpart. Substitution of graphite composites in truck bodies is also being considered.[26]

Other new uses for graphite fiber composites include extensive replacement of heavier materials in experimental electric automobiles.[27] Chemical plants, utilities, offshore drilling rigs, wastewater treatment plants, and food processing plants are all targets for composites applications.[28] Graphite epoxy tape-wound tubing has been used to build featherlight racing bicycles.[29] Graphite fibers are also used in ball valves[30] and for speaker cones.[31]

Liquid metal infiltration and fiber coating processes have been developed for making graphite metal composites.[32] Graphite-lead, for example, combines the strength, stiffness, and density of steel with the acoustical absorption capacity of pure lead.

A new supermaterial, tantalum carbide graphite composite, has been developed.[33] It is one of the hardest compounds ever manufactured. The compound has a melting point of 6,760° F and is reported to have extraordinary wear resistance and excellent resistance to thermal shock.

---

[1]Physical scientist, formerly with Division of Nonmetallic Minerals (now with International Data and Analysis).

[2]Chemical Marketing Reporter. Superior Graphite Adds Coke-Graphite Facility. V. 212, No. 12, Sept. 19, 1977, p. 76.
Foundry Management and Technology. News Briefs. V. 105, No. 11, November 1977, p. 10.
Industrial Minerals. Superior Graphite Facility. No. 121, October 1977, p. 15.
Skillings' Mining Review. Superior Graphite's Kentucky Facility. V. 66, No. 39, Sept. 24, 1977, p. 26.

[3]Engineering and Mining Journal. Markets. V. 178, No. 12, December 1977, p. 56.

[4]Engineering and Mining Journal. This Month in Mining. V. 178, No. 1, January 1977, p. 147.
Industrial Minerals. Graphite Decision by Yearend. No. 113, February 1977, p. 10.
Mining Magazine. Highlights. V. 136, No. 1, January 1977, p. 47.
World Mining. What's Going On in World Mining. V. 30, No. 2, February 1977, p. 80.

[5]U.S. Embassy, New Delhi, India. State Dept. Airgram A-225, Dec. 6, 1977, p. 8.

[6]Harbin, P. W. The Industrial Minerals of Japan. Industrial Minerals, No. 118, July 1977, pp. 41-42.

[7]Jolly, J. L. W. Trip Report: Mali, Niger, Nigeria, Kenya, and Zambia. U.S. BuMines Memo Dec. 1, 1977, p. 42. (available from author).

[8]Industrial Minerals. No. 117, June 1977, p. 67.
Mining Magazine. Highlights. V. 137, No. 1, July 1977, p. 65.

[9]Industrial Minerals. Graphite Refractory News. No. 115, April 1977, p. 14.
———. No. 118, July 1977, p. 59.
Mining Journal. Industry in Action. V. 289, No. 7404, p. 49.

[10]U.S. Embassy, Colombo, Sri Lanka. State Dept. Airgram A-16, Feb. 3, 1978, pp. 1-3.

[11]Industrial Minerals. The Industrial Minerals of Thailand. No. 117, June 1977, p. 37.

[12]American Metal Market. Trend Toward Big P/M Parts Seen Forcing Large Firm Concentration. V. 84, No. 65, Apr. 4, 1977, p. 20.

[13]Adams, J. S., and G. Douglas. Improved Bearing at Lower Cost Via Powder Metallurgy. Metal Prog., v. 112, No. 3, August 1977, pp. 39-42.

[14]Ceramic Industry. V. 110, No. 1, January 1978, p. 80.

[15]Foundry Management and Technology. New Foundry Products. V. 105, No. 2, February 1977, p. 60, 64.

[16]U.S. Code of Federal Regulations. Title 21—Food and Drugs; Chapter I—Food and Drug Administration, Department of Health, Education and Welfare; Subchapter A—General; Part 81—General Specifications and General Restrictions for Provisional Color Additives for Use in Food, Drugs and Cosmetics. Federal Register, v. 42, No. 229, Nov. 29, 1977, p. 60734.

[17]Chemical and Engineering News. New High-Grade Motor Oil Contains Graphite. V. 55, No. 29, July 18, 1977, pp. 5-6.

Chemical Week. Technology Newsletter. V. 121, No. 3, July 20, 1977, p. 39.

[18]Journal of Metals. Inclusions. V. 29, No. 12, December 1977, p. 5.

[19]Metal Progress. New Products. V. 111, No. 5, May 1977, p. 104.

[20]Electronic News. Harper Electric Offers Graphite Tube Furnaces. V. 22, No. 1136, June 27, 1977, p. 109.

Journal of Metals. Inclusions. V. 29, No. 9, September 1977, p. 6.

[21]Brick and Clay Record. Executive Report. V. 171, No. 1, July 1977, p. 7.

Materials Engineering. Prices and Supply. V. 85, No. 5, May 1977, p. 83.

[22]American Metal Market. Brush Wellman Receives Order for Graphite Fuel Cell Plates. V. 85, No. 152, Aug. 8, 1977, p. 28.

[23]Chemical Week. Stretching Carbon Fiber Uses. V. 120, No. 9, Mar. 2, 1977, pp. 32-33.

Furness, V. I. Working with Textiles. Chem. & Ind. (London), No. 24, Dec. 17, 1977, p. 974.

Iron Age. Aircraft's Composite Wing Drafted by Computer. V. 219, No. 10, Mar. 14, 1977, p. 46.

Materials Engineering. Composites News. V. 85, No. 6, June 1977, p. 58.

[24]Betz, R. O. Composites Poised for Plunge Into Auto Materials Pool. Iron Age, v. 219, No. 11, Mar. 21, 1977, pp. 58-61.

Miska, K. H. Detroit Looks to Advanced Composites To Shed Weight, Improve Fuel Economy. Mater. Eng., v. 86, No. 3, September 1977, pp. 66-68.

[25]American Metal Market. Ford Test Car To Have Composite Parts. V. 85, No. 211, Oct. 31, 1977, p. 2.

Chemical and Engineering News. Science & Technology. V. 55, No. 44, Oct. 31, 1977, p. 15.

Chemical Marketing Reporter. Graphite Automobile on Way for Ford. V. 212, No. 18, Oct. 31, 1977, p. 4.

[26]American Metal Market. International Harvester Testing a Composite To Replace Steel on Truck Cab, Frame. V. 85, No. 89, May 9, 1977, p. 20.

[27]Chemical Week. Research. V. 121, No. 8, Aug. 24, 1977, p. 37.

The Lamp (EXXON Corp.) Panorama. V. 59, No. 3, Fall 1977, p. 15.

[28]Industry Week. Business Trends. V. 192, No. 6, Mar. 14, 1977, p. 79.

[29]Materials Engineering. Versatility Marks Application of Tubing for Mechanical, Structural Uses. V. 86, No. 2, August 1977, pp. 45-47.

[30]———. Composites News. V. 86, No. 7, December 1977, p. 34.

[31]Scientific American. V. 236, No. 2, February 1977, p. 6.

[32]Metal Progress. Technology Forecast 1977. V. 111, No. 1, January 1977, p. 42.

[33]Chemical Week. Technology Newsletter. V. 121, No. 2, July 13, 1977, p. 55.

Industry Week. Emerging Technologies. V. 194, No. 3, Aug. 1, 1977, p. 31.

Science News. Technology. V. 112, No. 2, July 9, 1977, p. 25.

Gypsum

By J. W. Pressler[1]

The gypsum industry continued the expansion that started early in 1976, reflecting the 2 million housing unit starts in 1977 (including a record 1.45 million single-unit starts). Output of crude gypsum increased 12% to 13.4 million tons. Production of calcined gypsum increased 14% to 12.6 million tons. Sales of gypsum products increased 14% to 20.5 million tons. Imports of crude gypsum increased 14% to 7.1 million tons. Total value of gypsum products sold increased 39% to $911 million.

Table 1.—Salient gypsum statistics

(Thousand short tons and thousand dollars)

	1973	1974	1975	1976	1977
United States:					
Active mines and plants[1]	112	116	110	117	115
Crude:					
Mined	13,558	11,999	9,751	11,980	13,390
Value	$56,650	$52,894	$44,654	$59,888	$74,341
Imports for consumption	7,661	7,424	5,448	6,231	7,074
Byproduct gypsum sales	322	463	369	573	797
Calcined:					
Produced	12,592	10,993	9,181	11,036	12,590
Value	$205,326	$205,713	$186,478	$236,775	$277,835
Products sold (value)	$632,809	$623,102	r$525,051	$654,860	$910,526
Exports (value)	$7,360	$10,844	$10,481	$32,594	$15,703
Imports for consumption (value)	$21,937	$21,889	$19,817	$21,756	$31,398
World: Production	67,829	67,704	r65,279	r69,175	72,164

rRevised.

[1]Each mine, calcining plant, or combination mine and plant is counted as one establishment; includes plants that sold byproduct gypsum.

DOMESTIC PRODUCTION

The United States was the world's leading producer of gypsum, accounting for 18% of the total world output.

Forty-two companies mined crude gypsum at 69 mines in 22 States. Output increased 12% and was only 1% below the 1973 record. Leading producing States were Michigan, Texas, California, Iowa, Nevada, and Oklahoma. These six States produced more than 1 million tons each and together accounted for 70% of the total domestic production. Stocks of crude ore at mines at yearend were 2.6 million tons.

Leading companies were United States Gypsum Co. (12 mines), National Gypsum Co. and Georgia-Pacific Corp. (6 mines each), Celotex Div. of Jim Walter Corp. (4 mines), The Flintkote Co. (3 mines), and H. M. Holloway Inc. (1 mine). These 6 companies, operating 32 mines, produced 71% of the total crude gypsum.

Leading individual mines were United

States Gypsum's Plaster City mine in Imperial County, Calif.; National Gypsum's Tawas mine and United States Gypsum's Alabaster mine both in Iosco County, Mich.; H. M. Holloway's Lost Hills mine in Kern County, Calif.; Pacific Coast Building Products, Inc.'s Las Vegas mine in Clark County, Nev.; United States Gypsum's Southard mine in Blaine County, Okla.; and United States Gypsum's Sweetwater mine in Nolan County, Tex. These seven mines accounted for 34% of the national total. Average output per mine for the 69 U.S. mines was 194,000 tons, compared with 176,000 tons per mine in 1976 and 143,000 tons in 1975.

Thirteen companies calcined gypsum at 71 plants in 29 States. Output increased from 11 million tons of calcine valued at $237 million in 1976 to 12.6 million tons valued at $278 million in 1977, a tonnage increase of 14% compared with that of 1976. Output was only slightly below the 1973 record. Leading States were California, Texas, Iowa, and New York. These 4 States, with 24 plants, accounted for 39% of the national output.

Leading companies were United States Gypsum Co. (22 plants), National Gypsum Co. (18 plants), Georgia-Pacific Corp. (9 plants), The Flintkote Co. (6 plants), and Celotex Div. of Jim Walter Corp. (5 plants). These 5 companies, operating 60 plants, accounted for 86% of the national output.

Leading individual plants were United States Gypsum's Plaster City plant, Imperial County, Calif.; United States Gypsum's Shoals plant, Martin County, Ind.; United States Gypsum's Stony Point plant, Rockland County, N.Y.; Weyerhaeuser's Briar plant, Howard County, Ark.; Georgia-Pacific's Acme plant, Hardeman County, Tex.; United States Gypsum's Southard plant, Blaine County, Okla.; United States Gypsum's Sweetwater plant, Nolan County, Tex.; and United States Gypsum's Fort Dodge plant, Webster County, Iowa. These eight plants accounted for 23% of the national output. Average output per plant for the 71 U.S. plants was 177,000 tons, compared with 153,000 tons (revised) per plant in 1976 and 124,000 tons in 1975.

Occidental Petroleum Corp., Allied Chemical Corp., Valley Nitrogen Producers Inc., and California Industrial Minerals Co. (all in California), Occidental Petroleum Corp. in Florida, Miles Laboratories, Inc., in Indiana, Texasgulf Inc., in North Carolina, and Allied Chemical Corp. in West Virginia sold 797,000 tons of byproduct gypsum valued at $6.4 million for agricultural purposes.

On February 19, 1977, Pacific Coast Building Products, Inc., of Sacramento, Calif., purchased the Las Vegas, Nev., gypsum operations of Johns-Manville Corp., consisting basically of the Apex open pit mine and the Las Vegas wallboard manufacturing plant with an annual capacity of 240 million square feet. Pacific Coast Building Products also has a wallboard plant in Newark, Calif.

In the first quarter of 1977, National Gypsum Co. announced initiation of construction of a multimillion-dollar gypsum wallboard plant on the Hudson River in Rensselaer County, N.Y., to be completed in 1978. Another wallboard plant under construction in Wilmington, N.C., was also scheduled for 1978 completion.

Eight gypsumboard plant expansions and one plant startup increased the national production capacity an additional 0.5 billion square feet per year. The available capacity of operating gypsumboard plants in the United States at yearend 1977 was 17 billion square feet per year, a 3% increase compared with that of 1976. Total 1977 gypsumboard production in the United States was 15.4 billion square feet. This indicated a 91% national utilization of capacity for the year. Kaiser Cement & Gypsum Corp.'s wallboard plant in Rosario, N. Mex., rehabilitated and started up in the first quarter of 1977, was sold to Drywall Supply, Inc., of Denver, Colo. A wholly owned subsidiary of Drywall Supply, Western Gypsum Co., was operating the plant. The Locust Cove underground gypsum mine of United States Gypsum Co., Smyth County, Va., was reopened.

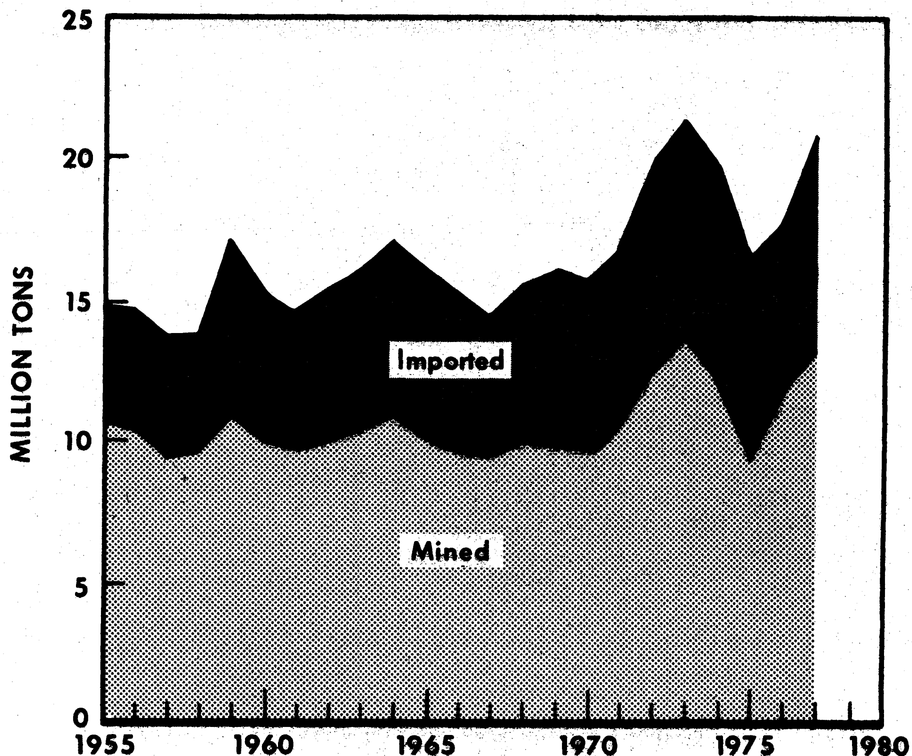


Figure 1.—Supply of crude gypsum in the United States.

Table 2.—Crude gypsum mined in the United States, by State

(Thousand short tons and thousand dollars)

State	1976			1977		
	Active mines	Quantity	Value	Active mines	Quantity	Value
Arkansas, Kansas, Louisiana	7	1,041	4,053	5	1,129	4,585
Arizona	4	139	529	4	187	775
California	4	1,647	7,897	5	1,629	8,500
Colorado	5	215	984	5	211	1,121
Idaho, Montana, South Dakota, Washington	5	137	841	5	168	1,152
Indiana, New York, Ohio, Virginia	6	1,448	8,488	5	1,487	10,456
Iowa	6	1,486	8,288	6	1,593	10,035
Michigan	5	1,837	9,842	5	1,924	8,778
Nevada	4	792	3,884	4	1,242	6,834
New Mexico	W	W	W	3	182	1,227
Oklahoma	7	1,120	5,822	7	1,238	6,959
Texas	7	1,531	6,322	7	1,718	8,837
Utah	5	270	1,657	5	324	2,510
Wyoming	3	317	1,280	3	356	2,571
Total[1]	68	11,980	59,888	69	13,390	74,341

W Withheld to avoid disclosing company proprietary data; included with Kansas, Arkansas, and Louisiana (1976 only).
[1]Data may not add to totals shown because of independent rounding.

Table 3.—Calcined gypsum produced in the United States, by State

(Thousand short tons and thousand dollars)

State	1976			1977		
	Active plants	Quantity	Value	Active plants	Quantity	Value
Arkansas, Illinois, Indiana, Kansas, Louisiana, Oklahoma	12	2,193	49,076	12	2,441	52,021
Arizona, Colorado, New Mexico, Utah	5	326	8,144	6	508	11,789
California	7	1,476	21,481	7	1,740	32,632
Delaware, Maryland, New Jersey, Pennsylvania, Virginia	9	1,286	29,511	8	1,350	36,778
Florida	3	378	7,359	3	571	13,112
Georgia	3	548	13,181	3	637	16,870
Iowa	5	1,003	20,823	5	1,049	24,118
Massachusetts, New Hampshire, New York	8	962	18,474	7	1,061	24,978
Michigan	4	456	13,924	4	529	13,087
Montana, Washington, Wyoming	4	423	10,023	4	467	12,335
Nevada	3	495	10,005	3	593	9,119
Ohio	3	396	7,839	3	368	8,408
Texas	6	1,094	26,934	6	1,277	22,586
Total[1]	72	11,036	236,775	71	12,590	277,835

[1]Data may not add to totals shown because of independent rounding.

CONSUMPTION AND USES

Apparent consumption of crude gypsum (production plus imports, minus exports) increased 13% to 20.3 million tons. Imports provided 35% of the crude gypsum consumed. Apparent consumption of calcined gypsum increased 14% to 12.6 million tons.

Stocks of crude gypsum at mines and calcining plants at yearend were 2.6 million tons. Of this, 1.9 million tons (73%) was at calcining plants in coastal States.

Of the total gypsum products sold or used, 5.8 million tons (28%) was uncalcined. Of the total uncalcined gypsum, 4 million tons (68%) was used for portland cement and 1.7 million tons (29%) was used in agriculture. The leading sales regions for gypsum used in cement were the Pacific, West South-Central, and West North-Central; these three regions accounted for 47% of the total. For agricultural gypsum, the Pacific sales region accounted for 68% of the total.

Of the total calcined gypsum, 95% was used for prefabricated products and 5% for industrial and building plasters. Of the prefabricated products, 80% was regular wallboard, 13% was fire-resistant Type X wallboard, and only 1% was lath. Of the regular wallboard, 86% was 1/2 inch and 7% was 3/8 inch. The leading sales regions for prefabricated products were the Pacific, South Atlantic, and West South-Central; these three regions accounted for 49% of the total. For plasters, the East North-Central, Middle Atlantic, and Pacific regions accounted for 57% of the total.

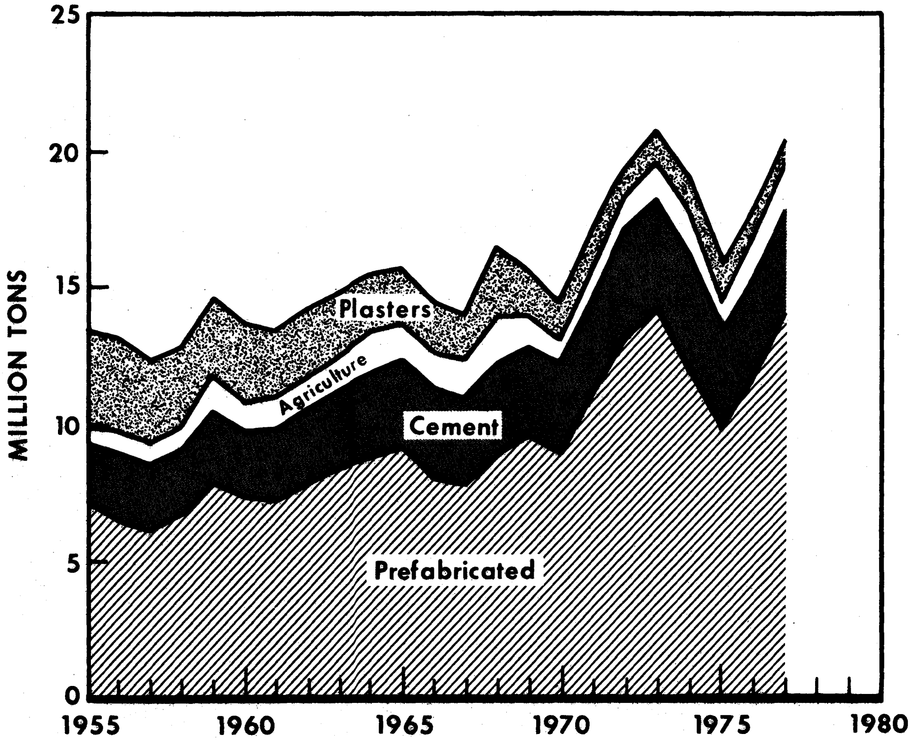


Figure 2.—Sales of gypsum products, by use.

Table 4.—Gypsum products (made from domestic, imported, and byproduct gypsum) sold or used in the United States, by use

(Thousand short tons and thousand dollars)

Use	1976		1977	
	Quantity	Value	Quantity	Value
Uncalcined:				
Portland cement	3,417	24,908	3,950	30,135
Agriculture[1]	1,714	12,229	1,675	13,176
Other	244	3,662	177	3,774
Total	5,375	40,799	5,802	47,085
Calcined:				
Industrial plaster	306	16,556	358	20,674
Building plaster:				
Regular base coat	155	6,193	133	5,855
Mill-mixed base coat	128	6,056	114	6,053
Veneer plaster	86	6,270	97	7,344
Gaging, molding, and Keene's cement	57	2,950	33	2,007
Other[2]	64	2,412	50	1,924
Total	490	23,881	427	23,183
Prefabricated products[3]	11,849	573,624	13,956	819,584
Total calcined	12,645	614,061	14,741	863,441
Grand total	18,020	654,860	20,543	910,526

[1]Includes 573,300 tons of byproduct gypsum in 1976 and 797,049 tons in 1977.
[2]Includes roof deck concrete and other uses.
[3]Includes weight of paper, metal, or other materials.

Table 5.—Prefabricated products sold or used in the United States, by product

Product	1976			1977		
	Thousand square feet	Thousand short tons[1]	Value (thousands)	Thousand square feet	Thousand short tons[1]	Value (thousands)
Lath:						
3/8 inch	173,437	135	$7,461	156,348	120	$8,315
1/2 inch	9,267	8	430	7,788	7	438
Total[2]	182,704	144	7,892	164,136	127	8,754
Veneer base	362,981	345	16,677	419,798	438	23,182
Sheathing	272,567	254	12,818	291,435	280	17,136
Regular gypsumboard:						
3/8 inch	983,762	757	39,124	893,288	685	42,970
1/2 inch	8,766,838	7,747	352,634	10,609,567	9,311	525,787
5/8 inch	561,503	530	28,951	647,223	609	40,056
1 inch	17,068	32	2,085	23,166	37	2,372
Other[3]	164,737	118	7,032	166,004	116	8,063
Total[2]	10,493,908	9,183	429,826	12,339,248	10,757	619,248
Type X gypsumboard	1,593,577	1,737	80,717	1,927,328	2,134	119,338
Predecorated wallboard	194,549	171	22,974	235,682	207	28,436
Other	17,293	14	2,721	13,613	13	3,490
Grand total[2]	13,117,579	11,849	573,624	15,391,240	13,956	819,584

[1]Includes weight of paper, metal, or other material.
[2]Data may not add to totals shown because of independent rounding.
[3]Includes 1/4, 5/16, 7/16, and 3/4-inch gypsumboard.

ENERGY

More efficient production scheduling and a higher rate of operational capacity contributed to a continued increase in the energy efficiency of the gypsum industry in 1977, with a 12.7% improvement compared with the base year of 1972. At yearend, the Gypsum Association announced improvement targets of 15% by 1980 and 22% by 1985. British thermal unit consumption per thousand square feet of gypsumboard sales in 1977 was 2.70 million, compared with 2.76 million in 1976.[2]

As reported by the Gypsum Association, fuel sources for the gypsum industry in the first half of 1977 follows: Natural gas, 72.74%; electricity, 5.73%; coal, 2.11%; propane, 1.70%; fuel oil No. 1, 1.79%; fuel oil No. 2, 13.63%; and fuel oil Nos. 4 and 6, 2.30%.

PRICES

The average value of crude gypsum increased from $5.00 per ton in 1976 to $5.55 in 1977. The average value of calcined gypsum increased from $21.45 per ton in 1976 to $22.07 in 1977. The average value of byproduct gypsum sold increased from $7.36 in 1976 to $8.04 per ton in 1977.

The average value of gypsum products sold or used increased from $36.34 in 1976 to $44.32 per ton in 1977. Prefabricated products were valued at $58.73 per ton, industrial plasters at $57.75 per ton, building plaster at $54.29 per ton, and uncalcined products at $8.12 per ton.

Quoted prices for gypsum products are published monthly in Engineering News-Record. Prices at yearend showed a wide range, based on delivered prices. Regular 1/2-inch wallboard prices ranged from $54.90 per thousand square feet at Dallas to $115 at Minneapolis. Prices for building plaster ranged from $57.45 per ton at Los Angeles to $100.00 at Denver.

FOREIGN TRADE

In 1977, the gypsum industry continued to rely on imports for slightly more than one-third of apparent consumption. Imports of crude gypsum were from Canada (75%), Mexico (20%), Jamaica (3%), and the Dominican Republic, Japan, Italy, and the United Kingdom, (the other 2%). Imports increased 14% to 7.1 million tons. Most of the imported crude gypsum was mined by subsidiaries of U.S. companies in Canada and Mexico. Total value of gypsum and gypsum products imported in 1977 was $31.4 million, an increase of 44% compared with the revised figure for 1976. Most of the increase was represented by the importation of 65 million square feet of wallboard from Canada (84%) and Mexico (16%). Total value of gypsum product exports to all countries was $15.7 million, a decrease of 52% compared with that of 1976.

Table 6.—U.S. exports of gypsum and gypsum products

(Thousand short tons and thousand dollars)

Year	Crude, crushed, or calcined		Other manufactures n.e.c. (value)	Total value
	Quantity	Value		
1975	75	4,505	5,976	10,481
1976	284	6,739	25,855	32,594
1977	143	6,090	9,613	15,703

Table 7.—U.S. imports for consumption of gypsum and gypsum products

(Thousand short tons and thousand dollars)

Year	Crude		Ground or calcined		Alabaster manufactures[1] (value)	Other manufactures n.s.p.f.[2] (value)	Total value
	Quantity	Value	Quantity	Value			
1975	5,448	16,021	2	172	1,365	r2,259	r19,817
1976	6,231	18,061	22	224	1,572	r1,899	r21,756
1977	7,074	21,949	4	190	1,955	7,304	31,398

rRevised.
[1]Includes imports of jet manufactures, which are believed to be negligible.
[2]Revised in 1975 and 1976 to include "gypsum or plaster building boards and lath" (TSUSA 245.7000), previously comprised of "articles, not specifically provided for, of plaster of Paris, with or without reinforcement" (TSUSA 512.4100 and 512.4400).

Table 8.—U.S. imports for consumption of crude gypsum, by country

(Thousand short tons and thousand dollars)

Country	1976		1977	
	Quantity	Value	Quantity	Value
Australia	([1])	([1])	--	--
Brazil	8	10	--	--
Canada	4,468	13,811	5,307	18,282
Dominican Republic	84	1,496	70	582
Italy	([1])	7	([1])	10
Jamaica	356	574	238	543
Japan	--	--	12	151
Mexico	1,315	2,163	1,448	2,381
United Kingdom	--	--	([1])	([1])
Total	6,231	18,061	[2]7,074	21,949

[1]Less than 1/2 unit.
[2]Data do not add to total shown because of independent rounding.

WORLD REVIEW

Domestic and foreign resources of gypsum are adequate for any foreseeable time. World reserves are conservatively estimated at 2 billion tons.

Canada.—Production of gypsum in Canada is closely related to activity in the residential building sector in the Eastern United States and Canada. Normally, 75% of Canadian gypsum production has been exported to the United States. Canadian consumption has remained reasonably steady during the past 5 years at a level of 2.2 million tons, 72% in wallboard manufacturing plants, 25% as a set retardant in cement manufacturing, and 3% in plaster manufacturing.

Canada was the second leading producer of crude gypsum, accounting for 11% of the world total. About 80% of the gypsum mined in Canada was from the Atlantic Provinces of Nova Scotia (69%), Newfoundland (10%), and New Brunswick (1%). These quarries were operated by Canadian subsidiaries of U.S. gypsum products manufacturers, and 98% of their production was exported to the eastern seaboard of the United States.

The new underground gypsum mine of Westrock Industries Ltd., Drumbo, Ontario, was expected to be in production by May 1978. The difficult shaft-sinking technology developed on this project is discussed under Technology. The new mine will provide high-quality gypsum for 30 years at the planned rate of 1,000 tons per day; output will be used at the company's plant at Clarkson, 62 miles distant in the manufacture of gypsum wallboard and joint cements.

Egypt.—The Government announced

that a new deposit of gypsum had been discovered in the Western Desert near Sidi Abdel Rahman. Initial tests on the gypsum samples taken from the deposit showed it to be of high quality. To develop the new discovery, a company will be established with a joint capital of £E35 million ($45 million) by Egyptian and Kuwaiti interests. Eighty percent of the production from the deposit will be exported.[3]

Another Government press release reported the discovery of a new gypsum mine with reserves of 300 million tons in the Western Desert near Burg El Arab, west of Alexandria. Geologists estimated that the find will meet domestic requirements for approximately 70 years.[4]

France.—France was the fourth leading gypsum-producing country, with 9% of the world total.

Mexico.—In 1977, Mexico produced 1.65 million tons of crude gypsum, 1.45 million tons of which was exported to the United States. The remainder was used in the cement industry as a set retardant and as the raw material supply for two small gypsumboard plants owned by subsidiaries of United States Gypsum Co. and Kaiser Cement & Gypsum Corp. At San Marcos Island, Baja California, 1.34 million tons of crude gypsum was produced and exported by the Mexican subsidiary of Kaiser Cement & Gypsum Corp., Cia. Occidental Mexicana S.A. This deposit has large reserves of high-quality gypsum ore and serves the west coast of the United States. At yearend, Mexicanization of the subsidiary was proceeding according to the plan of the Mexican Government, which requires that 51% of the equity be sold to Mexican nationals and the Federal Government of Mexico.[5]

South Africa, Republic of.—South Africa's small gypsum industry once again experienced a dull year in 1977, reflecting for the third consecutive year a sluggish domestic market. Based on provisional data, approximately 440,000 tons was consumed, with volume and value of local sales off during the year by about 12% and 2%, respectively.

Gypsum occurs extensively in the western and northwestern Cape Province, in the Kimberley district of the Orange Free State, and in central Transvaal Province. The Kimberley district is South Africa's most productive area, in large measure because of the proximity of railroad transportation. The gypsum and gypsite horizons average 70% gypsum, and the mine-run ore is upgraded to 90% gypsum by washing, principally to remove the unwanted clays, followed by drying, for direct sale or calcination as required.[6]

Gypsum Industries, Ltd., the predecessor of which pioneered the manufacture of gypsumboard in South Africa in 1928, reported that output from its three processing plants was used in plasterboard manufacturing (61%), as a set retarder in cement manufacturing (37%), and in agriculture (2%).[7]

Sudan.—Gypsum deposits of Miocene age occur in three districts along the coast of the Red Sea north of Port Sudan. These deposits were formed by the evaporation of seawater in shallow lagoons, and one apparently accumulated in a fault trough connected to the sea. The total amount of gypsum reserves in the three districts was reported as 92 million tons in one report,[8] and as 224 million tons in another.[9]

U.S.S.R.—The U.S.S.R. produced 8% of the world's gypsum in 1977 and ranked fifth in total world production.

Table 9.—Gypsum: World production, by country

(Thousand short tons)

Country[1]	1975	1976	1977[p]
North America:			
Canada[2 3]	[r]6,305	6,616	7,759
Cuba[e]	94	94	100
Dominican Republic[4]	162	140	184
El Salvador[e]	7	7	8
Guatemala	14	15	22
Honduras	1	[r e]11	20
Jamaica	[r]264	279	237
Mexico	1,384	1,559	1,649
Nicaragua	[e]39	[r e]33	40
United States	9,751	11,980	13,390

See footnotes at end of table.

Table 9.—Gypsum: World production, by country —Continued

(Thousand short tons)

Country[1]	1975	1976	1977[p]
South America:			
Argentina	563	559	612
Bolivia[4]	1	[e]1	--
Brazil	[r]445	601	[e]610
Chile	199	133	[e]130
Colombia	220	[e]220	[e]220
Ecuador	[r] [e]33	[r] [e]44	48
Paraguay	17	18	15
Peru	[r] [e]330	189	[e]220
Venezuela	233	193	134
Europe:			
Austria[2]	[r]788	849	892
Belgium[2]	244	242	185
Bulgaria	304	[e]317	[e]330
Czechoslovakia	702	728	660
France[2]	[r]6,475	[e]6,500	[e]6,400
German Democratic Republic	337	332	350
Germany, Federal Republic of (marketable)[2]	2,297	2,315	[e]2,315
Greece	459	490	[e]450
Ireland	[r]365	391	[e]400
Italy	[r] [e]4,630	[r] [e]4,630	4,608
Luxembourg	5	2	3
Poland[e] [5]	1,320	[r]1,380	1,380
Portugal	165	176	[e]180
Spain	4,652	[e]4,650	[e]4,740
Switzerland[e]	[r]80	[r]80	80
U.S.S.R.[e] [5]	[r]5,500	[r]5,500	5,700
United Kingdom[2]	3,835	3,693	[e]3,600
Yugoslavia	[r]496	465	[e]500
Africa:			
Algeria[e]	[r]190	[r]190	190
Angola[e]	44	44	44
Egypt	[r]662	514	561
Ethiopia	--	--	[e]1
Kenya[2]	[e]110	86	29
Libya	[e]4	66	320
Mauritania	14	12	11
Niger	1	3	3
South Africa, Republic of	594	532	485
Sudan[2]	33	20	5
Tanzania	14	[e]15	[e]15
Tunisia	[e]55	43	--
Zambia	8	4	4
Asia:			
Burma	43	50	37
China, People's Republic of[e]	[r]990	1,100	1,100
Cyprus	[r]25	60	56
India	[r]898	801	847
Indonesia	([6])	([6])	--
Iran	5,952	7,165	[e]7,400
Iraq	171	[e]180	[e]180
Israel	220	220	[e]220
Japan[7]	206	71	1
Jordan	33	23	24
Korea, Republic of[e] [5]	[r]440	[r]550	660
Lebanon	[e]14	[e]14	17
Mongolia[e]	[r]30	[r]30	30
Pakistan	[r]362	493	315
Philippines[8]	[r]8	3	--
Saudi Arabia[e]	19	19	22
Syrian Arab Republic[e]	[r] [e]66	69	[e]70
Taiwan	3	3	8
Thailand	281	296	[e]300
Turkey	[r]37	36	[e]33
Vietnam[e]	8	11	13
Oceania: Australia	[r]1,028	1,020	992
Total	[r]65,279	69,175	72,164

[e]Estimate. [p]Preliminary. [r]Revised.
[1]Gypsum is also produced by Romania, but production data are not available.
[2]Includes anhydrite.
[3]Shipments.
[4]Net exports.
[5]Includes byproduct gypsum.
[6]Revised to none.
[7]Excludes byproduct gypsum, which in 1975 amounted to 5,500,000 tons.
[8]Excludes byproduct gypsum as follows in thousand short tons: 1975—122, 1976—65, 1977—NA.

TECHNOLOGY

The utilization of gypsum-based compounds in underground mining as fireproof coatings, for speedy economical construction of explosion proof stoppings, and for backfilling of drift linings was demonstrated by British Gypsum Ltd. of Nottingham, England. Emplacement was by a slurry-spraying machine.[10]

On May 9, 1977, National Gypsum Co. of Dallas, Tex., and Yoshino Gypsum Co. of Tokyo, Japan, signed a major technical exchange agreement. Yoshino, the largest gypsum manufacturer in Japan, will contribute its expertise in the recycling of byproduct gypsum into wallboard, and National Gypsum will share its knowledge of lightweight wallboard production, energy-saving calcining techniques, and fire and acoustical testing technologies.[11]

An asbestos-free, fiberglass-reinforced gypsumboard for protecting structural steel beams from fire for 1 hour was tested to the requirements of the British Standard in England. Its added strength and proven fire resistance allowed it to be used in the formation of smoke and plenum barriers, fire checks, and column casing.[12]

Contracting for the largest purpose-built drilling rig in North America and using a liner-sinking technique new to this continent, the Canadian firm of Westroc Industries, Drumbo, Ontario, sunk a 12.5- by 455-foot vertical access shaft as part of its new gypsum mine development. Shaft-sinking time was reduced by one-third, and costs were reduced 20%. A water table only 4 feet below the surface and 165 feet of overburden consisting of glacial till with several water-bearing zones complicated the project. After the 15-foot-diameter shaft was drilled with a rotary drill, drilling mud was used to keep the sides from collapsing before liner emplacement. Ten-foot sections of concrete liner encased in steel were progressively placed into the shaft, welded together, and sunk to the bottom of the troublesome section of the shaft. After water tightness was achieved, the liner was surrounded by grout, the bottom casing plug was drilled out, and drilling continued to the 455-foot level.[13]

---

[1]Physical scientist, Division of Nonmetallic Minerals.
[2]U.S. Department of Energy. Voluntary Business Energy Conservation Program. Prog. Rept. 6, April 1978, pp. 110-111.
[3]U.S. Embassy, Cairo, Egypt. State Department Airgram A-146, Sept. 13, 1977, p. 4.
[4]U.S. Embassy, Cairo, Egypt. State Department Airgram A-48, Apr. 11, 1977, 4 pp.
[5]Kaiser Cement & Gypsum Corp. Annual Report, 1977. P. 14.
[6]South Africa Department of Mines, Geological Survey. Mineral Resources of the Republic of South Africa. Handbook 7, 5th ed., 1976, pp. 42-43.
U.S. Embassy, Johannesburg, South Africa. State Department Airgram A-05, Jan. 27, 1978, pp. 42-43.
[7]Industrial Minerals (London). No. 122, November 1977, pp. 39-41.
[8]Medani, A. H. Preliminary Account of the Gypsum Deposits of the Sudan. Econ. Geol., v. 69, No. 5, August 1974, pp. 693-696.
[9]U.S. Embassy, Khartoum, Sudan. State Department Airgram A-87, Aug. 21, 1976, p. 3.
[10]Mining Journal (London). U.K.-Made, Gypsum-Based Products With Many Uses. V. 288, No. 7400, June 17, 1977, p. 471.
[11]National Gypsum Co. (Dallas, Tex.). News Release 05-9-77, May 9, 1977, 2 pp.
[12]Financial Times (London). Sept. 1, 1977, p. 6.
[13]The Northern Miner. Hughes 230-Ton Drilling Rig Boring 15-Foot Diameter Mine Shaft. V. 63, No. 29, Sept. 29, 1977, p. 12.

Helium

By Russell J. Foster[1]

Domestic sales of high purity helium (minimum 99.995% purity) in 1977 increased 37% to 789 million cubic feet.[2] The Bureau of Mines sold 28% of the total, and private industry accounted for the remainder. Exports of high purity helium, all by private producers, declined 3% to 168 million cubic feet. The Bureau of Mines f.o.b. plant price for high purity helium remained at $35 per thousand cubic feet, unchanged since 1961. High purity helium sold by private producers averaged approximately $22.50 per thousand cubic feet.

DOMESTIC PRODUCTION

Nine plants with the capacity to extract helium from natural gas were operational in 1977. Seven of the plants were owned by private industry and the other two were owned by the U.S. Government and operated by the Bureau of Mines. Five extraction plants were located in Kansas, two in Texas, and one each in New Mexico and Oklahoma.

Total helium extracted from natural gas in 1977, by private and government plants, was 1.5 billion cubic feet, an increase of 12% over the amount produced in 1976. High purity helium extraction increased 27%, but the amount of crude helium extracted declined 9%. High purity helium produced for sale comprised 64% of the total helium extracted and crude helium constituted 36%. The Bureau of Mines accounted for 23% of the high purity and 22% of the crude helium extracted, and private industry the remainder.

The Bureau of Mines awarded two contracts to CTI-Cryogenics, a division of Helix Technology Corp., for the construction, startup, and testing of a new helium purification facility capable of producing 600,000 cubic feet of pure helium per day from a 70% to 78% crude helium feed gas, and a new 500-liter-per-hour-capacity helium liquefaction facility at the Bureau's Exell, Tex., plant.

Liquid helium production capacity of the Bureau will be increased to about 100 liters per hour with the addition of another helium liquefier at the Amarillo, Tex., shipping terminal in 1978. The unit was purchased from Kerr-McGee Corp.'s Navajo, Ariz., plant, which closed in 1976.

Table 1.—Helium extracted from natural gas in the United States

(Thousand cubic feet)

	1973	1974	1975	1976	1977[p]
Crude helium:[1]					
Extracted at Bureau of Mines plants	175,976	169,414	183,725	[r]195,758	117,686
Extracted at private industry plants	2,381,971	15,073	149,794	391,553	419,228
Total	2,557,947	184,487	333,519	[r]587,311	536,914
High purity helium:[2]					
Extracted at Bureau of Mines plants	180,114	168,662	184,524	[r]177,677	219,495
Extracted at private industry plants	467,102	[3]530,312	[3]560,899	[3]574,087	[3]737,453
Total	647,216	698,974	745,423	[r]751,764	956,948
Grand total	3,205,163	883,461	1,078,942	1,339,075	1,493,862

[p]Preliminary. [r]Revised.
[1]Excludes crude helium purified after interplant transfer.
[2]Includes only those quantities produced for sale; quantities entering conservation storage system after purification are included under crude helium.
[3]Includes helium purified at the Bureau of Mines Keyes plant for the accounts of others.

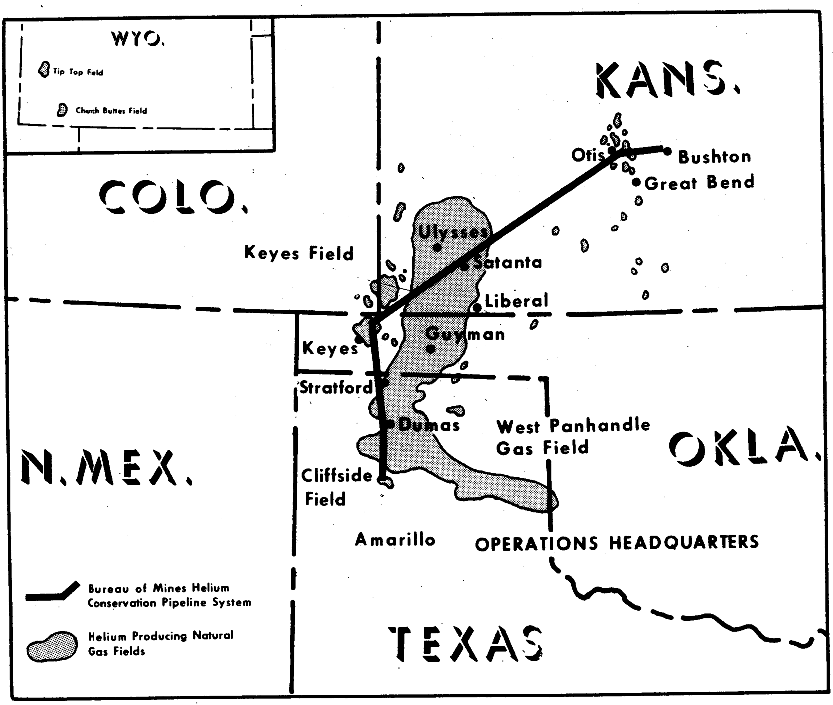


Figure 1.—Major U.S. helium-producing gasfields.

Table 2.—Ownership and location of helium extraction plants in the United States, 1977

Category and owner or operator	Location	Product purity
Government owned:		
Bureau of Mines	Exell, Tex	Crude helium.
Do	Keyes, Okla	Crude and high purity helium.
Private industry:		
Alamo Chemical Co.-Gardner Cryogenics Corp	Elkhart, Kans	High purity helium.
Cities Service Cryogenics, Inc	Scott City, Kans	Crude helium.[1]
Cities Service Helex, Inc	Ulysses, Kans	Crude and high purity helium.
Kansas Refined Helium Co	Otis, Kans	High purity helium.
Northern Helex Co	Bushton, Kans	Crude helium.
Phillips Petroleum Co	Hansford County, Tex	Do.
Western Helium Co	Shiprock, N. Mex	High purity helium.

[1]Output is piped to Cities Service Helex, Inc., plant at Ulysses, Kans., for purification.

Table 3.—Summary of Bureau of Mines helium plant and Amarillo shipping terminal operations

(Thousand cubic feet)

	1975	1976	1977
Supply:			
Inventory at beginning of period[1]	9,291	9,805	8,381
Helium extracted:[2]			
Exell plant:			
Crude	36,111	12,443	8,733
Keyes plant:			
Crude	147,614	r183,315	108,953
High purity[3]	186,399	r178,966	218,876
Total Keyes plant	334,013	362,281	327,829
Total extracted	370,124	374,724	336,562
Helium returned in containers (net)	1,349	r-1,891	-5,671
Total supply	380,764	r382,638	339,272
Disposal:			
Sales of high purity helium	184,524	r177,677	219,495
Net deliveries to helium conservation system[4]	186,435	196,580	114,056
Inventory at end of period[1]	9,805	8,381	5,721
Total disposal	380,764	r382,638	339,272

rRevised.
[1]At Exell and Keyes plants and at Amarillo shipping terminal.
[2]Excludes conservation helium produced from native gas withdrawal wells at Cliffside field that have been invaded by stored helium.
[3]Excludes 39,396,000 cubic feet purified for others in 1975, 63,226,000 cubic feet in 1976, and 169,970,000 cubic feet in 1977.
[4]Excludes return of conservation helium produced as indicated in footnote 2 to conservation storage system.

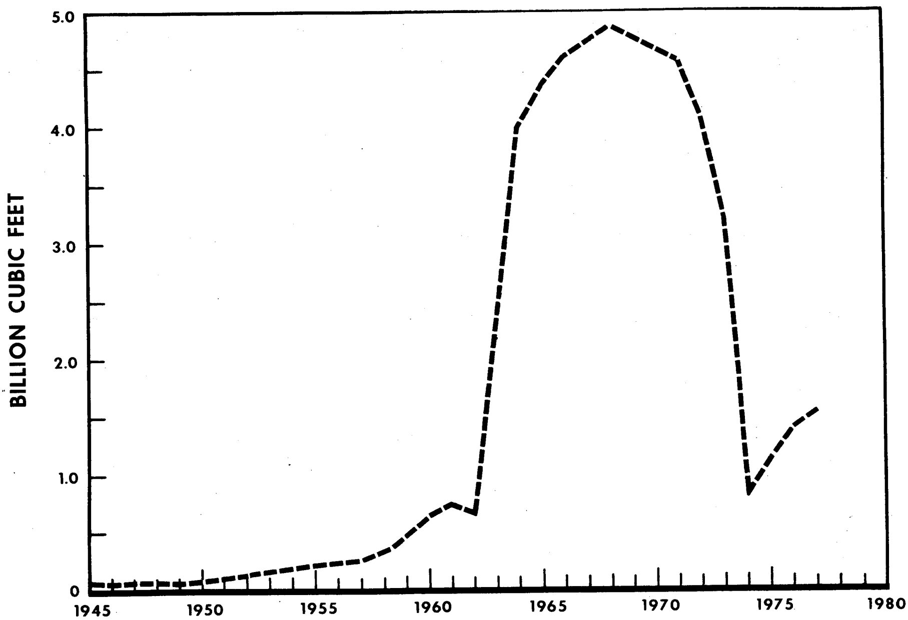


Figure 2.—Helium production in the United States, 1945-77.

CONSUMPTION AND USES

Principal domestic end uses of helium in 1977 were cryogenics, welding, and purging and pressurizing. Other uses included synthetic breathing mixtures, chromatography, leak detection, lifting gas, heat transfer, and controlled atmospheres. Demand during the year was centered mainly in the Pacific and Gulf Coast States.

Federal agency purchases in the form of direct sales from the Bureau of Mines constituted about 78% of the Bureau's total high purity helium production. Almost all of the remaining sales of high purity helium by the Bureau were to Federal agencies through General Services Administration contracts with private distributors. Federal agencies are required by law to purchase from the Bureau. These contracts made relatively small quantities of helium readily available to Federal installations at reduced freight charges for small purchases.

The Bureau of Mines f.o.b. plant price of high purity helium in 1977 was $35 per thousand cubic feet, unchanged since 1961, and maintained for the purpose of financing the Government's helium conservation program. Except in special circumstances, this was not competitive with the private producer average price of $22.50 per thousand cubic feet, f.o.b. plant.

All high purity helium sold by the Bureau of Mines was shipped in gaseous form in cylinders, railroad tank cars, highway tanker trailers, and in liquid form in containerized dewars from the Amarillo shipping terminal. Private industry distributors shipped helium in both gaseous and liquid forms. Much of the helium transported in liquid form was delivered by semitrailer and/or containerized dewars to distribution centers where it was regasified and compressed into trailers and small cylinders for delivery to the end user.

Table 4.—Total sales of high purity helium in the United States

(Million cubic feet)

Year	Quantity
1973	e530
1974	e570
1975	601
1976	578
1977	p789

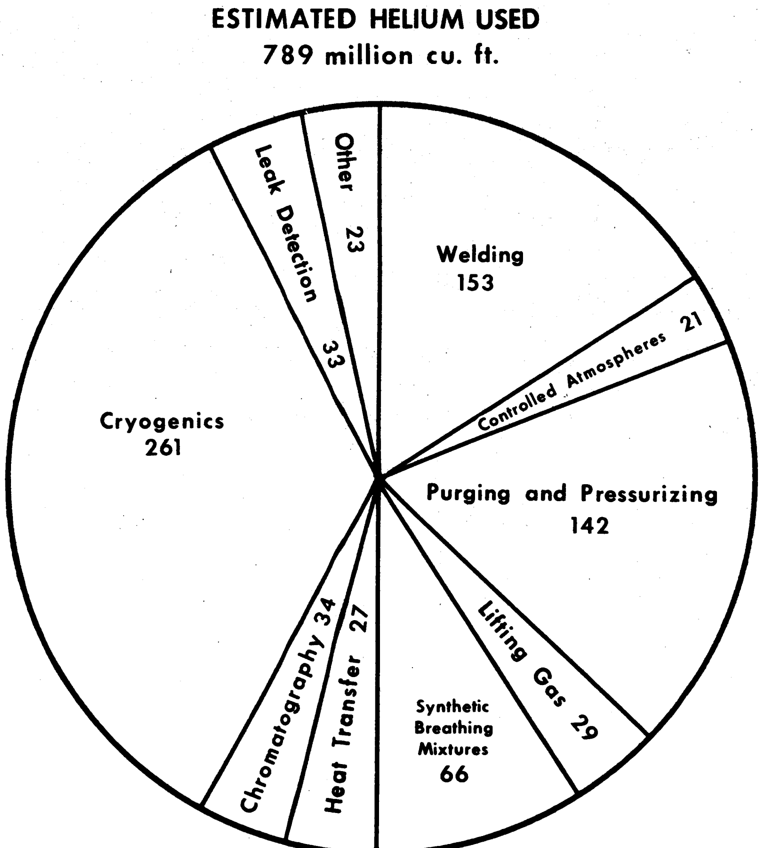
eEstimate. pPreliminary.

Table 5.—Bureau of Mines sales of high purity helium, by recipient

(Thousand cubic feet)

	1975	1976	1977
Federal agencies:			
Energy Research and Development Administration[1]	17,184	14,596	22,297
Department of Defense	60,551	67,827	114,690
National Aeronautics and Space Administration	21,046	8,884	24,694
National Weather Service	1,746	1,515	1,682
Other[2]	4,968	4,757	8,868
Total Federal agencies	105,495	97,579	172,231
Private helium distributor sales[3]	77,049	[r]77,577	45,023
Commercial sales	1,980	2,521	2,241
Grand total	184,524	[r]177,677	219,495

[r]Revised.
[1]Became part of Department of Energy on Oct. 1, 1977.
[2]Includes quantities used by the Bureau of Mines.
[3]Most of this was purchased by commercial firms which sold equivalent quantities to Federal installations under contract agreements with the General Services Administration.



Source: Midwest Research Institute "Comprehensive Investigation and Report on Helium Uses," January 31, 1977

Figure 3.—Helium consumption by end use in the United States, 1977.

CONSERVATION

Helium held in the Bureau of Mines conservation storage system, which includes the conservation pipeline network and the Cliffside gasfield near Amarillo, Tex., increased 1% in 1977 to 39,475 million cubic feet. Helium stored under the conservation program was 37,780 million cubic feet, an increase of 114 million cubic feet during 1977. Private producers had a balance of 1,695 million cubic feet stored under contract with the Bureau in the conservation system (for future redelivery) at yearend 1977.

The conservation storage system contains crude helium purchased by the Bureau of Mines under contracts entered into with four companies in 1961, and crude helium accepted through November 12, 1973, under a court order obtained during 1973 by three of the companies.

Table 6.—Summary of Bureau of Mines helium conservation system[1] operations

(Thousand cubic feet)

	1975	1976	1977
Helium in conservation storage system at beginning of period:			
Stored under Bureau of Mines conservation program[2]	37,283,348	37,469,783	37,666,363
Stored under contract for private producers' own accounts	995,987	1,087,587	1,424,931
Total	38,279,335	38,557,370	39,091,294
Input to system:			
Net deliveries from Bureau of Mines plants[3]	186,435	196,580	114,056
Stored under contract for private producers' own accounts	200,131	583,133	582,935
Total	386,566	779,713	696,991
Redelivery of helium stored under contract for private producers' own accounts	-108,531	-245,789	-312,856
Net addition to system	278,035	533,924	384,135
Helium in conservation storage system at end of period:			
Stored under Bureau of Mines conservation program[2]	37,469,783	37,666,363	37,780,419
Stored under contract for private producers' own accounts	1,087,587	1,424,931	1,695,010
Total	38,557,370	39,091,294	39,475,429

[1]Includes conservation pipeline system and Cliffside field.
[2]Includes helium accepted after Apr. 4, 1973, under court order.
[3]Excludes return to system of conservation helium produced from native gas withdrawal wells at Cliffside field which have been invaded by stored helium.

Table 7.—Deliveries and withdrawals of crude helium stored for private companies' own accounts in the Bureau of Mines conservation storage system, 1977

(Thousand cubic feet)

Owner	Plant location	Delivered	Withdrawn	Net
Cities Service Helex, Inc	Ulysses, Kans	--	979	-979
Northern Helex Co	Bushton, Kans	347,210	121	347,089
Phillips Petroleum Co	Dumas, Tex	20,700	44,873	-24,173
Jack B. Kelley Co	Bushton, Kans	--	8,636	-8,636
Kansas Refined Helium Co	do	215,025	142,886	72,139
Linde Div., Union Carbide Corp	do	--	96,532	-96,532
Airco, Inc	Murray Hill, N. J	--	18,828	-18,828
Total[1]		582,935	312,856	270,079

[1]Data may not add to totals shown because of independent rounding.

RESOURCES

As of December 31, 1977, domestic measured and indicated helium resources were estimated at 255.2 billion cubic feet. The resources include measured and indicated reserves estimated at 91.6 and 50.5 billion cubic feet, respectively, in natural gas with a minimum helium content of 0.3%. The remaining resource base included 39.5 billion cubic feet stored in the Bureau's conservation storage system, 66.8 billion cubic feet of helium in measured natural gas reserves with a helium content of less than 0.3%, and 6.8 billion cubic feet of indicated helium in natural gas with a helium content of 0.1% to 0.3%. Approximately 39% of the domestic helium reserves are under Federal lease. Included are the Tip Top and Church Buttes fields in Wyoming, the Keyes field in Oklahoma, and the Cliffside field in Texas.

The majority of domestic helium reserves are located in the midcontinent and Rocky Mountain regions of the United States. A total of 69 gasfields in 10 States contain measured and indicated helium reserves. About 85% of these reserves are located in the Hugoton field in Kansas, Oklahoma, and Texas; the Keyes field in Oklahoma, the Panhandle and Cliffside fields in Texas, and the Tip Top field in Wyoming. Approximately 53% of the measured and indicated reserves (0.3% or greater helium content) at yearend 1977 were in currently producing gasfields. In 1977, about 20% of the helium-rich natural gas (0.3% or greater helium content) produced was processed for helium extraction. Helium produced from the remaining helium-rich natural gas output was dissipated incident to the consumption of the gas.

The Bureau examined a total of 362 gas samples from 16 States and 1 foreign country during 1977 in connection with its efforts to survey and identify possible new sources of helium supply. None of the samples collected and analyzed indicated the presence of major new deposits of helium.

FOREIGN TRADE

Exports of high purity helium, all by private industry, declined 3% in 1977 to 168 million cubic feet. Nearly 76% of exported helium was shipped to Europe, primarily the United Kingdom, 37%; Belgium-Luxembourg, 26%; and France, 10%. The remaining exports were distributed as follows: Asia, 12%; North America, 7%; South America, 3%; and Oceania, 2%. Continued exports of large quantities of helium to Western Europe during 1977 were attributed mainly to its use in the exploration for and development of oil and gas deposits, especially in the North Sea area.

Table 8.—Exports of high purity helium from the United States

(Million cubic feet)

Year	Quantity
1973	[e]117
1974	[e]129
1975	[1]144
1976	[1]174
1977	[1]168

[e]Estimate.
[1]Bureau of the Census.

WORLD REVIEW

World production of helium, exclusive of the United States, was estimated at 149 million cubic feet in 1977. Canada produced about 15 million cubic feet from one plant in Saskatchewan owned by Canadian Helium, Ltd. However, depletion of the helium-containing natural gasfield forced this plant to close in 1977.[3] Production from a plant near Paris, France, was approximately 11 million cubic feet. The U.S.S.R. and the central economy countries of Europe produced an estimated 123 million cubic feet. A helium extraction plant with a capacity of 150 million cubic feet per year came onstream at Odolanow, Poland, as part of a natural gas upgrading facility, which removes both nitrogen and helium from the gas. Airco, Inc., has contracted to market all helium exported from this plant.

TECHNOLOGY

Midwest Research Institute prepared a report on helium under a Bureau of Mines contract. The study included identification and description of present and potential uses of helium; the volume currently required by each end use; and a forecast of total U.S. helium requirements through the year 2000.

The Bureau has developed analytical methods to meet the specialized needs of helium users. A helium analysis sensitive to 10 parts per trillion freon was created to assist the National Aeronautics and Space Administration with upper atmosphere ozone studies. To aid geochemical uranium prospecting, an analysis for helium in air with a sensitivity to 1 part per million was generated. Analysis of air for the helium-3 isotope down to 1 part per trillion was developed for the Energy Research and Development Administration's analysis of stack gases.

Eight firms from the Federal Republic of Germany and Switzerland signed an agreement with General Atomics Co. to pool their knowledge of helium turbine nuclear reactors. The system uses helium heated by the nuclear reaction to drive a gas turbine that generates electricity, rather than a conventional nuclear system which utilizes a steam turbine.[4]

In December, project U-25B of the joint United States-Soviet magnetohydrodynamics program began producing electricity for the Moscow power grid. The system moves ionized gas (plasma) through a helium-cooled magnetic field which deflects the ions to electrodes, creating an electric current.[5]

---

[1]Physical scientist, Division of Nonmetallic Minerals.

[2]All helium statistics in this chapter are in terms of contained helium measured at 14.7 pounds per square inch absolute at 70°F.

[3]Wall Street Journal. Canadian Helium to End Its Production in Spring. V. 188, No. 121, Dec. 21, 1976.

[4]Energy User News. 9 Firms Study Helium-Turbine Reactor. V. 1, No. 7, Nov. 15, 1976.

[5]Science News. U.S.-Soviet MHD Plant Generates First Power. V. 113, No. 1, Jan. 7, 1978, p. 6.

Iron Ore

By F. L. Klinger[1] and C. T. Collins[2]

World production of, and trade in iron ore in 1977 declined from the levels of 1976. Production was estimated at 844 million long tons,[3] about 5% less than in 1976. World trade declined about 6%, to 340 million tons, of which about 275 million tons was oceanborne. The declines were due mainly to relatively weak demand for iron and steel in the United States, Western Europe, and Japan. World stocks of ore at producers' and consumers' yards probably totaled about 200 million tons at yearend, not including those in the U.S.S.R., Eastern Europe, or the People's Republic of China.

Production of iron ore in the United States declined by 30% in 1977 owing to strikes by workers at major producing facilities in the Lake Superior district. There were also significant declines in France, Sweden, and Venezuela, as well as reduced output in major producing countries such as the U.S.S.R., Brazil, Liberia, and India. A notable exception was the Republic of South Africa, where a large increase in output and exports took place in 1977. The leading producing countries continued to be the U.S.S.R., Australia, and Brazil; the leading exporters were Australia, Brazil, and Canada.

Iron ore prices increased in 1977 but increases were small, mostly less than 10% compared with those of 1976; many prices were unchanged from 1976 levels. The price of Swedish high-phosphorus ore continued to fall. Some price increases of up to 30% were announced for Japanese contracts, but these usually represented renegotiations of prices unchanged for 2 years or more. Oversupply of iron ore relative to demand was expected to result in lower prices for some producers in 1978.

Transportation costs continued to increase, although ocean freight rates remained low in 1977. The trend toward increasing size of iron ore cargoes continued, on the U.S. Great Lakes as well as ocean routes, as shippers attempted to reduce unit costs of transportation. Transport of iron ore slurries by pipeline also increased.

World production of iron ore pellets continued to rise in 1977, and probably exceeded 200 million tons. New plants or expansions of existing facilities were completed or under construction in the United States, Brazil, Canada, the U.S.S.R., and several other countries. World production capacity for pellets was expected to exceed 270 million tons annually by the end of 1980. Direct-reduction plants were also being built in several countries having access to low-cost natural gas. Most of these projects, however, resulted from investments committed in previous years; few new projects were announced in 1977. The depressed ore market and uncertainty about its recovery led to deferral of several mine and plant projects, and the closure of some mines during 1977.

The use of flotation and high-intensity magnetic separation processes for beneficiation of iron ore continued to grow. In the United States, the substitution of coal for natural gas or fuel oil in pelletizing of iron ore continued to be studied by the Bureau of Mines and private companies. Projects for production of low-Btu gas from coal, for use in pelletizing, were also being organized by the Bureau and by a private company, in cooperation with the Department of Energy.

The first Preparatory Meeting on Iron Ore was held at Geneva in 1977 by the United Nations Conference on Trade and Development (UNCTAD). Representatives of more than 40 nations attended. The object of the meeting was to investigate ways by which less developed nations, who depend to a large extent on income from iron ore exports, might be aided in stabilizing or increasing such income. A list of topics for study was negotiated by producer and consumer groups, and further meetings were scheduled for 1978. The Association of Iron Ore Exporting Countries was joined by Liberia in 1977, but Chile and Tunisia withdrew. At yearend, member countries included Australia, Sweden, India, Venezuela, Peru, Algeria, Liberia, Mauritania, and Sierra Leone.

Table 1.—Salient iron ore statistics

(Thousand long tons and thousand dollars)

	1973	1974	1975	1976	1977
United States:					
Iron ore (usable,[1] less than 5% manganese):					
Production[2]	87,669	84,355	78,866	79,993	55,750
Shipments	[3]90,654	[3]84,985	[3]75,695	[2]77,076	[2]54,053
Value	[3]$1,163,710	[3]$1,388,447	[3]$1,620,599	[2]$1,871,114	[2]1,422,696
Average value at mines per ton	$12.84	$16.34	$21.41	$24.28	$26.32
Exports	2,747	2,323	2,537	2,913	2,143
Value	$37,922	$35,148	$60,071	$82,192	$62,760
Imports for consumption	43,296	48,029	46,743	44,390	37,905
Value	$533,488	$696,298	$860,496	$980,348	$956,584
Consumption (iron ore and agglomerates)	146,922	138,160	114,126	125,424	116,034
Stocks Dec. 31:					
At mines	10,876	9,405	12,299	13,993	14,811
At consuming plants	45,990	45,247	52,231	56,246	42,271
At U.S. docks	3,053	3,272	4,614	4,763	2,979
Manganiferous iron ore (5% to 35% manganese): Shipments	181	[r]244	142	[r]229	193
World: Production	832,343	881,244	[r]888,178	[r]886,157	844,000

[r]Revised.
[1]Direct shipping ore, concentrates, agglomerates, and byproduct ore (mainly pyrite cinder and agglomerates).
[2]Includes byproduct ore.
[3]Excludes byproduct ore.

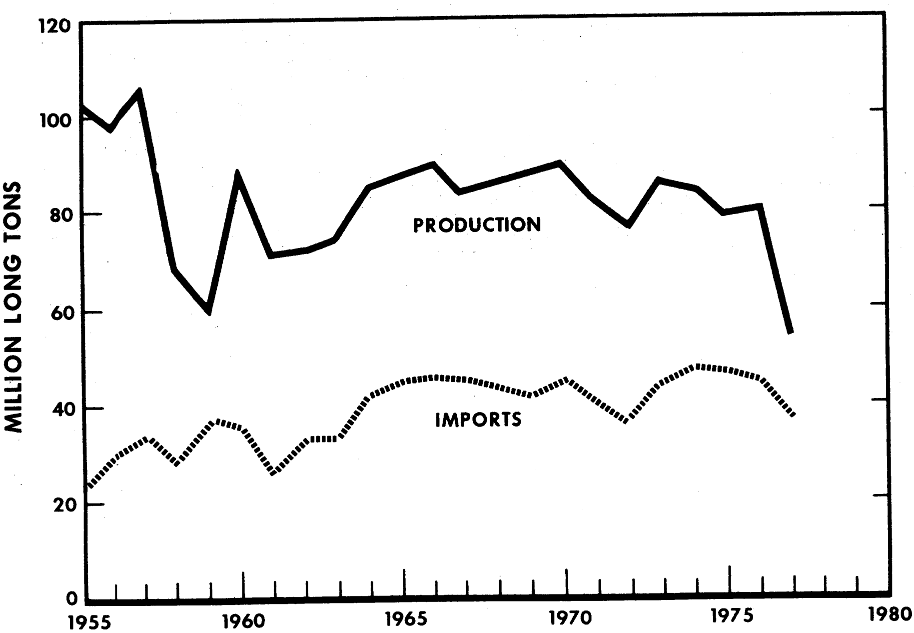


Figure 1.—United States iron ore production and imports for consumption.

EMPLOYMENT

Statistics on employment and productivity in the U.S. iron ore industry in 1977 are shown in table 2. Employment data were supplied by the Mining Enforcement and Safety Administration (MESA). These statistics include persons employed in mines and mills but do not include approximately 2,600 persons engaged in management, research, or office work.

The average number of persons employed in 1977 was 20,162, compared with 20,456 in 1976. Owing to work stoppages at many mines and plants, output of crude and usable ore declined by 30% in 1977; total worker-hours declined by 22%; and average output per worker-hour dropped by about 10%. The decline in worker-hours was less than the decline in output of ore in Minnesota and Michigan, probably because the large, high-productivity taconite operations were affected by strikes while several smaller operations, including the natural ore pits in Minnesota, continued to operate.

DOMESTIC PRODUCTION

U.S. mine production and shipments of iron ore in 1977 declined 30% compared with those of 1976. Shipments of ore from the Lake Superior district were down 34%. The reductions were due principally to strikes by most local unions of the United Steelworkers of America (USW) in the Lake Superior district. U.S. shipments for the year totaled 54 million tons, valued (f.o.b.) at $1.4 billion.

The work stoppages in the Lake Superior district began August 1 and lasted from 112 to 137 days. The earliest local settlement occurred on November 20, and the latest on December 15. The stoppages affected about 15,000 workers, and all except 1 of the 14 pellet-producing operations in Minnesota, Michigan, and Wisconsin. Natural ore mines of four companies in Minnesota and one company in Michigan were not affected, nor were iron ore mines and pelletizing plants in the rest of the country; however, the strikes idled an estimated 75% of U.S. production capacity for iron ore, 85% of U.S. production capacity for iron ore pellets, and (by October) about half of the U.S. ore-carrying fleet on the Great Lakes until late in November. The principal demand by the unions was for incentive pay for production workers, such as that paid to USW workers at ironmaking and steelmaking plants. The mining companies' position was that the issue of incentive pay was covered by the Experimental Negotiating Agreement signed by the USW in April 1977; that this was not a local issue; and that strikes by local unions were therefore illegal. In the final settlements, the companies agreed to incentive pay plans under which most workers would receive 55 to 60 cents per hour increase in earnings, and workers not eligible for incentive pay would receive an increase of about 30 cents per hour, effective November 1, 1979.

Crude ore production in 1977 was 158.4 million tons, a 29% decrease compared with that of the previous year. Six of the 54 producing mines in 1977 were underground. The remaining 48 open pit mines accounted for 96% of total output, and 99% of all ore was shipped to beneficiation plants, the same proportions as in 1976 and 1975. The average iron content of crude ore produced in 1977 was about 32%. The number of tons of crude ore mined for each ton of usable ore produced was 2.84, compared with 2.72 in 1975 and 2.50 in 1973.

Production of usable ore in 1977 consisted of about 80% pellets and other agglomerates, 16% concentrates, and 4% direct shipping ore. The average iron content of all usable ore (including byproduct ore) was 61.9%. The Lake Superior district accounted for nearly 79% of national production. Minnesota produced 55.5%, Michigan 22%, and the remainder was produced in 15 other States.

In Minnesota, Inland Steel Corp. began production of iron ore pellets at the Minorca taconite plant in March. The Minorca project at Virginia, Minn., became completely operational in May, and the first shipment of pellets was on June 9. The 2.6-million-ton-per-year-capacity plant is the eighth major taconite facility on the Mesabi range and the first to use coal for pelletizing fuel. Hibbing Taconite Co. shipped its first trainload of pellets early in 1977, while construction continued on expansion of facilities that were scheduled for completion in 1979. Construction also continued on expansion of the Minntac facility operated by United States Steel Corp. at Mountain Iron, where production capacity was scheduled to increase to 18.5 million tons of pellets per year by late 1978.

Reserve Mining Co. began a major project to switch tailings disposal from Lake Superior to an on-land site, after the Minnesota Supreme Court upheld a lower court's approval of the company's proposed tailings disposal basin at Milepost 7. Construction began June 1 at the 6-square-mile area located about 7 miles from the Silver Bay plant. Fine tailings will be pumped to the site via pipeline, while coarse tailings will be transported by rail. Other improvements were to include extensive modifications at the concentrator and pelletizing plant to improve dust control, reduce particulate emissions, and to improve the quality of iron ore concentrate.

In May, the Minnesota legislature raised the production tax on taconite pellets to $1.25 per ton, and imposed a tax of 10 cents per ton on taconite tailings discharged into State waters. The latter tax, which affected only Reserve Mining Co., was being contested in the State courts.

In Michigan, Cleveland-Cliffs Iron Co. continued expansions at the Tilden and Empire facilities. Productive capacities for pellets are scheduled to reach 8 million tons per year at each facility, at Tilden in 1979 and at Empire in early 1980. Inland Steel Corp. announced plans to begin phasing out production at the Sherwood underground mine at Iron River because of lack of demand for high-phosphorus ore. The mine was scheduled to be closed in 1978.

In New Jersey, Mt. Hope Iron Mining Co., Inc., began production and shipments of magnetite concentrates from the Mt. Hope underground mine near Dover. The historic mine had been closed since 1959.

In Pennsylvania, Bethlehem Steel Corp. permanently closed the Grace mine and pelletizing plant and the Cornwall pellet plant on September 30. The closings were reportedly due to Bethlehem's reduced ore requirements and affected 900 employees. The Grace mine had been operated since 1958.

In Wisconsin, a mining taxation law was enacted on June 30, 1977. The law imposes a tax of up to 20% on net proceeds of mining operations, including taconite operations of the Jackson County Iron Co. at Black River Falls, Wis.

A group of six Japanese companies headed by the Mitsubishi Corp. reportedly canceled plans to exploit the Klukwan iron deposits north of Juneau, Alaska, owing to reduced demand for steel in Japan. Negotiations had been conducted with United States Steel Corp.

Several U.S. mines were temporarily closed in 1977, owing to reduced demand for iron ore. Hanna Mining Co. announced on January 1 that the Whitney natural ore mine at Hibbing, Minn., would be closed for the year. Jones & Laughlin Steel Corp. announced the temporary closing of Benson Mines at Star Lake, N.Y., on October 22, affecting about 300 employees. The Pea Ridge undergound mine and pelletizing plant at Sullivan, Mo., was closed on December 23. About 1,000 employees were affected. The operating company, Meramec Mining Co., was dissolved when Bethlehem Steel Corp. withdrew its 50% ownership, and the mine was placed on a standby basis by the remaining partner, St. Joe Minerals Corp.

CONSUMPTION

Total consumption of iron ore and agglomerates in 1977 was 7.5% less than in 1976. Consumption in blast furnaces declined 7%, while that in steelmaking furnaces dropped 51%. Of total consumption, blast furnaces accounted for 98.7%; steelmaking furnaces, 0.5%; and the remaining 0.8% was used in the manufacture of cement, heavy-media materials, pigments, and other miscellaneous products. In blast furnaces, the weight ratio of iron ore and agglomerates consumed to pig iron produced was approximately 1.57:1.

Iron ore pellets made up 59.5% of all iron ore and agglomerates consumed in 1977 and 68.5% of all agglomerates consumed. Sinter made up 27% of all iron ore and agglomerates consumed, and natural ores accounted for the remaining 13.5%.

Consumption data are shown in tables 11 and 12. In these tables, iron ore concentrate used to produce agglomerates such as pellets or sinter at mine sites is not reported as iron ore consumed; its consumption was reported when such agglomerate was used at the furnace site (table 11). Iron ore concentrate and fines used to produce sinter at ironmaking and steelmaking plants are reported in table 12 as iron ore consumed, while consumption of agglomerates from this source is included in table 11. In table 12, the difference in weight between iron ore consumed and agglomerate produced results from the elimination of moisture as well as the addition of materials such as flue dust, mill scale, lime, and coke.

Consumption of iron ore, as reported by the American Iron Ore Association (AIOA), was 108.5 million tons in 1977. The difference between this figure, and that reported by the Bureau of Mines in table 11, is mainly due to different reporting procedures for sinter. The AIOA reports iron ore consumed in sintering plants at iron and steel works, while the Bureau reports the gross weight of sinter consumed in ironmaking and steelmaking furnaces. The AIOA figure thus does not include the weight of additives such as flue dust, mill scale, slag, etc. that are used for production of sinter and constitute part of the furnace charge. The AIOA figure also does not include iron ore used for miscellaneous purposes, as listed in table 11. As a result, the AIOA annual data on consumption are usually 6% to 7% less than those reported by the Bureau.

STOCKS

Stocks of iron ore and agglomerates at U.S. mines, docks, and consuming plants totaled 60 million tons on December 31, 1977, a decrease of 15 million tons, or 20%, from the level 1 year earlier. The decline was due largely to reduced mine shipments and a higher than normal rate of consumption from consuming-plant stocks during the 4-month strike period; also, imports of ore were lower than in recent years.

Monthend stocks of ore at consuming plants during 1977 ranged from a high of 51.8 million tons in January to a low of 39 million tons in April, while those at the mines ranged from a high of 26 million tons in April to a low of 14.4 million tons in November. Of the 45.3 million tons on hand at U.S. docks and consuming plants at yearend, 38% consisted of domestic ores, 29% of Canadian ores, and 33% of other foreign ores.

PRICES

Published prices for all grades of Lake Superior iron ore (delivered rail-of-vessel at lower lake ports) increased 4.5% early in 1977, but remained unchanged during the rest of the year. Prices for natural ores (basis 51.5% Fe, natural) were increased by 92 cents per long ton in January, and pellet prices were increased in February by 2.4 cents per long ton unit (ltu) of contained iron, natural. The new prices were $21.18 for Mesabi non-Bessemer ore and $21.43 for Old Range non-Bessemer; iron ore pellets were 55.5 cents per ltu. Increases in the cost of transportation and handling after the effective dates of the new prices (January 7 to February 16) were to be borne by the buyer.

The average value (f.o.b. mine or concentrating plant) of usable iron ore shipped from domestic mines in 1977 was $26.32 per long ton, compared with $24.28 in 1976 and $21.41 in 1975. These values were calculated from producers' statements and approximated the commercial selling price less costs of mine-to-market transportation.

Prices for Canadian and many other foreign ores increased in 1977, but the relatively low level of world demand and increasing accumulations of ore stocks tended to keep prices down. Most increases were on the order of 5% to 10% compared with 1976, and while larger increases were announced, these often applied to contracts under which prices had not changed in 2 years or more. Many contract prices were unchanged from 1976 levels. Some prices declined, such as Swedish high-phosphorus ore (Kiruna D; 60% Fe, 1.8% P), which fell to about $13 per metric ton c.i.f. Rotterdam in mid-1977, compared with $16.10 in mid-1976.

In Canada, the price of Wabush pellets, f.o.b. Pointe Noire, increased in February to 49.6 cents per ltu of iron and manganese combined, up 4% from the price in effect since August 1976. Under Japanese contracts, 1977 prices (f.o.b.) for other Canadian ores rose as follows: Carol Lake pellets, up 11% to 50 cents/ltu Fe; Carol Lake concentrates, up 7% to about 20 cents/ltu; and Wesfrob (Tasu) pellet feed, up 11% to $14.25 per dry metric ton (65% Fe). Lac Jeannine concentrate, c.i.f. North Sea ports, was reportedly priced at $20.22 per metric ton, up 0.2% from 1976.

The price of Brazilian iron ore, c.i.f.

North Sea ports, was about $22 per metric ton, up slightly from 1976. Contract prices (f.o.b.) for Brazilian pellets to West European and Japanese consumers were reportedly 43.5 and 45.3 cents/ltu Fe, respectively.

The price for Liberian (Bong Range) concentrate, c.i.f. North Sea ports, was reported at $18.88 per metric ton, up 2% from 1976.

In late 1977, f.o.b. prices for foreign iron ores under most Japanese contracts indicated the following ranges: For lump ore, $10.30 to $18.80 per long ton; for fines, $9.90 to $15.00; and for pellets (excluding Canada and Brazil), 32.5 to about 43 cents/ltu Fe.

The f.o.b. value of Venezuelan ore imported for consumption in the United States, as indicated by Bureau of the Census data, averaged $19.27 per long ton in 1977, compared with $16.85 in 1976.

TRANSPORTATION

Iron ore shipments from U.S. ports on the Great Lakes to lower lake destinations in 1977 totaled 41.5 million tons, 34% less than in 1976. The decline was due to reduced production and rail movements of ore during the 1977 strikes. Shipments from all U.S. ports except Superior, Wis. were less than in 1976; declines ranged from about 22% at Escanaba, Mich., to 66% at Taconite Harbor, Minn. Shipments from Superior increased by 25%, partly due to large stockpiles of ore on hand and the greatly increased loading capacity of the port which was largely in place by midyear. Statistics on shipments of ore from these ports in 1977 are shown in the accompanying tabulation:

Lake shipping port	Number of vessels loaded[1]	Total tonnage shipped[1] (thousand long tons)	Average cargo (long tons)	Largest cargo (long tons)
Duluth, Minn	577	10,687	18,521	41,335
Silver Bay, Minn	253	4,449	17,585	47,810
Taconite Harbor, Minn	103	3,501	33,989	55,861
Two Harbors, Minn	107	3,201	29,920	49,988
Superior, Wis	337	7,701	22,852	55,144
Escanaba, Mich	414	7,890	19,058	[2]33,704
Marquette, Mich	207	4,030	19,468	30,080
Total or average	1,998	41,459	23,056	XX

XX Not applicable.
[1]Including shipments in January 1977; excluding January-March 1978.
[2]A cargo of 51,922 long tons was loaded at Escanaba on Feb. 6, 1978.

Principal source: Annual Report of Lake Carriers Association, 1977.

The average size of iron ore cargoes shipped from Great Lakes ports increased about 11% in 1977, as compared with 1976, continuing a long-term trend. During 1977, the 1,000-foot, self-unloading ore carrier *Mesabi Miner* began service during the summer and was the fourth vessel of its size to begin operating on the Great Lakes. Seven more carriers of this type were under construction or planned to start service by 1981, and will have carrying capacities of 59,000 to 62,000 long tons of ore at maximum draft.

Lake freight rates for iron ore were increased in April 1977 to the following values (per gross ton): From the head of the lakes to lower lake ports, $4.41; from Marquette, Mich., to lower lake ports, $3.62; and from Escanaba, Mich., to Lake Erie, $3.33 and to lower Lake Michigan ports, $2.64. These rates were about 9% higher than those prevailing in 1976.

Most rail freight rates for iron ore increased about 11% in 1977 compared with the previous year's rates. Published rates in effect in October 1977 included the following (per gross ton): From the Mesabi Range to Duluth-Superior, $2.90 to $3.09; from the Marquette range to Escanaba, $1.56; Mesabi Range to Pittsburgh district, $22.00; Black River Falls (Wis.) to Chicago, $4.57; Lake Erie ports to Pittsburgh and Wheeling districts, $5.78; Baltimore to Pittsburgh, $8.48; Benson Mines to Cleveland, $10.39; and Winton Junction (Wyo.) to Geneva, Utah, $4.31.

New port facilities were nearing completion by yearend at Superior, Wis., and Two Harbors, Minn. At Superior, Burlington-Northern Railway raised its annual ore-handling and shipping capacity to 18 million tons compared with about 8 million tons previously, and ore storage capacity was increased to more than 5 million tons. Cost of this project was reportedly $70 million. At Two Harbors, the Duluth, Missabe & Iron Range Railway was increasing its ore loading capacity to a reported 27 million tons per year at a cost of $35 million; completion was expected in 1978. Late in 1977, Republic Steel Corp. announced plans to build a $20 million iron ore transfer terminal on Lake Erie at the mouth of the Cuyahoga River, to be completed by the 1980 shipping season. All three of these port developments are designed to accommodate 1,000-foot carriers.

Reduced shipments of iron ore from U.S. lake ports in 1977 was accompanied by a rise of about 9% in Canadian ore shipments to receiving ports on the Great Lakes. Lake shipments from Canada rose to 25.6 million tons, of which 75% came from ports in Quebec through the St. Lawrence Seaway and was mostly destined for U.S. ports. Imports of Canadian ore in the customs districts of Buffalo, Cleveland, Detroit, and Chicago were estimated at 19 million tons in 1977. The vessel freight rate for iron ore from the Gulf of St. Lawrence to Lake Erie ports in 1977 was $3.01 per gross ton, subject to St. Lawrence Seaway toll of 45 cents per net ton in the Montreal-Lake Ontario section. Charges of $100 per lock in the Welland Canal were paid by the shipowner. The published rail freight rate in eastern Canada, from Schefferville to Sept-Iles, was $2.13 per gross ton in late 1977, compared with $1.10 in August 1976. The rail rate from Ross Bay to Sept-Iles, which affects ore shipped from Wabush Mines and most ore shipped by Iron Ore Co. of Canada, was $2.50 per gross ton in late 1977, compared with $1.40 in August 1976.

Ocean freight rates for iron ore remained low in 1977. Rates published in *Metal Bulletin* for individual cargoes indicated the following charges per ton destined for European ports: $2 to $2.50 from eastern Canada; $3 from West Africa; $2.75 to $4.00 from Brazil; $5 to $6 from western Australia; and less than $2 from Norway. Rates to the U.S. East Coast were about $1.50 from eastern Canada and $4 from Brazil, while those from Australia to Japan were about $4.50 to $5.

Improvements in the capacity of foreign iron ore shipping and receiving ports to accommodate larger ore carriers continued. The port of Narvik (Norway), through which most Swedish iron ore exports are shipped, was expected to be able to handle carriers of up to 350,000 deadweight tons (dwt) in 1978. The port of Saldanha Bay (the Republic of South Africa) was loading carriers of up to 150,000 dwt in 1977, and loadings of 250,000-dwt carriers were expected in 1978. A new port capable of handling vessels of 150,000 dwt was completed at Ponta Ubu, Brazil. In India, the ports of Mormugao and Vizaghapatnam were being improved to accommodate vessels of up to 100,000 dwt. Record cargoes of 269,000 tons at Tubarão, Brazil, and 182,000 tons at Sept-Iles, Canada, were loaded in 1977; both shipments were destined for Japan. The largest cargo of iron ore discharged at Europoort (the Netherlands) in 1977 was about 164,000 tons. In the United Kingdom, where most incoming cargoes of iron ore were less than 30,000 tons in the 1960's, cargoes of 100,000 tons or more were received at Port Talbot, Immingham, and Redcar during the year. In the United States, most incoming cargoes continued to be limited to 65,000 tons or less.

The world's longest iron ore pipeline began operating in 1977, at the Samarco project in Brazil. The pipeline extends about 240 miles, from the Germano mine in Minas Gerais to Ponta Ubu on the Atlantic coast. The 20-inch-diameter pipeline is capable of transporting about 12 million tons of iron ore concentrate per year. Previously, the longest operating pipeline for iron ore was about 70 miles, located at the Savage River project in Tasmania, Australia. Other pipelines under construction in 1977 were a 20-mile line in Argentina and a 40-mile line in western India. In New Zealand, offshore loading of magnetite concentrate by submarine pipelines (about 1-1/2 miles long) increased at the Waipipi and Taharoa beach-sand mines; about 3 million tons of concentrate annually were being exported to Japan, in slurry-ships of up to 130,000 dwt.

FOREIGN TRADE

U.S. exports of iron ore in 1977 totaled 2.1 million tons, valued at $62.8 million. This was a decline of 26% in tonnage and 24% in value, compared with those of 1976, and was due largely to reduced shipments from mines in the Lake Superior district. The average value of exports rose to $29.28 per ton in 1977, from $28.22 in 1976.

U.S. imports of iron ore for consumption in 1977 totaled nearly 38 million tons, a decrease of 15% from the level of 1976. Imports from Canada were 67% of the total, an increased proportion that was due partly to reduced domestic output. Imports from Venezuela made up 16% of the total, and those from Brazil and Liberia made up 6% and 5%, respectively. For the first time since imports have been reported by customs districts, Cleveland received the largest share of imports (23%) in 1977, followed by Philadelphia (17%), Chicago (16%), and Baltimore (15%).

The value, f.o.b. country of origin, of imports in 1977 was $956.6 million, a decline of 2% from that of 1976. The average value of imported ore was $25.23, compared with $22.08 in 1976 and $18.41 in 1975.

WORLD REVIEW

Argentina.—Development of the Sierra Grande iron ore project in Patagonia was continued. Major facilities reportedly completed during the year included the concentrator at the mine site; a 20-mile slurry pipeline from the concentrator to a pelletizing site at Punta Colorada; and port facilities at Punta Colorada capable of loading vessels of 25,000 dwt.

Australia.—Shipments of iron ore products totaled 89.7 million tons in 1977, about 5 million tons less than production. Exports totaled about 79 million tons and the balance was shipped for domestic consumption. Pellet shipments totaled about 9.4 million tons. Shipments of iron ore products by company in 1977 were as follows (in million tons): Hamersley Iron Pty. Ltd., 32.4; Mt. Newman Mining Co. Pty. Ltd., 29.4; Cliffs Western Australia Mining Co. (Robe River), 12.9; Broken Hill Pty. Co. Ltd. (BHP), 6.3; Goldsworthy Mining Ltd., 6.5; and Savage River Mines, 2.2.

The Hamersley and Mt. Newman companies announced plans to build concentrating plants for lower grade ores; both plants were scheduled for completion in 1979. These improvements were expected to raise annual production capacity at Hamersley by 6 million tons and at Mt. Newman by 5 million tons. Also, production capacity for crude ore at Robe River was being raised by 4 million tons per year; the project was 35% completed by yearend.

Dampier Mining Co. Ltd., a subsidiary of BHP, acquired a 50% interest in the railway and port facilities of the Robe River project.

Bolivia.—A 2-year study of the feasibility of establishing a direct-reduction plant and a small steelmaking facility at Corumba, Brazil, using iron ore from the Mutún deposits of Bolivia and natural gas from the Bolivian Santa Cruz field was completed for the Bolivian Government in 1977 by Arthur G. McKee Co. of Cleveland, Ohio. Implementation of the project was reported to be contingent upon construction of a gas pipeline from Santa Cruz.

Brazil.—Production and exports of iron ore products declined in 1977. Total shipments were estimated at 73 million tons, and exports at 59 million tons; both figures were about 10% less than in 1976. Shipments by the largest producers were (in million tons): Companhia Vale do Rio Doce (CVRD), 46.3; Mineraçoes Brasileiras Reunidas (MBR), 13.1; Ferteco Mineração S.A., 4.9; S.A. Mineração da Trindade (SAMITRI), 5.0; and Companhia Siderúrgica Nacional (CSN), 2.2.

CVRD completed construction of a third pelletizing plant at Tubarão. The plant began production in January 1977 and has an annual output capacity of 3 million tons. It is owned 51% by CVRD and 49% by Finanziaria Siderurgica S.p.A. of Italy. A pelletizing plant was also completed at Ponta Ubu, about 55 miles south of Vitoria, by Samarco Mineração S.A.; the plant has an annual production capacity of about 5 million tons and is owned 51% by SAMITRI and 49% by Utah International, Inc., of the United States. Completion of these plants raised Brazilian production capacity for pellets to about 15 million tons annually.

The Samarco project, which includes the Germano mine and concentrator in Minas Gerais, a 240-mile pipeline for iron ore concentrate from the mine to the pelletizing plant at Ponta Ubu, and port facilities at Ponta Ubu, was completed in 1977. Production capacity of the project is 7.5 million tons of flotation concentrate (67% Fe) per year, of which 5 million tons can be pelletized. The port facilities accommodate vessels of 150,000 dwt. Cost of the project was estimated at $600 million.

CVRD continued construction of a concentrator at Conceição, near Itabira. The plant will include 16 high-intensity magnetic separators of the Jones type and was scheduled for completion in 1978. Total production capacity for ore products at Conceição was expected to increase by about 50%, to 20 million tons per year.

Companhia Siderurgica da Guanabara (COSIGUA) completed construction of a direct-reduction plant west of Rio de Janeiro. The plant has a production capacity of about 350,000 tons of sponge iron per year and is the first commercial plant to employ the Purofer reduction process.

Plans by CVRD to develop the large high-grade iron ore deposits of Serra dos Carajas for production in the early 1980's received a major setback in 1977, when United States Steel Corp. decided not to participate and sold its 49% interest in the venture to CVRD for about $40 million.

Canada.—Shipments of iron ore products in 1977 totaled 55.4 million tons including 29.3 million tons of pellets. Shipments for export totaled 43.6 million tons, of which 48% was destined for the United States, 23% for Common Market countries, and 7% for Japan. Exports to the United States increased, while shipments to Europe and Japan were less than in 1976. Total shipments by the largest producers were as follows (in million tons): Iron Ore Co. of Canada, 24.8 including 15.5 of pellets; Quebec Cartier Mining Co., 13.3 (all concentrate); and Wabush Mines, 5.6 (all pellets).

Sidbec-Normines Inc. was building two pelletizing plants at Port Cartier, one of which was completed in 1977. Each plant was designed to produce 3 million tons of pellets per year. Plant feed will be concentrate produced at Lac Jeannine, from crude ore produced at Fire Lake; mining and concentrating was being done for Sidbec by Quebec Cartier Mining Co.

The Hilton Mine, operated by Pickands Mather & Co., was closed April 30, 1977. Bethlehem Steel Corp. announced that its Marmoraton operations in Ontario would be closed in early 1978. Steep Rock Iron Mines Ltd. was expected to cease production at Atikokan, Ontario, in 1979; the company also continued to evaluate low-grade magnetite ores at Bending Lake but decided to defer production plans due to poor market conditions.

Chile.—Shipments of iron ore reported by Compania de Acero del Pacifico (CAP) in 1977 totaled 8.1 million tons, of which 7.5 million tons were exported. A pelletizing plant with an annual production capacity of 3.4 million tons was being built to agglomerate fines from CAP's Algorrobo mine; completion of the $250 million project was expected by early 1978.

European Community (EC).—Production, trade, and consumption of iron ore by the EC declined in 1977, compared with those of 1976. Production was down 18% to 44.2 million tons; imports declined about 11% to an estimated 112 million tons; exports (almost all of which were from France to Belgium/Luxembourg) dropped by more than 20% to an estimated 12.2 million tons; and consumption was about 7% less than in 1976. The declines in production and exports were mainly due to reduced output of French mines in the Lorraine district; imports were mainly reduced by the Federal Republic of Germany, the United Kingdom, and Belgium-Luxembourg. Imports by France increased 10% to nearly 15 million tons. Competition from high-grade ores produced outside the EC was expected to cause further production declines in EC countries, especially in France but also in the Federal Republic of Germany, Luxembourg, and the United Kingdom, where the iron content of crude ores produced ranges from about 25% to 31% and is difficult to raise by beneficiation.

Two new sintering plants were brought into production by the British Steel Corp. (BSC) in 1977 and completion of a third was expected in 1978. The 3-million-ton-per-year pelletizing plant under construction at BSC's Redcar works was also expected to begin production in 1978. Construction continued on two direct-reduction plants at Hunterston, Scotland, and another plant was under construction at Emden, West Germany; all three plants were of the Midrex type. Total annual production capacity for sponge iron was expected to be 0.8 million tons at Hunterston by 1979 and 1.2 million tons at Emden by 1981.

India.—Production, exports, and consumption of iron ore in 1977 were little changed from the levels of 1976. In Karnataka State, production at the Donimalai mine of the National Minerals Development Corp. was scheduled to begin in late 1977; production capacity was to be about 3 million tons per year. Construction of the Kudremukh project near Mangalore was continued, although cost of the $600 million project reportedly would increase by $100 million over the original figure. The pelletizing plant being built for Mandovi Pellets

Ltd. in Goa was still under construction at yearend.

Japan.—Imports of iron ore reported by the Japan Iron and Steel Federation totaled 130.5 million wet tons in 1977, slightly less than in 1976. The major source countries continued to be Australia, Brazil, and India. Consumption of iron ore was reported at 128.4 million dry tons including 15.5 million tons of pellets.

Liberia.—Exports of iron ore products in 1977 totaled 17.4 million tons, the lowest figure since the late 1960's. Large accumulations of stocks were reported for the major producers; the total may have exceeded 7 million tons by yearend. Shipments by company were as follows (in million tons): Liberian-American Swedish Minerals Co. (Lamco), 8.1; Bong Mining Co., 5.9; National Iron Ore Co., 2.8; and Liberia Mining Co. (LMC), 0.6. LMC terminated mining operations in March 1977. Lamco's pelletizing plant was closed for an indefinite period in late 1977, and the company's expansion project at Tokadeh was deferred. Bong Mining Co. completed its second pelletizing plant, raising its total production capacity for pellets to about 4.7 million tons per year.

Mauritania.—Exports of iron ore by Société Nationale Industrielle et Minière (SNIM) totaled 8.3 million tons in 1977, 13% less than 1976.

Mexico.—Mexico apparently continued to be essentially self-sufficient in iron ore. Production of pig iron and sponge iron was increased, and virtually no imports or exports of iron ore were reported. Published Mexican statistics on output of iron ore, however, were too low to account for apparent demand and it was likely that production data shown in table 20 for 1977 are about 20% too low. Output of iron ore products by three of the five major producers in 1977 was as follows (in million tons): La Perla Minas de Fierro S.A., 2.0; Las Encinas S.A., 1.5; and Consorcio Minero Pena Colorada S.A., 1.3. Production by Fundidora de Monterrey S.A. in Jalisco and Coahuila was not reported but was probably 1.5 million tons or more in 1977; the company completed a large concentrator at Durango and a pelletizing plant at Monterrey in 1976. Also, production data were not available from Michoacan, where concentration of magnetite began in 1976 to supply a pelletizing plant at the Lazaro Cardenas steelworks. Mexican production capacity for iron ore products in 1977 was probably about 8 million tons per year, and with ongoing expansion of capacity by Pena Colorada, was likely to reach 9 million tons by 1979.

An important adverse development in 1977 was that reserves of iron ore in Michoacan were reported to be less than half the quantity previously estimated. Owing to the requirements of the Lazaro Cardenas project, and increasing ironmaking capacity elsewhere in Mexico, additional sources of iron ore, from domestic production or imports, were likely to be needed by 1985.

New Zealand.—Production and exports of magnetite concentrates from beach sands on North Island were increased in 1977. Exports by Waipipi Iron Sands Ltd. to Japan were 25% more than in 1976. Exports from Taharoa by New Zealand Steel Ltd. were estimated at more than 1 million tons; and additional capacity for concentration and offshore loading was reportedly being installed.

Philippines.—No production of iron ore was reported in 1977, following government suspension of beach sand operations in 1976 for environmental reasons. At Villanueva, Mindanao, a $195 million iron ore sintering facility was completed by Philippine Sinter Corp., a subsidiary of Kawasaki Steel Corp. of Japan. The plant reportedly had a production capacity of 5 million tons of sinter per year. The product was being shipped to Japan in vessels specially equipped for transportation of sinter. The port facility was reportedly capable of accommodating vessels of up to 250,000 dwt and may be used as a stockpiling or transshipment point for iron ore destined for the Far East.

Spain.—Production and consumption of iron ore in 1977 were practically unchanged from those of 1976, but trade declined. Exports dropped by almost one-third, to an estimated 1.5 million tons, while imports declined about 25% to 4.7 million tons.

A new ore loading pier was completed at Sagunto in 1977 by Cia. Minera de Sierra Menera. The new pier accommodates vessels of 80,000 dwt, compared with 20,000 dwt at the older pier. In Vizcaya, production of low-grade (30% to 35% Fe) iron ore reportedly began in 1977 at the Bodovalle-Gallarte mining project. The ore was shipped to Sestao for sintering.

South Africa, Republic of.—Production and exports of iron ore continued to increase in 1977 as the recently expanded Sishen mine and associated concentration and transportation facilities were operated for the first full year. Shipments of beneficiated ore from Sishen totaled 17.3 million tons, of which nearly 70% was exported through the new port of Saldanha Bay. The mine was operated by South African Iron & Steel Industrial Corp. Ltd. (ISCOR). ISCOR's consumption of iron ore increased about 12% to 7.4 million tons, as a new blast furnace and sintering plant were completed at Newcastle.

Shipments of byproduct magnetite concentrate to Japan by Palabora Mining Co. Ltd. were expected to cease in early 1978 due to termination of the export contract.

Swaziland.—Swaziland Iron Ore Development Co. ended mining operations in November 1977. Shipments of ore were expected to continue until stockpiles were depleted, possibly in 1979.

Sweden.—Production and exports of iron ore declined in 1977 by 15% and 17%, respectively, compared with those of 1976. Exports (18.6 million tons) were the lowest since 1962. Total shipments by the three major producers were (in million tons): Luossavaara-Kiirunavaara AB (LKAB), 18.9; Gränges AB, 1.6; and Stora Kopparbergs Bergslags AB, 1.1. Low demand in Europe led to a decline of 17% in the average f.o.b. value of Swedish ore compared with that of 1976, and stocks of ore rose to a record level of nearly 15 million tons.

LKAB suspended production of pellets at Malmberget in March 1977, and mining operations at Svappavaara in April awaiting improved market conditions. Production capacity at the Svappavaara pellet plant was increased to 3 million tons per year. LKAB's expansion of port facilities at Narvik, Norway, was completed in 1977; carriers of up to 350,000 dwt will be accommodated, and a new shiploader was installed which has a loading capacity of up to 10,000 tons per hour. Shipping capacity of the port was stated to be 30 million tons of iron ore per year.

U.S.S.R.—Exports of iron ore in 1977 were estimated at about 40 million tons, of which 90% was destined for East European countries, principally Poland and Czechoslovakia.

Soviet output of iron ore pellets was estimated at 32 million tons in 1977. Production capacity for pellets reportedly increased by a total of 5 million tons annually, following completion of plant expansions at the Mikhailov and Lebedi projects in Kursk and Belgorod States. At Kremenchug in the Ukraine, construction continued on two additional pelletizing lines scheduled to have a combined production capacity of 6 million tons per year; these plants were of the grate-kiln type manufactured by Allis Chalmers Corp. of Milwaukee, Wis. Orders for four Midrex direct-reduction plants and a 2.5-million-ton-per-year pelletizing facility were reportedly received in 1977 by the West German firms of Korf Stahl AG and Salzgitter AG, respectively; the plants were to be constructed at Kursk.

Venezuela.—Production and exports of iron ore in 1977 were 23% to 25% less than in 1976. Shipments by C.V.G. Ferrominera Orinoco were reported at 11.9 million tons. Projects under construction for Ferrominera included an expansion of output capacity of the ore drying plant to 14 million tons annually, and a pelletizing plant designed for an output of 6.5 million tons per year. The high-iron-briquet (HIB) reduction plant, in which United States Steel Corp. owns a minority interest, was temporarily closed to permit modifications and expansion of production capacity to 600,000 tons of briquets per year. Transportation of ore products from Puerto Ordaz to Matanzas will be facilitated by a railway being built by Siderurgica del Orinoco (SIDOR). Construction also continued on direct-reduction plants of the Midrex and HyLSA types for SIDOR at Matanzas.

TECHNOLOGY

Technological improvements in the iron ore industry were mainly concerned with increasing efficiency and lowering unit costs of mining and milling, concentration, agglomeration, and transportation. The trend toward increasing use of larger mining and milling equipment such as drills, shovels, trucks, and grinding mills was evident worldwide. In U.S. taconite mines, rotary drills capable of drilling blastholes 12 to 15 inches in diameter continued to increase in number, although jet-piercing drills were still preferred at two operations in Minnesota. Shovels with buckets of 16-cubic-yard capacity were used by Hibbing Taconite Co. and a 22-yard unit was in use at an Australian hematite mine. Front-end loaders were increasingly used in place of shovels for clean-up and loading operations, and were the only loading equipment at a large mine in Brazil. Trucks with haulage capacities of 150 tons were in use at several

U.S. and foreign iron ore mines, and 200- to 225-ton units were being used at two large Australian mines; however, smaller units of 85- to 100-ton capacity were preferred by some operators because of lower initial cost, higher operating availability, and ability to navigate steeper grades.

Autogenous grinding mills 36 feet in diameter were installed by Hibbing Taconite Co. in the United States, and mills 32 feet in diameter were in use in Canada at the Mt. Wright concentrator of Quebec Cartier Mining Co.

The use of flotation and wet high-intensity magnetic separation, for concentration of fine-grained hematite ores, was also increasing. Cationic flotation of silica, also called reverse- or inverse-flotation, was installed in 1977 at the Germano concentrator in Brazil and in Liberia at the Bong and Lamco concentrators, all of which have multi-million-ton throughput capacities. Production capacity of the Tilden project in Michigan, which uses a process of selective flocculation and desliming followed by cationic flotation, was being doubled to 20 million tons of crude ore per year. Flotation of silica from magnetite concentrate, as a final cleaning step, was also being used at the Empire concentrator in Michigan and will be installed in the new plant of Reserve Mining Co. in Minnesota which is scheduled for completion in 1980. Flotation cells with volumes of up to 1,000 cubic feet have been tested at the Empire plant.

Wet high-intensity magnetic separation (WHIMS) was being used to produce high-grade hematite concentrate at large concentrators in Brazil and Liberia, and the first commercial unit of this type to be installed in the United States was operating at the Sunrise concentrator of CF&I Steel Corp. near Guernsey, Wyo. Other WHIMS installations were scheduled in Canada, Norway, and Australia.

The Bureau of Mines continued to investigate cationic flotation and WHIMS as means of economically producing high-grade concentrate from low-grade hematite ores of the western Mesabi Range.

Heavy-media (HM) concentration was used at the large Sishen concentrator in the Republic of South Africa, which has an annual production capacity of 18 million tons. HM is also to be the main concentrating method at concentrators being built by the Hamersley and Mt. Newman companies in Australia. The Reichert cone, originally developed for gravity concentration of beach sand materials in Australia, was being used to upgrade magnetite concentrates at Taharoa, New Zealand, and was being installed by the Iron Ore Co. of Canada as a possible replacement for Humphreys spirals; low capital cost and increased throughput capacity appeared to be advantages of this equipment.

With restricted supplies of natural gas and fuel oil for some iron ore pelletizing operations in the Lake Superior district, the use of pulverized coal was being tested by several pellet producers, as well as by the Bureau of Mines[4] which was also investigating the use of lignite and subbituminous coal from deposits in the western United States. Production of low- and intermediate-Btu gas from coal, for use as pelletizing fuel, was also being investigated by the Bureau, and a coal-gasification project was planned by Erie Mining Co. and the U.S. Energy Research and Development Administration.[5] A study of coal-gasification processes, done under contract for the Bureau of Mines, investigated the technical and economic feasibility of gasifying coal for use in pellet induration.[6]

Direct reduction of iron ore continued to grow, especially in fuel-rich countries. New plants were completed in 1977 in Canada, Brazil, Mexico, and Venezuela, and other plants were under construction or planned in 17 or more countries. World production capacity for direct-reduced iron was estimated at about 11 million tons annually at the end of 1977, but owing to weak demand, operating problems, and other factors, total production was probably less than half of this figure. Production of direct-reduced iron in the United States continued to be limited to three plants, and no additional plants were planned owing to restricted availability of natural gas.

---

[1]Supervisory physical scientist, Division of Ferrous Metals.

[2]Mineral specialist, Division of Ferrous Metals.

[3]Unless otherwise stated, the unit weight used in this chapter is the long ton of 2,240 pounds.

[4]Nigro, John C. and R. K. Zahl. Pulverized Coal-Firing Systems for Induration of Iron Oxide Pellets. Proc. 2d Internat. Symp. on Agglomeration, Atlanta, Ga., Mar. 6-10, 1977, publ. in ch. 25 of Agglomeration 77, AIME, New York, v. 1, 1977, pp. 437-463.

[5]Skillings' Mining Review. Erie Mining Chosen for Coal Gasification Plant. V. 66, No. 18, Apr. 30, 1977, p. 11.

[6]Ashworth, R. A., K. C. Vyas, and D. G. Bonamer. Study of Low and Intermediate BTU Gas From Coal for Iron Ore Pelletizing. BuMines Open File Rept. 36-77, 1977, 283 pp.; Available from National Technical Information Service, Springfield, Va., PB 264 702/AS.

Table 2.—Employment at iron ore mines and beneficiating plants, quantity and tenor of ore produced, and average output per worker in 1977, by district and State

District and State	Average number of employees (thousands)	Worker-hours (thousands)	Crude ore (thousand long tons)	Usable ore (thousand long tons)	Iron contained (thousand long tons)	Iron content (natural, percent)	Average per worker-hour		
							Crude ore (long tons)	Usable ore (long tons)	Iron contained (long tons)
Lake Superior:									
Michigan	4	6,273	31,439	12,319	7,798	63.3	5.01	1.96	1.24
Minnesota	12	16,098	97,131	30,943	19,157	61.9	6.03	1.92	1.19
Wisconsin	(1)	365	2,100	690	448	64.9	5.75	1.89	1.23
Total or average[2]	16	22,736	130,669	43,952	27,404	62.3	5.75	1.93	1.21
Other States[3]	4	7,649	27,713	11,281	6,757	59.9	3.62	1.47	0.88
Grand total or average[4]	20	30,385	158,382	55,233	34,161	61.8	5.21	1.82	1.12

[1] Less than 1/2 unit.
[2] Data may not add to totals shown because of independent rounding.
[3] Includes California, Colorado, Georgia, Missouri, Montana, Nevada, New Jersey, New York, Pennsylvania, Texas, Utah, and Wyoming.
[4] Excludes byproduct ore.

Table 3.—Crude iron ore mined in the United States, in 1977, by district, State, and variety

(Thousand long tons and exclusive of ore containing 5% or more manganese)

District and State	Number of mines	Hematite	Limonite	Magnetite	Total quantity[1]
Lake Superior:					
Michigan	6	W	--	W	31,439
Minnesota	24	10,802	--	86,329	97,131
Wisconsin	1	--	--	2,100	2,100
Total reportable[1]	31	10,802	--	88,429	130,669
Eastern States[2]	5	W	W	W	3,696
Western States:					
Utah	4	--	--	4,439	4,439
Other[3]	14	W	W	15,818	19,578
Total reportable	18	W	W	20,258	24,017
Total withheld[1 4]	--	15,473	3,125	20,296	--
Grand total[1]	54	26,275	3,125	128,982	158,382

W Withheld to avoid disclosing company proprietary data; included with "Total withheld" and "Total quantity."
[1]Data may not add to totals shown because of independent rounding.
[2]Includes Georgia, New Jersey, New York, and Pennsylvania.
[3]Includes California, Colorado, Missouri, Montana, Nevada, Texas, and Wyoming.
[4]Total withheld data included with "Total quantity" for each respective district or State.

Table 4.—Crude iron ore mined in the United States, in 1977, by district, State, and mining method

(Thousand long tons and exclusive of ore containing 5% or more manganese)

District and State	Open pit	Under-ground	Total quantity[1]
Lake Superior:			
Michigan	W	W	31,439
Minnesota	97,131	--	97,131
Wisconsin	2,100	--	2,100
Total reportable[1]	99,231	W	130,669
Eastern States[2]	W	W	3,696
Western States:			
Utah	4,439	--	4,439
Other[3]	15,687	3,891	19,578
Total reportable[1]	20,126	3,891	24,017
Total withheld	32,510	2,625	([4])
Grand total[1]	151,867	6,515	158,382

W Withheld to avoid disclosing company proprietary data; included with "Total withheld" and "Total quantity."
[1]Data may not add to totals shown because of independent rounding.
[2]Includes Georgia, New Jersey, New York, and Pennsylvania.
[3]Includes California, Colorado, Missouri, Montana, Nevada, Texas, and Wyoming.
[4]Total withheld data included with "Total quantity" for each respective district or State.

Table 5.—Crude iron ore shipped from mines in the United States, in 1977, by district, State, and disposition

(Thousand long tons and exclusive of ore containing 5% or more manganese)

District and State	Direct to consumers	To beneficiating plants	Total quantity[1]
Lake Superior:			
Michigan	W	W	31,250
Minnesota	--	96,488	96,488
Wisconsin	--	2,100	2,100
Total reportable[1]	W	98,587	129,837
Eastern States[2]	--	3,723	3,723
Western States:			
Utah	W	W	4,443
Other[3]	206	19,464	19,670
Total reportable	206	19,464	24,113
Total withheld	1,614	34,079	(4)
Grand total[1]	1,820	155,854	157,673

W Withheld to avoid disclosing company proprietary data; included with "Total withheld" and "Total quantity."
[1]Data may not add to totals shown because of independent rounding.
[2]Includes Georgia, New Jersey, New York, and Pennsylvania.
[3]Includes California, Colorado, Missouri, Montana, Nevada, Texas, and Wyoming.
[4]Total withheld data included with "Total quantity" for each respective district or State.

Table 6.—Usable iron ore produced in the United States, in 1977, by district, State, and variety

(Thousand long tons and exclusive of ore containing 5% or more manganese)

District and State	Hematite	Limonite	Magnetite	Total quantity[1]
Lake Superior:				
Michigan	W	--	W	12,319
Minnesota	4,544	--	26,399	30,943
Wisconsin	--	--	690	690
Total reportable	4,544	--	27,089	43,952
Eastern States[2]	W	W	W	[3]2,020
Western States:				
Utah	--	--	2,001	2,001
Other[4]	W	W	6,326	[3]7,778
Total reportable[1]	W	W	8,326	[3]9,779
Total withheld	6,934	621	7,719	(5)
Grand total[1]	11,479	621	43,134	[3]55,750

W Withheld to avoid disclosing company proprietary data; included with "Total withheld."
[1]Data may not add to totals shown because of independent rounding.
[2]Includes Georgia, New Jersey, New York, and Pennsylvania.
[3]Includes byproduct ore.
[4]Includes California, Colorado, Missouri, Montana, Nevada, New Mexico, Texas, and Wyoming.
[5]Total withheld data included with "Total quantity" for each respective district or State.

Table 7.—Usable iron ore produced in the United States, in 1977, by district, State, and type of product

(Thousand long tons and exclusive of ore containing 5% or more manganese)

District and State	Direct-shipping ore	Agglomerates	Concentrates	Iron content (natural, percent)
Lake Superior:				
Michigan	W	W	--	63
Minnesota	--	26,343	4,600	62
Wisconsin	--	690	--	65
Total reportable	W	27,033	4,600	62
Eastern States[1] [2]	--	W	1,378	62
Western States[2] [3]	W	5,444	2,768	60
Total withheld	1,986	12,542	--	--
Grand total[2]	1,986	45,019	8,746	62

W Withheld to avoid disclosing company proprietary data; included with "Total withheld."
[1]Includes Georgia, New Jersey, New York, Pennsylvania, and Tennessee.
[2]Includes byproduct ore.
[3]Includes California, Colorado, Missouri, Montana, New Mexico, Nevada, Texas, Utah, and Wyoming.

Table 8.—Shipments of usable iron ore from mines in the United States in 1977

(Thousand long tons and thousand dollars exclusive of ore containing 5% or more manganese)

District and State	Gross weight of ore shipped				Iron content of ore shipped				Total value[1]
	Direct-shipping ore	Agglom-erates	Concen-trates	Total quantity[1]	Direct-shipping ore	Agglom-erates	Concen-trates	Total quantity[1]	
Lake Superior:									
Michigan	W	W	W	12,009	W	W	W	7,559	356,227
Minnesota	--	25,122	5,123	30,245	--	15,897	2,789	18,687	782,627
Wisconsin	--	668	--	668	--	437	--	437	W
Total reportable	W	25,790	5,123	42,922	W	16,335	2,789	26,683	1,138,854
Eastern States[2] [3]	--	W	W	1,757	--	W	W	1,097	44,020
Western States:									
Utah	W	--	W	1,932	W	--	W	1,045	W
Other[3] [4]	206	5,576	1,660	7,442	124	3,496	880	4,500	199,386
Total reportable[1]	206	5,576	1,660	9,374	124	3,496	880	5,545	199,386
Total withheld	1,614	12,354	1,730	([5])	870	7,813	1,017	([5])	40,436
Grand total[1]	1,820	43,720	8,513	54,053	994	27,644	4,687	33,324	1,422,696

W Withheld to avoid disclosing company proprietary data; included with "Total withheld."
[1]Data may not add to totals shown because of independent rounding.
[2]Includes Georgia, New Jersey, New York, Pennsylvania, Tennessee, and Virginia.
[3]Includes byproduct ore.
[4]Includes California, Colorado, Missouri, Montana, Nevada, New Mexico, Texas, and Wyoming.
[5]Total withheld data included with "Total quantity" for each respective district or State.

Table 9.—Usable iron ore produced in Lake Superior district, by range

(Thousand long tons and exclusive after 1905 of ore containing 5% or more manganese)

Year	Marquette	Menominee	Gogebic	Vermilion	Mesabi	Cuyuna	Spring Valley	Black River Falls	Total[1]
1854-1972	408,724	310,995	320,334	103,528	2,876,807	70,336	8,149	2,564	4,101,435
1973	9,036	2,404	--	--	60,021	--	--	956	72,416
1974	8,920	2,419	--	--	58,484	--	--	899	70,723
1975	12,443	2,331	--	--	51,177	--	--	784	66,735
1976	14,663	2,318	--	--	49,764	--	--	668	67,413
1977	W	W	--	--	30,943	--	--	690	43,952
Total[1]	W	W	320,334	103,528	3,127,196	70,336	8,149	6,561	4,422,674

W Withheld to avoid disclosing company proprietary data; included in "Total."
[1]Data may not add to totals shown because of independent rounding.

Table 10.—Average analyses of total tonnage[1] of all grades of iron ore shipped from the U.S. Lake Superior district

Year	Quantity (thousand long tons)	Content (percent)[2]					
		Iron	Phosphorus	Silica	Manganese	Alumina	Moisture
1973	76,281	60.66	0.030	6.77	0.33	0.41	3.79
1974	72,194	60.26	.030	6.68	.35	.40	3.94
1975	64,174	60.91	.030	6.72	.28	.39	3.53
1976	64,928	61.38	.029	6.72	.26	.43	3.20
1977	43,239	61.66	.028	6.60	.28	.44	2.99

[1]Railroad weight—gross tons.
[2]Iron and moisture on natural basis; phosphorus, silica, manganese, and alumina on dried basis.

Source: American Iron Ore Association. Iron Ore, 1977, p. 92; 1976, p. 94.

Table 11.—Consumption of iron ore and agglomerates in the United States in 1977

(Thousand long tons and exclusive of ore containing 5% or more manganese)

State	Iron ore and concentrates[1]		Agglomerates[2]		Miscellaneous[3]	Total reportable[4]
	Blast furnaces	Steel furnaces	Blast furnaces	Steel furnaces		
Alabama, Kentucky, Texas	1,925	W	6,698	W	W	8,623
California, Colorado, Utah	1,694	W	5,394	W	W	7,089
Ohio and West Virginia	2,261	101	21,171	59	W	23,592
Illinois, Indiana, Michigan	1,929	--	39,251	W	W	41,179
Maryland, New York, Pennsylvania	6,246	196	27,932	56	W	34,430
Undistributed	--	135	--	85	901	1,121
Total[4]	14,055	432	100,446	200	901	116,034

W Withheld to avoid disclosing company proprietary data; included in "Undistributed."
[1]Not including pellets or other agglomerated products.
[2]Includes 55,414,320 tons of pellets produced at U.S. mines and 13,566,746 tons of foreign pellets and other agglomerates.
[3]Includes iron ore consumed in production of cement and ferroalloys, and iron ore shipped for use in manufacture of paint, ferrites, and heavy media.
[4]Data may not add to totals shown because of independent rounding.

Table 12.—Iron ore consumed in production of agglomerates at iron and steel plants in 1977, by State

(Thousand long tons)

State	Iron ore consumed[1]	Agglomerates produced
Alabama, Kentucky, Texas	2,643	3,264
California, Colorado, Utah	1,766	2,004
Ohio and West Virginia	2,040	3,040
Illinois, Indiana, Michigan	5,908	9,617
Maryland, New York, Pennsylvania	9,173	13,061
Total	21,530	[2]30,987

[1]Includes domestic and foreign ores.
[2]Data do not add to total shown because of independent rounding.

Table 13.—Beneficiated iron ore shipped from mines in the United States[1]

(Thousand long tons and exclusive of ore containing 5% or more manganese)

Year	Beneficiated ore	Total iron ore	Proportion of beneficiated to total (percent)
1973	86,894	90,654	95.9
1974	79,995	84,985	94.1
1975	73,951	75,695	97.7
1976	74,848	76,697	97.6
1977	52,061	53,880	96.6

[1]Beneficiated by further treatment than ordinary crushing and screening. Excludes byproduct ore.

Table 14.—Production of iron ore agglomerates[1] in the United States, by type

(Thousand long tons)

Type	Agglomerates produced	
	1976	1977
Sinter, nodules, cinder	[2]32,955	[3]31,381
Pellets	64,305	44,626
Total	97,260	76,007

[1]Production at mines and consuming plants.
[2]Includes 16,318,600 tons of self-fluxing sinter.
[3]Includes 16,131,480 tons of self-fluxing sinter.

Table 15.—Stocks of usable iron ore at mines,[1] Dec. 31, by district

(Thousand long tons)

District	1976	1977
Lake Superior	7,954	9,207
Other States	6,039	5,604
Total	13,993	14,811

[1]Excluding byproduct ore.

Table 16.—Average value of usable iron ore[1] shipped from mines or beneficiating plants in the United States in 1977

(Dollars per long ton)

Type of ore	District		
	Lake Superior	Eastern	Western
Direct-shipping, hematite and magnetite	W	--	10.87
Concentrates, hematite and magnetite	14.27	18.65	16.88
Concentrates, limonite	--	W	W
Agglomerates	28.86	W	29.33

W Withheld to avoid disclosing company proprietary data.
[1]F.o.b. mine or plant. Excludes byproduct ore.

Table 17.—U.S. exports of iron ore, by country

(Thousand long tons and thousand dollars)

Country	1975 Quantity	1975 Value	1976 Quantity	1976 Value	1977 Quantity	1977 Value
Austria	5	132	--	--	--	--
Canada	2,485	59,170	2,897	80,981	2,136	62,539
France	6	78	11	1,129	(1)	4
Japan	40	658	(1)	2	1	16
Mexico	1	12	(1)	5	(1)	3
Norway	--	--	--	--	2	24
Taiwan	--	--	--	--	2	107
United Kingdom	(1)	3	5	32	(1)	3
Other	(1)	18	(1)	43	1	62
Total[2]	2,537	60,071	2,913	82,192	2,143	62,760

[1]Less than 1/2 unit.
[2]Data may not add to totals shown because of independent rounding.

Table 18.—U.S. imports for consumption of iron ore, by country

(Thousand long tons and thousand dollars)

Country	1975 Quantity	1975 Value	1976 Quantity	1976 Value	1977 Quantity	1977 Value
Africa, Western, n.e.c	112	1,702	--	--	--	--
Angola	213	4,961	--	--	--	--
Australia	803	8,512	616	12,384	305	5,771
Brazil	7,525	120,947	5,388	111,797	2,243	53,342
Canada	19,111	420,116	24,962	625,588	25,283	693,384
Chile	932	12,172	608	7,962	566	8,346
India	164	1,661	130	1,198	(1)	2
Italy	--	--	3	103	--	--
Japan	56	1,024	--	--	--	--
Liberia	2,496	38,909	2,152	34,198	1,792	30,226
Morocco	--	--	11	259	--	--
Norway	53	1,285	151	4,949	--	--
Peru	1,551	32,627	716	15,233	1,020	35,478
Philippines	14	478	4	170	--	--
South Africa, Republic of	129	2,475	162	4,979	249	5,325
Sweden	182	5,783	442	9,412	153	3,989
Tunisia	--	--	--	--	27	509
U.S.S.R	265	2,518	44	471	86	1,125
Venezuela	13,137	205,304	9,001	151,635	6,179	119,076
Other	(1)	22	(1)	10	(1)	11
Total	46,743	860,496	44,390	980,348	[2]37,905	956,584

[1]Less than 1/2 unit.
[2]Data do not add to total shown because of independent rounding.

Table 19.—U.S. imports for consumption of iron ore, by customs district

(Thousand long tons and thousand dollars)

Customs district	1975		1976		1977	
	Quantity	Value	Quantity	Value	Quantity	Value
Baltimore	10,832	181,979	9,279	197,218	5,629	141,660
Buffalo	2,759	62,775	3,471	93,307	2,575	69,602
Charleston	154	4,076	190	5,043	39	920
Chicago	4,026	82,517	6,037	137,956	5,910	152,635
Cleveland	5,556	116,315	7,736	193,430	8,724	242,332
Detroit	1,899	45,556	1,881	53,891	2,224	66,286
Galveston	--	--	--	--	102	3,031
Houston	690	14,938	153	3,228	852	22,188
Los Angeles	56	803	150	2,707	217	3,872
Mobile	4,265	70,764	4,627	91,364	3,837	82,939
New Orleans	624	10,344	809	14,237	806	17,123
Philadelphia	15,274	256,820	9,597	176,787	6,502	140,847
Portland, Oreg	310	5,407	198	3,451	34	596
Seattle	([1])	([1])	34	809	--	--
Wilmington, N.C	296	8,084	226	6,798	449	12,269
Other	2	118	2	122	3	284
Total	46,743	860,496	44,390	980,348	[2]37,905	956,584

[1]Less than 1/2 unit.
[2]Data do not add to total shown because of independent rounding.

Table 20.—Iron ore, iron ore concentrates, and iron ore agglomerates: World production by country

(Thousand long tons)

Country[1]	Gross weight[2]			Metal content[3]		
	1975	1976	1977[p]	1975	1976	1977[p]
North and Central America:						
Canada[4]	46,128	57,630	55,421	28,724	36,030	34,649
Mexico[5]	4,974	5,380	5,296	3,316	3,586	3,530
United States[6]	78,866	79,993	55,750	48,266	49,362	34,489
South America:						
Argentina	260	498	523	[r]133	255	267
Bolivia (exports)	31	--	7	[r]20	--	4
Brazil	88,474	92,601	[e]86,000	57,508	60,191	[e]55,700
Chile	[r]10,833	9,896	7,771	[r]6,664	6,088	4,802
Colombia	529	490	591	227	225	272
Peru	[r]7,631	4,701	6,087	4,987	3,040	3,937
Venezuela	24,381	18,390	14,173	[r]15,115	11,401	8,787
Europe:						
Albania[7]	[r] [e]640	748	[e]748	[r] [e]224	[e]262	[e]262
Austria	3,772	3,724	3,395	1,182	1,147	1,052
Belgium	92	62	46	28	19	14
Bulgaria	2,300	2,279	2,235	[r]763	736	716
Czechoslovakia	1,745	1,874	1,959	[r]524	487	509
Denmark	13	8	5	5	3	2
Finland[8]	894	1,149	1,123	[r]510	687	668
France	48,863	44,467	36,056	15,067	13,574	10,873
German Democratic Republic[9]	58	58	71	23	23	28
Germany, Federal Republic of (salable)	3,236	2,220	2,431	1,036	738	803
Hungary	632	592	517	151	141	123
Italy[10]	[r]531	506	463	234	253	194
Luxembourg	[r]2,278	2,046	1,524	[r]662	605	442
Norway	4,044	3,909	3,665	2,620	2,524	2,366
Poland	1,173	663	634	352	199	190
Portugal[11]	55	47	51	[r]23	27	27
Romania	3,017	2,790	2,707	980	725	704
Spain	7,520	7,488	7,775	3,634	3,742	3,845
Sweden	30,379	29,390	25,015	19,332	18,807	16,009
U.S.S.R	229,126	235,333	233,947	135,185	138,846	138,028
United Kingdom	4,419	4,510	3,685	[r]1,193	1,172	958
Yugoslavia	5,156	4,193	4,381	1,898	1,475	1,552
Africa:						
Algeria	[r]3,139	3,138	3,642	[r]1,695	1,695	1,966
Angola	2,707	[e]--	[e]--	[e]1,638	[e]--	[e]--
Egypt	[r]1,070	1,223	1,365	[r]534	611	683
Kenya[12]	[r]17	[e]16	16	[r] [e]10	[r] [e]10	[e]10
Liberia	[e]24,000	18,517	17,850	[e]14,714	11,943	11,513
Mauritania	[r]8,540	9,511	9,639	[r]5,509	6,135	6,217

See footnotes at end of table.

Table 20.—Iron ore, iron ore concentrates, and iron ore agglomerates: World production by country —Continued

(Thousand long tons)

Country[1]	Gross weight[2]			Metal content[3]		
	1975	1976	1977[p]	1975	1976	1977[p]
Africa —Continued						
Morocco	545	338	401	[r]343	213	257
Rhodesia, Southern[e]	590	590	540	378	378	320
Sierra Leone	1,431	--	--	[r]902	--	--
South Africa, Republic of[13]	12,104	15,416	26,063	7,565	9,634	16,289
Swaziland	[r]2,205	1,905	1,418	1,389	1,144	851
Tunisia	[r]606	477	339	[r]312	246	172
Asia:						
China, People's Republic of[e]	64,000	64,000	64,000	32,000	32,000	32,000
Hong Kong	[r]164	36	--	[r]83	19	--
India	[r]40,751	42,757	41,639	[r]25,511	26,765	26,066
Indonesia	347	287	307	202	161	171
Iran[14]	985	1,085	1,085	600	660	660
Japan[15]	715	746	673	[r]416	443	393
Korea, North[e]	9,250	9,350	9,350	3,700	3,740	3,740
Korea, Republic of	[r]565	629	643	[r]316	352	360
Malaysia	343	303	325	209	185	198
Philippines	1,330	562	--	799	315	--
Thailand	32	25	62	19	15	37
Turkey	[r]2,322	3,394	3,368	[r]1,336	1,951	1,937
Oceania:						
Australia	[r]96,109	91,782	94,580	[r]60,578	57,779	59,349
New Zealand[16]	2,261	2,435	2,643	1,289	1,388	1,504
Total	[r]888,178	886,157	844,000	[r]512,633	514,152	490,495

[e]Estimate. [p]Preliminary. [r]Revised.

[1]In addition to the countries listed, Cuba and Vietnam may produce iron ore, but definitive information on output levels, if any, is not available.

[2]Insofar as availability of sources permits, gross weight data in this table represent the nonduplicative sum of marketable direct shipping iron ores, iron ore concentrates, and iron ore agglomerates produced by each of the listed countries. Concentrates and agglomerates produced from imported iron ores have been excluded, under the assumption that the ore from which such materials are produced has been credited as marketable ore in the country where it was mined.

[3]Data represent actual reported weight of contained metal or are calculated from reported metal content. Estimated figures are based on latest available iron ore content reported, except for the following countries from which grades are U.S. Bureau of Mines estimates: Albania, Denmark, Hungary, Southern Rhodesia, the People's Republic of China, and North Korea.

[4]Gross weight and metal content of shipments of usable iron ore, including byproduct ore, dry tons.

[5]Gross weight calculated from reported iron content based on grade of 66.67% Fe.

[6]Includes byproduct ore.

[7]Nickeliferous iron ore.

[8]Includes magnetite concentrate, pelletized iron oxide (from pyrite sinter) and roasted pyrite (purple ore).

[9]Includes "roasted ore," presumably pyrite sinter, not separable from available sources.

[10]Excludes iron oxide pellets produced from pyrite sinter.

[11]Includes manganiferous iron ore.

[12]For cement manufacture.

[13]Includes byproduct magnetite as follows in thousand long tons: 1975—[r]2,873; 1976—[r]3,413; 1977—4,970.

[14]Year beginning March 21 of that stated.

[15]Concentrate including concentrate derived from iron sand as follows in thousands long tons: 1975—[r]174; 1976—191; 1977—124.

[16]Largely concentrates from magnetite-titanium sands.

Iron Oxide Pigments

By Cynthia T. Collins[1]

Production and trade in finished iron oxide pigments continued to rise in 1977. Increased construction and durable goods production during the year stimulated demand for pigments in building materials and coatings of all kinds. The $73.9 million value of finished iron oxide pigment sales and the $20.6 million value of imports indicated a $94.5 million market in 1977, compared with an $81 million market in 1976.

Ground was broken in September for Mobay Chemical Corp.'s $50 million iron oxide pigment plant at New Martinsville, W.Va. The 45,000-ton-per-year-capacity plant will be the largest single iron oxide pigment facility in the United States when completed in 1981. Completion of the initial stage is planned for the third quarter of 1978. Iron oxide will be produced by the aniline-based process of Mobay's parent company, Bayer AG of the Federal Republic of Germany. The process, which involves reduction of nitrobenzene to aniline with iron, reportedly is economical and environmentally sound.

Meramec Mining Co. ceased production at its Pea Ridge mine near Sullivan, Mo., on December 23.[2] The company, a joint venture of Bethlehem Steel Corp. and St. Joe Minerals Corp., mined iron ore principally for production of iron and steel; they also produced, as a byproduct, a high-purity magnetite concentrate ("M-25 Oxide") which was sold for use in ferrite manufacture. St. Joe Minerals Corp. continued production of M-25 Oxide from stocks of crude ore at the Pea Ridge plant.

Table 1.—Salient iron oxide pigments statistics in the United States

	1973	1974	1975	1976	1977
Mine production short tons	W	W	r43,335	r66,848	59,233
Crude pigments sold or used do	W	W	r40,154	r59,636	55,953
Value thousands	$931	$1,429	$1,093	$1,263	$1,600
Iron oxides from steel plant wastes short tons	NA	W	19,252	21,403	20,824
Value thousands	NA	W	$1,102	$1,258	$1,638
Finished pigments sold short tons	148,802	147,544	104,840	135,915	140,707
Value thousands	$43,514	$60,612	$46,206	$64,506	$73,851
Exports short tons	9,888	9,666	8,780	5,805	6,493
Value thousands	$3,101	$3,466	$2,523	$3,353	$4,065
Imports for consumption short tons	51,183	54,215	27,979	50,102	58,694
Value thousands	$12,005	$16,367	$9,184	$16,554	$20,596

rRevised. NA Not available. W Withheld to avoid disclosing company proprietary data.

DOMESTIC PRODUCTION

Production of finished iron oxide pigments, as measured by sales, increased 3.5% over that of 1976. Production of natural iron oxides remained very close to that of the previous year, while synthetic pigment production increased by nearly 7%. Production of synthetic blacks, browns, and reds all showed gains, but yellows declined following a large increase in 1976.

The value of overall sales was up 14.5%; this partly reflected increases in average unit values for both natural and synthetic pigments of about 9% in 1977. The average unit value of synthetic pigments was more than five times greater than that of natural oxides.

Table 2 reflects sales data compiled from responses by 19 companies (see table 3) to the Bureau of Mines annual canvass and represents 95% coverage. While most companies reported gains in 1977, a few showed a decline in production and two regular respondents reported no production.

Domestic production of 20,824 short tons of iron oxides from steel plant wastes was slightly less than that of the previous year. Five companies produced iron oxide as a byproduct from steel plant dusts or regenerated pickle liquor. Although a small amount of these oxides were used for pigment, the majority was used in the manufacture of ferrites.

Domestic mine production of crude iron oxide pigments declined 11% in 1977. Shipments decreased by 6%, but total f.o.b. mine value increased 27%, indicating a larger increase in unit values. The decline in crude pigment production was due in part to a strike in the iron ore industry which idled Cleveland-Cliffs Iron Co.'s Mather mine in Michigan from August 1 to November 21. The company produces pigment-grade hematite from the Mather mine in addition to iron ore for the steel industry.

Table 2.—Finished iron oxide pigments sold by processors in the United States, by type

Pigment	1976		1977	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Natural:				
Black: Magnetite	7,235	$602	5,825	$475
Brown:				
Iron oxide[1]	8,252	2,306	8,730	2,665
Umbers:				
Burnt	5,248	2,242	4,979	2,480
Raw	1,827	768	2,066	954
Red:				
Iron oxide[2]	37,227	3,003	37,414	3,113
Sienna, burnt	672	401	739	475
Yellow:				
Ocher[3]	5,461	539	6,438	619
Sienna, raw	645	319	708	361
Total natural	66,567	10,180	66,899	[4]11,143
Synthetic:				
Brown: Iron oxide[5]	7,682	6,305	10,149	8,650
Red: Iron oxides	23,285	18,776	26,317	23,884
Yellow: Iron oxide	27,013	20,886	25,498	21,028
Total synthetic	57,980	45,967	61,964	53,562
Unspecified, including mixtures of natural and synthetic iron oxides	11,368	8,359	11,844	9,147
Grand total	135,915	64,506	140,707	[4]73,851

[1]Includes Vandyke brown.
[2]Includes pyrite cinder.
[3]Includes yellow iron oxide.
[4]Data do not add to total shown because of independent rounding.
[5]Includes synthetic black iron oxide.

Table 3.—Producers of iron oxide pigments in the United States in 1977

Producer	Mailing address	Plant location
Finished pigments:		
BASF Wyandotte Corp	100 Cherry Hill Rd. Parsippany, N.J. 07054	Wyandotte, Mich.
Blue Ridge Talc Co., Inc	Box 39 Henry, Va. 24102	Henry, Va.
Chemalloy Co., Inc	Box 350 Bryn Mawr, Pa. 19101	Bryn Mawr, Pa.
Chemetron Corp., Pigments Div	491 Columbia Ave. Holland, Mich. 49423	Huntington, W.Va.
Cities Service Co., Columbian Div	Box 5373 Akron, Ohio 44313	St. Louis, Mo.; Monmouth Junction, N.J.; Trenton, N.J.
Combustion Engineering, Inc., CE Minerals Div.	901 East 8th Ave. King of Prussia, Pa. 19406	Camden, N.J.
DCS Color & Supply Co., Inc	1050 East Bay St. Milwaukee, Wis. 53207	Milwaukee, Wis.
E. I. du Pont de Nemours & Co., Inc.	Pigments Dept. Wilmington, Del. 19898	Newark, N.J.
Ferro Corp., Ottawa Chemical Div	700 North Wheeling St. Toledo, Ohio 43605	Toledo, Ohio.
Foote Mineral Co	Route 100 Exton, Pa. 19341	Exton, Pa.
Hoover Color Corp	Box 218 Hiwassee, Va. 24347	Hiwassee, Va.
Mineral Pigments Corp	7011 Muirkirk Rd. Beltsville, Md. 20705	Beltsville, Md.
New Riverside Ochre Co	Box 387 Cartersville, Ga. 30120	Cartersville, Ga.
Pfizer Inc., Minerals, Pigments & Metals Div.	235 East 42d St. New York, N.Y. 10017	Emeryville, Calif.; East St. Louis, Ill.; Easton, Pa.
Prince Manufacturing Co	700 Lehigh St. Bowmanstown, Pa. 18030	Quincy, Ill., Bowmanstown, Pa.
Reichard-Coulston Inc	15 East 26th St. New York, N.Y.10010	Bethlehem, Pa.
George B. Smith Chemical Works, Inc.	1 Center St. Maple Park, Ill. 60151	Maple Park, Ill.
Solomon Grinding Service	Box 1766 Springfield, Ill. 62705	Springfield, Ill.
Sterling Drug, Inc., Hilton-Davis Chemicals Div.	2235 Langdon Farm Rd. Cincinnati, Ohio 45237	Cincinnati, Ohio.
Sterling Drug, Inc., Thomassett Color Div.	120 Lister Ave. Newark, N.J. 07105	Newark, N.J.
Crude pigments:		
Cleveland-Cliffs Iron Co., Mather Mine & Pioneer Plant.	1460 Union Commerce Bldg. Cleveland, Ohio 44115	Negaunee, Mich.
Hoover Color Corp	Box 218 Hiwassee, Va. 24347	Hiwassee, Va.
Meramec Mining Co	Martin Towers, Room 1836 Bethlehem, Pa. 18016	Sullivan, Mo.
New Riverside Ochre Co	Box 387 Cartersville, Ga. 30120	Cartersville, Ga.

CONSUMPTION AND USES

Consumption of iron oxide pigments increased in 1977 because of strong demand for coatings and building materials in the durable goods and construction markets. Demand for iron oxide pigments was also strengthened by the continued popularity of brown and yellow shades in exterior and interior paints.[3] A color preference survey in midyear found that 10 of the 15 most popular exterior paint colors, and 30 out of 50 interior colors, were shades of brown or yellow.[4] Furniture manufacturers reported continued popularity of brown and red-brown shades in wood finishes, for which umbers and siennas were in strong demand. Demand for iron oxides, which are nontoxic, was also increased by legislation in recent years that bans toxic substances in coatings.

Data were not previously collected by the Bureau of Mines on specific end uses, and responses to a revised annual canvass for 1977 were incomplete. However, a 75% sample of respondents showed the following end use breakdown for iron oxide pigments:

End uses	Percent
Coatings (industrial finishes, trade sales paints, varnishes, lacquers)	37.0
Construction materials (cement, mortar, preformed concrete, roofing granules)	15.0
Ferrites and other electronic and magnetic applications	13.0
Industrial chemicals (such as catalysts)	12.5
Animal feed and fertilizers	9.0
Colorants for plastics, rubber, paper, glass, ceramics	5.0
Foundry sands	4.0
Heavy media for coal washing	4.0
Other (including cosmetics, jeweler's rouge)	.5
Total	100.0

Further analysis of the end use data indicates that 50% of synthetic pigment production went into coatings and 12% went into construction materials. The largest percentage of oxides consumed in ferrite manufacture were synthetic, although some natural pigments were sold for that use. Coatings accounted for 21% of natural pigment sales during the year and construction materials accounted for 19%. All iron oxides used for animal feed, fertilizers, foundry sands, and heavy media were natural materials.

PRICES

Prices increased in July 1977 for many categories of iron oxide pigments. Prices for synthetic brown, red, and yellow oxides, and for raw umber, ocher, and Vandyke brown increased by 2 cents to 4 cents per pound. Prices for red domestic primers, and burnt umber decreased slightly, however. Some companies were also adding 5 cents to 8 cents per pound on orders of less than 1 ton quantities.[5]

Table 4.—Prices quoted on finished iron oxide pigments, per pound, bulk shipments, December 31, 1977

Pigment	Low	High	Pigment	Low	High
Black:			Red:		
Synthetic	$0.3100	$0.3825	Domestic primers	$0.1650	$0.2200
Micaceous	.3800	.4000	Pure, synthetic	.4300	.4500
			Spanish	--	.2625
Brown:			Yellow:		
Ground iron ore	.0750	.0900	Synthetic	.3975	.4175
Metallic	.1175	.1275	Ocher, domestic	.1275	.1275
Pure, synthetic	.4000	.4700			
Sienna, Italian, burnt	.3400	.4700			
Umber, Turkey, burnt	.2400	.2600			
Umber, Turkey, raw	.2425	.2725			
Vandyke brown	.2725	.2925			

Source: American Paint Journal.

FOREIGN TRADE

Exports of pigment-grade iron oxides and hydroxides in 1977 increased 12% in quantity and 21% in value, compared with 1976. Exports to Canada comprised 62% of the total, and those to the United Kingdom, 10%. Exports of other grades of iron oxides rose 49% and values 59% over those of the previous year. The largest gains were in exports to Canada, Mexico, the Netherlands, and the United Kingdom. Average values for exports in 1977 were 31 cents per pound for pigment-grade iron oxides and 71 cents per pound for the category designated as other iron oxides, excluding pigment grade.

Imports for consumption of iron oxide pigments increased 17% in 1977 compared with 1976 levels. The value of imports increased 24%, reflecting price increases in almost all categories of natural and synthetic oxides. The largest gain was in synthetic pigment imports, which comprised 83% of total imports. Iron oxides from the Federal Republic of Germany accounted for 54% of synthetic imports and those from Canada comprised 33%. Average value of synthetic pigment imports was 20 cents per pound. Crude and refined umbers and siennas from Cyprus accounted for 65% of natural pigment imports and Vandyke brown from the

Federal Republic of Germany accounted for 10%. Average values for natural pigment imports ranged from 4 cents per pound for imports from Cyprus to 28 cents per pound for imports from Austria.

Table 5.—U.S. exports of iron oxides and hydroxides, by country

Destination	1976				1977			
	Pigment grade		Other grade		Pigment grade		Other grade	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Argentina	--	--	--	--	--	--	16	$37
Australia	158	$110	59	$141	104	$85	205	474
Belgium-Luxembourg	1	1	261	262	8	22	32	61
Brazil	35	41	484	468	43	41	287	443
Canada	3,935	1,362	962	835	4,011	1,257	1,678	1,168
Colombia	15	13	41	34	27	16	10	8
Denmark	--	--	--	--	26	67	53	260
Ecuador	9	12	1	1	13	13	6	3
Finland	28	22	--	--	46	29	--	--
France	158	196	149	157	138	211	160	222
Germany, Federal Republic of	125	89	307	640	107	173	497	973
Guatemala	2	2	71	85	3	3	3	3
Hong Kong	--	--	--	--	163	217	12	24
India	(1)	1	8	17	2	8	32	60
Indonesia	3	4	--	--	89	39	152	206
Iran	2	2	--	--	17	5	--	--
Ireland	5	9	58	93	8	6	4	3
Italy	78	109	571	826	35	82	176	414
Jamaica	--	--	--	--	16	19	--	--
Japan	56	140	1,233	1,742	111	168	933	1,663
Korea, Republic of	151	153	254	399	100	131	46	99
Kuwait	--	--	--	--	--	--	170	222
Liberia	15	12	--	--	8	5	12	9
Mexico	78	70	178	200	194	129	382	486
Netherlands	96	75	411	717	112	97	1,295	2,088
Netherlands Antilles	--	--	45	59	--	--	49	70
New Zealand	14	9	--	--	19	12	--	--
Philippines	98	80	6	5	88	74	--	--
Portugal	--	--	64	91	--	--	76	220
Singapore	38	67	71	16	49	110	--	--
South Africa, Republic of	7	6	21	16	14	12	54	89
Spain	14	74	46	27	10	5	--	--
Taiwan	--	--	62	111	30	25	163	153
Turkey	--	--	--	--	--	--	47	81
United Arab Emirates	--	--	50	135	--	--	--	--
United Kingdom	454	449	524	852	625	770	1,518	2,366
U.S.S.R	--	--	--	--	--	--	822	748
Venezuela	82	80	66	47	219	150	92	31
Yugoslavia	--	--	--	--	--	--	18	12
Other	148	165	59	59	58	84	36	54
Total	5,805	3,353	6,062	8,035	6,493	4,065	9,036	12,750

[1]Less than 1/2 unit.

Table 6.—U.S. imports for consumption of iron oxide pigments

Kind	1976 Quantity (short tons)	1976 Value (thousands)	1977 Quantity (short tons)	1977 Value (thousands)
Natural:				
Crude:				
Siennas	466	$82	480	$124
Umbers	6,223	421	6,262	431
Other	9	12	27	11
Total	6,698	515	[1]6,770	566
Refined:				
Ochers	53	11	44	13
Siennas	158	40	140	47
Umbers	685	140	695	160
Vandyke brown	739	147	1,052	194
Other	1,222	178	1,075	215
Total	2,857	516	3,006	[1]628
Synthetic	40,547	15,523	48,918	19,402
Grand total	50,102	16,554	58,694	20,596

[1]Data do not add to total shown because of independent rounding.

Table 7.—U.S. imports for consumption of iron oxide and iron hydroxide pigments, by country

Country	Natural 1976 Quantity (short tons)	Natural 1976 Value (thousands)	Natural 1977 Quantity (short tons)	Natural 1977 Value (thousands)	Synthetic 1976 Quantity (short tons)	Synthetic 1976 Value (thousands)	Synthetic 1977 Quantity (short tons)	Synthetic 1977 Value (thousands)
Austria	39	$20	39	$22	--	--	--	--
Belgium-Luxembourg	--	--	--	--	153	$69	54	$35
Canada	29	5	54	15	11,792	2,831	16,298	3,514
China, People's Republic of	11	2	--	--	5	12	--	--
Cyprus	6,761	492	6,359	469	--	--	5	3
France	(1)	1	--	--	16	6	20	17
Germany, Federal Republic of	714	148	1,014	195	21,169	10,716	26,300	13,772
India	--	--	6	1	--	--	37	5
Italy	386	90	467	133	--	--	--	--
Japan	36	20	64	34	5,078	1,039	3,412	960
Mexico	--	--	--	--	845	299	905	310
Netherlands	--	--	20	3	69	36	56	9
Portugal	--	--	271	18	--	--	--	--
Romania	20	7	--	--	1	(1)	--	--
South Africa, Republic of	40	7	40	9	--	--	20	3
Spain	1,102	136	872	141	38	11	107	51
Sweden	--	--	--	--	--	--	17	4
United Kingdom	417	104	564	153	1,381	504	1,687	715
Other	--	--	7	1	--	--	(1)	3
Total[2]	9,555	1,032	9,776	1,195	40,547	15,523	48,918	19,402

[1]Less than 1/2 unit.
[2]Data may not add to totals shown because of independent rounding.

TECHNOLOGY

Advances in technology continued to assure iron oxides a competitive place among many kinds of pigments. Demand by coatings manufacturers for easy dispersability of pigments has led to increased use of micronization, a jet milling process which yields smaller and more uniform particle size distributions. Continued improvement of natural iron oxide pigments now includes the availability of micronized grades of most varieties.[6] In dry form, all grades of pigments consist of clusters of primary particles, most of which require further grinding and dispersion in a medium. Some dispersing mills employ discs or blades attached to a high-speed rotating shaft, and some contain a cylinder filled with sand, glass or ceramic beads, or steel shot into which the mixture is pumped. Within the cylinder, rotating discs circulate the mixture through the abrasive. In these types of mills, particles are separated and dispersed by the swirling action of the discs and/or the shearing action of the abrasive. A new type of mill developed in Belgium reportedly combines the effectiveness of both kinds of mill but eliminates the abrasives. In the new mill the discs are faced with crystals of extremely hard materials, such as tungsten carbide, borazon, or synthetic diamond. Shearing action takes place when particles impinge against the sharp crystals on the rotating discs. Manufacturers of magnetic tape were expected to be among the first to use the new type of mill because of their requirement for finely ground iron oxide.[7]

The use of computers in production of iron oxide pigments has increased efficiency of color measurement and matching. Producers' quality assurance programs are also improved by computer applications of data on chroma, hue, and lightness.[8]

Advancing technology in the coatings industry also affects the competitiveness of various pigments. A recently introduced styrene-acrylic copolymer latex coating was developed for its resistance to salt spray and flash rusting. This latex is compatible with iron oxide pigments, which are widely used in formulation of rust inhibiting and marine coatings.[9]

Research into iron oxides for uses other than paint pigment continued in 1977. Iron oxide pigments with improved color stability in cement and other masonry materials were developed in England. These iron oxides are now available in yellow, red, and black shades.[10] Ceramic glazes were studied in an effort to determine the extent to which the release of lead and zinc in the glaze was a function of the coloring oxide additives. It was determined that iron oxide pigments affect lead and zinc leaching only moderately; their effect was less than that of copper and chromium oxides.[11]

A process for the regeneration of hydrochloric acid (HCl) waste pickle liquor was developed which is especially suited to low-volume, single-line steel service centers. The system uses thermal decomposition to convert iron chlorides into hydrochloric acid and iron oxide.[12] Iron oxides from regenerated pickle liquor are used principally in production of ferrites. An improved process was developed for recovery of iron oxide and chlorine from dust produced in chlorination of titaniferous ores. Hot chlorinator dust was reacted with controlled amounts of oxygen in a four-stage process which separated gaseous chlorine and particulate iron oxide. Chlorine was reused in the chlorination process and the recovered iron oxide was suitable for various pigment uses.[13] A variety of industrial uses of waste sludge containing 65% iron oxide were investigated. Possible applications included iron-containing glass, bricks, welding material for ceramics and refractories, and washes for the steel industry.[14]

A method was developed for the quantitative analysis of the major elements of some ferrites. The technique is an adaptation of the generally practiced "Coprex" method; it is reported to analyze simply and efficiently for quantities of manganese, zinc, nickel, and iron in ferrites when the approximate composition is known. The method is considered to be effective for analysis of small experimental batches or samples.[15]

---

[1]Mineral specialist, Division of Ferrous Metals.
[2]American Metal Market. Joint Owners to Close Up Meramec Mine. V. 85, No. 244, Dec. 19, 1977, p. 27.
[3]American Paint & Coatings Journal. Public Remains Loyal...Earthtones, Yellows Still the Favorites. V. 61, No. 54, June 20, 1977, p. 56.
[4]Color Corporation of America. Color Preference Survey- Interior/Exterior. June 1, 1977, 5 pp.
[5]Chemical Marketing Reporter. Iron Oxide Pigments Rise; Sales Volume Is Picking Up. V. 212, No. 3, July 18, 1977, p. 35.
[6]American Paint & Coatings Journal. The Markets. V. 60, No. 44, Apr. 12, 1976, p. 30.
[7]Financial Times. Diamonds Make the Finest Powders. No. 27,439, Dec. 19, 1977, p. 8.
[8]American Paint & Coatings Journal. Talk on Iron Oxides Draws Many Questions From Piedmont Society Members. V. 62, No. 23, Nov. 14, 1977, p. 71.
[9]———. Coatings Update. V. 62, No. 6, Aug. 22, 1977, pp. 54-55.
[10]———. Coatings Update. V. 62, No. 8, Sept. 5, 1977, p. 53.
[11]Buldini, P. L. Influence of Coloring Oxides on Heavy Metals Release From Ceramic Glazes. Ceram. Bull., v. 56, No. 11, November 1977, pp. 1012-1014.
[12]Labee, C. J. Sliding Bed HCl Regeneration Process. Iron and Steel Eng., v. 54, No. 9, September 1977, pp. 91-92.
[13]Hartmann, A., A. Kulling, and H. Thumm (assigned to Kronos Titan G.m.b.H., Leverkusen, Germany). Process for Recovery of Iron Oxide and Chlorine From Dust Produced in Chlorination of Titaniferous Ores. U.S. Patent 4,060,584, Feb. 14, 1977.
[14]Mukherjee, J. L., S. Ganapathy, C. S. Larson, and S. D. Brown. Utilization of a Waste Sludge Containing Iron Oxide. Pres. at Am. Ceram. Soc. Ann. Meeting, Chicago, Ill., Apr. 27, 1977; Ceram. Bull., v. 56, No. 3, March 1977, p. 336.
[15]Schrey, F., and P. K. Gallagher. X-Ray Fluorescence Analysis of Some Ferrite Compositions. Ceram. Bull., v. 56, No. 11, November 1977, pp. 981-983.

Iron and Steel

By D. H. Desy[1]

In 1977, the steel industry in most of the world remained in a relatively depressed condition. Western Europe was one of the regions most affected by generally low demand and oversupply of steel. In Japan, steel production declined 4.7%. Steel production in the U.S.S.R. continued to increase, but at a lower rate than planned. Some developing countries showed substantial increases in steel production, but many were reconsidering earlier expansion plans for their steel industries.

The United States produced 125.3 million tons[2] of raw steel, 2% less than in 1976 but 7.5% more than in 1975. The domestic steel industry operated at 78.4% of its production capability. Net shipments of steel products increased 2% to 91.1 million tons, despite the decline in raw steel production, owing to inventory changes.[3]

Domestic steel prices rose by an average of 6% during the year. The United States exported 3.1 million tons and imported 19.9 million tons of major iron and steel products in 1977.

Table 1.—Salient iron and steel statistics

(Thousand short tons)

	1973	1974	1975	1976	1977
United States:					
Pig iron:					
Production	101,318	95,477	79,721	86,848	81,494
Shipments	101,628	95,941	79,240	86,693	82,392
Exports	15	101	60	58	51
Imports for consumption	446	342	478	r415	373
Steel:[1]					
Production of raw steel:					
Carbon	132,747	126,608	100,360	112,008	108,130
Stainless	1,889	2,150	1,111	1,684	1,862
All other alloy	16,163	16,962	15,171	14,308	15,341
Total	150,799	145,720	116,642	128,000	125,333
Index[2]	118.5	114.5	NA	NA	NA
Capability utilization[3]	NA	NA	76.2	80.9	78.4
Total shipments of steel mill products	111,430	109,472	79,957	89,447	91,147
Exports of major iron and steel products	4,962	6,992	3,975	3,671	3,098
Imports of major iron and steel products	15,608	16,746	12,488	r15,038	19,930
World production:					
Pig iron	552,000	564,000	r528,298	r551,193	542,696
Raw steel (ingots and castings)	769,000	780,000	r710,106	r747,103	741,648

rRevised. NA Not available.
[1]American Iron and Steel Institute (AISI).
[2]Based on average production in 1967 as 100. Not computed after 1974.
[3]Defined by AISI as the tonnage capability to produce raw steel for a full order book based on the current availability of raw materials, fuels, and supplies of the industry's coke, iron, steelmaking, rolling, and finishing facilities, recognizing current environmental and safety requirements. Not computed before 1975.

Legislation and Government Programs.—A report to the President on a comprehensive program for the steel industry, prepared by an interagency task force, was released on December 6, 1977. The report's major recommendation was a trigger price mechanism to initiate immediate investigations of possible steel dumping, with resolution required in 60 to 90 days, to replace the existing procedure, which normally required more than a year. The task force also recommended tax incentives to encourage modernization of steel plants, rationalization of environmental policies and procedures, community and labor assistance, and other general measures, including a study of legal barriers to joint ventures and mergers, increased research and development, and government review of transportation systems serving the steel industry.

PRODUCTION AND SHIPMENTS OF PIG IRON

Domestic production of pig iron totaled 81.5 million tons in 1977, a decrease of 5.3 million tons, or 6% less than that produced in 1976. Shipments were 82.4 million tons, 5% less than in 1976. Average production of pig iron per blast furnace day increased to 1,935.8 tons, compared with 1,930.1 tons in 1976 and 1,837.4 tons in 1975, according to the American Iron and Steel Institute (AISI). There were 107 furnaces in blast at the beginning of the year, compared with 134 at yearend. No ferroalloy blast furnaces were in operation at yearend. There was a total of 193 blast furnaces standing at the beginning of the year, declining to 179 at yearend.

Metalliferous Materials Consumed in Blast Furnaces.—For each ton of pig iron produced in 1977, an average of 1,645 tons of metalliferous materials was consumed in blast furnaces. The revised figure for 1976 was 1,654 tons. Total net iron ore and agglomerates consumed in blast furnaces was 126.7 million tons. The total tonnage of iron ore, including manganiferous ore, consumed by agglomerating plants at or near the blast furnaces in producing 34.9 million tons of agglomerates was 23.6 million tons. The revised 1976 figure for consumption of iron ore, including manganiferous ore, was 26.3 million tons. Other materials consumed by agglomerating plants included mill scale, flue dust, slag, coke breeze, and fluxes. Domestic pellets charged to the blast furnaces totaled 61.9 million tons, and sinter charged was 35.4 million tons. Pellets and other agglomerates from foreign sources amounted to 15.1 million tons.

Blast furnace oxygen consumption totaled 28.9 billion cubic feet according to AISI, compared with 26.9 billion cubic feet in 1976 and 25.9 billion cubic feet in 1975. Blast furnaces, through tuyere injection, consumed 12.4 billion cubic feet of natural gas, 3.1 billion cubic feet of coke oven gas, 438 million gallons of oil, 109 million gallons of tar, pitch, and miscellaneous fuels, and 147,343 tons of bituminous coal in 1977.

PRODUCTION AND SHIPMENTS OF STEEL

Steel production early in the year was reduced by shortages of natural gas resulting from severe weather in January and February. One small integrated steel mill (Alan Wood Steel Co.) and several minimills went bankrupt during the year. Youngstown Sheet and Tube Co. and Bethlehem Steel Corp. closed some of their facilities at Youngstown, Ohio, Johnstown, Pa., and Lackawanna, N.Y., and several other steel companies temporarily shut down some of their operating facilities. Foreign imports, including some allegedly imported at less than fair prices, were cited as the major reason for the cutbacks.

The domestic steel industry produced 125.3 million tons of raw steel in 1977, 2% less than the 128 million tons produced in 1976. Production in 1977 was 78.4% of industry raw steel production capability, compared with 80.9% in 1976. Of the total, 61.8% was produced by the basic oxygen process, 16.0% by open hearth furnaces, and 22.2% by electric furnaces.

Shipments of steel products for the year totaled 91.1 million tons, 2% more than the 89.4 million tons shipped in 1976. The increase in shipments, despite the decline in raw steel production, was attributed to inventory increases in 1976 and withdrawals in 1977. Shipments to the automotive industry totaled 21.5 million tons, slightly more than in 1976, and shipments to service centers rose 5% to 15.3 million tons. Shipments to the oil and gas industry increased 38%, and shipments to the construction industry increased 1%.

Materials Used in Steelmaking.—Metallic materials charged to domestic steel furnaces in 1977, per ton of steel produced, averaged 1,230 pounds of pig iron, 1,025 pounds of scrap, 24 pounds of ferroalloys, and 20 pounds of ore and agglomerates. According to AISI, steelmaking furnaces consumed 0.5 million tons of fluorspar, 1.2 million tons of limestone, 7.3 million tons of lime, and 1.1 million tons of other fluxes. Oxygen consumption in steelmaking totaled 190.3 billion cubic feet, compared with 196.3 billion cubic feet in 1976.

CONSUMPTION OF PIG IRON

Total pig iron consumed for all purposes in 1977 was 82.0 million tons. Of the 77.1 million tons used in steelmaking, basic oxygen furnaces consumed 63.9 million tons; open hearth furnaces, 12.5 million tons; and electric furnaces, 0.7 million tons. Iron foundries and miscellaneous users consumed 1.3 million tons, and 3.0 million tons was used in making direct castings, primarily ingot molds and stools.

PRICES

Prices of tin-mill products were raised 5% effective March 13. Carbon and alloy tool steel prices were increased an average of 8% on April 1, flat-rolled stainless steel prices increased 8% on May 9, and high-speed tool steel prices went up 8% to 12% on June 15. A general price rise of 6% on most carbon steel products became effective on June 19. Welded mechanical tubing prices were raised 7% on July 4, and oil-country tubular products went up 7% in price on August 1. On September 4, prices of tin-mill products rose 7% and prices of structural shapes rose 6%.

In August, stainless steel billet prices were raised 4% to 8%, and effective October 3, prompted by increases in the price of molybdenum, price of most molybdenum-bearing grades of stainless steel were raised 6% to 7%. In November, some producers lowered prices on most grades of flat-rolled stainless steel to levels prevailing in January.

The composite price for pig iron, according to Iron Age magazine, rose from $187.67 to $191.75 per ton on August 8. The Iron Age finished steel composite price rose from 15.146 cents per pound in January to 15.941 cents per pound in July and 16.043 cents per pound in September, an average increase of 6% for the year.

FOREIGN TRADE

Exports of major iron and steel products amounted to 3.1 million tons in 1977, 16% less than in 1976. The value of the exports totaled $2.28 billion, compared with imports valued at $5.94 billion, resulting in an unfavorable balance of trade in iron and steel products of $3.65 billion. Imports of major iron and steel products totaled 19.9 million tons, 33% above 1976 imports. The value of these imports was 29% above the 1976 value. Imports from Western Europe increased sharply over those in 1976, while imports from Japan remained about the same.

Imported steel was reportedly sold in the United States at prices below those of domestic steel, prompting several major U.S. steel producers to file dumping charges against Japanese and European producers. The Treasury Department made a preliminary determination that five Japanese steel companies had sold carbon steel plate on the west coast at prices substantially below production costs. Importers were required to post a bond equivalent to a 32% tariff until a final determination was made.

As part of a comprehensive program for the steel industry, proposed by an interagency task force, a system of trigger prices on imported steel was devised, which was intended to replace the former antidumping procedure in most cases. This system was to become effective early in 1978. Import quotas on specialty steel (stainless and alloy tool steel), which were instituted in mid-1976, were continued through 1977.

WORLD REVIEW

NORTH AMERICA

Canada.—The Canadian iron and steel industry showed general improvement in 1977 compared with its performance in 1976. Raw steel production increased 2.3% to 15.0 million tons, and net shipments of rolled steel products increased 5.3% to 11.4 million tons, but pig iron production declined slightly to 10.6 million tons. Imports and exports of iron and steel products increased 12% and 22%, respectively. The increase in low-priced steel imports led to antidumping complaints by several steel producers. The Government determined that material injury had been caused to Canadian producers by imports of wide flange shapes and bar angles, and import duties were imposed.

The Steel Co. of Canada, Ltd. (Stelco) continued with the construction of its new greenfield integrated steel plant at Nanticoke, Ontario, with startup of the first phase scheduled for April 1980. The first phase, which will have a capacity of 1.3 million tons, will include a raw material receiving dock, a coke oven battery, a blast furnace, two basic oxygen furnaces, and a continuous slab-casting machine. Slabs will initially be shipped to Stelco's Hilton Works at Hamilton, Ontario, for finishing. Stelco did not operate its SL-RN direct-reduction plant at Bruce Lake, Ontario, for most of the year.

The Algoma Steel Corp., Ltd. suspended operations at its Canadian Furnace Division at Port Colborne, Ontario, in March and banked its No. 5 blast furnace at Sault Ste. Marie, Ontario.

Dominion Foundries and Steel, Ltd. (DOFASCO) had under construction a second basic oxygen steelmaking shop, with one 250-ton vessel, scheduled to begin operation in May 1978.

Sidbec-Dosco, Ltd., began operation for testing of its second Midrex direct-reduction unit at Contrecoeur, Quebec, in August 1977. Sidbec was also completing installation of two 150-ton electric-arc furnaces, a six-strand continuous billet caster, and a single-strand continuous slab caster. The Quebec Government approved $128 million in new financing for Sidbec for the 1978 fiscal year. In September, Sidbec purchased the bankrupt Questell division of QSP Ltd., a minimill at Longueuil, Quebec, a suburb of Montreal.

Sydney Steel Corp. (SYSCO) of Sydney, Nova Scotia, received a $19.5 million government loan, which will be used for capital expenditures to improve productive capacity. A consortium of Canadian, U.S., and European companies decided to postpone construction of a 2.5-million-ton-per-year plant proposed for Gabarouse Bay, Cape Breton Island, Nova Scotia.

Mexico.—The Mexican Government took the first steps towards the merger of three partially or wholly government-owned integrated steel companies, Altos Hornos de Mexico, S.A. (AHMSA), Fundidora Monterrey, S.A., and Siderúrgica Lázaro Cárdenas-Las Truchas, S.A. (SICARTSA), by appointing a government official as vice chairman of the boards of these companies. This move was taken to promote greater economy and efficiency of operations.

The third stage of the expansion program of Fundidora Monterrey was completed in May with the startup of the new basic oxygen furnace installation, which raised the capacity of the plant 67% to 1.65 million tons per year. Fundidora Monterrey had a 49-day labor strike lasting from May 23 to July 10. It was estimated that the strike caused a production loss of 3,000 tons per day.

The expansion of AHMSA at Monclova, Coahuila, continued with the startup of a new cold-rolling mill in May. The second stage of SICARTSA's new greenfield plant on the Michoacán coast was indefinitely postponed. Hojalata y Lámina, S.A. (HYLSA) began production in April at its second direct-reduction plant at Xoxtla, Puebla, which has a capacity of 770,000 tons per year.

Because of lack of demand, the Mexican Government, through a joint government-private commission, was considering restructuring expansion plans for the steel industry to avoid excess capacity.

SOUTH AMERICA

Argentina.—Acindar-Industria Argentina de Aceros S.A., a privately owned steel company, was constructing an integrated steel plant at Villa Constitucion in the Province of Santa Fe. The plant will have a capacity of 660,000 tons per year and will include one Midrex 400 series direct-reduction module. The plant is scheduled to begin operation in the last quarter of 1978.

Dalmine Siderca S.A.I.y C. continued operation of its Midrex direct-reduction facility at Campana, which had begun operations in October 1976 and closed temporarily in December. The plant restarted in January 1977 and reached design capacity of around 1,000 tons per day in a few days. Daily production has averaged around 1,200 tons with a record production for 1 day of 1,500 tons.

Bolivia.—Siderurgica Boliviana, S.A. (SIDERSA), the Bolivian Government iron and steel corporation, approved a feasibility study for an integrated steel plant based on the Mutún iron ore deposit. Sponge iron would be produced by a direct-reduction process utilizing natural gas and melted in three 86-ton electric-arc furnaces. The plant is projected to produce 660,000 tons per year of direct-reduced iron and 580,000 tons per year of raw steel. Two continuous-casting machines will produce billets, which will be rolled to produce 495,000 tons per year of round bars, light sections, and wire rods. Brazil has agreed to purchase 90% of the output; the remainder will be used in Bolivia. The project is contingent on the construction of a natural gas line from Santa Cruz, Bolivia, to Corumbá, Brazil. Part of the gas would go to the reduction plant to be built near the ore deposit in Bolivia, and the major portion would go to Brazil for distribution in that country.

Brazil.—The steel industry led industrial growth in Brazil in 1977; raw steel production increased 20.5% to 12.2 million tons, while pig iron production rose 19.8% to 10.8 million tons. A direct-reduction plant, the first to use the Purofer process, was put into operation during the year by Cia. Siderúrgica da Guanabara (COSIGUA).

There were delays in implementing the planned steel complex at Tubarão in the State of Espírito Santo, owing to difficulties in financing. Phase II expansion at the Government-controlled steel plants was essentially completed.

Chile.—The Government-owned steel enterprise, Compañía de Acero de Pacífico (CAP), which accounts for 95% of sales and production, incurred a loss of $4.7 million in 1977. However, domestic steel sales increased 17%, more than compensating for the decrease in exports, and raw steel production increased 13.7%, reaching 604,000 tons. CAP has phased out its open hearth furnaces and now operates two basic oxygen converters having a combined capacity of 1.10 million tons per year; however, output is restricted by the rolling capacity of 825,000 tons per year.

Colombia.—The steel industry of Colombia consists of one integrated plant and six semi-integrated scrap-based electric-arc-furnace plants. The integrated plant, Acerias Paz del Rio, S.A. (PDR), located at Belencito, Boyacá Province, has a capacity of 330,000 tons of raw steel per year, and includes coke ovens, a sintering plant, a blast furnace, three 20-ton Thomas converters, an electric arc furnace, a slabbing-blooming mill, and hot-finishing mills for bars, wire rods, structural shapes, and sheet. Feasibility studies have been completed for conversion of one of the Thomas converters to a bottom-blown oxygen converter and expansion of the plant capacity to as much as 1 million tons per year.

The semi-integrated plants have a combined capacity of about 60,000 tons per year and produce rolled nonflat products and some castings and grinding balls for local consumption. The location of these plants has been influenced by the division of the country into geographic zones by the mountainous Andean terrain, which impedes transportation between zones.

In addition to expansion of the PDR plant, plans include raising the capacity of the semi-integrated plants to 450,000 tons by 1980, construction of two direct-reduction sponge iron plants with a combined capacity of 500,000 tons, and construction of a new integrated steel plant, probably on the Atlantic coast near Barranquilla, with a production capacity of approximately 1.3 million tons per year.

Venezuela.—Two direct-reduction units began operation at the Government-owned plant of Corporacion Venezolana de Guyana - Siderurgica del Orinoco (CVG-SIDOR) at Matanzas, near Ciudad Guayana. One unit used the Hojalata y Lámina (HyL) process and the other the Midrex process; both had a capacity of 400,000 tons per year and operated intermittently throughout the year. The ESSO-Fior process direct-reduction unit of Fior de Venezuela S.A., completed in 1976, also operated intermittently. The HIB (high-iron briquet) process plant at Porto Ordaz was temporarily closed to permit expansion to 660,000 tons' capacity.

Feasibility studies were concluded, and engineering planning was begun by British Steel Corp. (BSC) for the projected steel plant of the Zulia Regional Development Corp. (Corpozulia) near Maracaibo. The plant is to use conventional blast furnace-basic oxygen technology, and the first phase is scheduled to begin operation in 1982 with an initial production capacity of 1.2 million tons. The decision to use coal-based technology was influenced by the presence of nearby coal reserves estimated at 1.5 billion tons. Preliminary tests have shown that the coal is suitable for coking if blended with imported low-volatile coal.

EUROPE

European Communities (EC).—The steel industry of the nations of the EC was in a depressed condition throughout the year.

Raw steel production was 139 million tons, 6% less than in 1976 and only slightly above the low point reached in 1975, and the industry was operating at 60% of capacity. The anticrisis plan instituted by former EC Steel Commissioner Henri Simonet, which included voluntary production quotas, went into effect January 1, 1977. However, the plan proved to be ineffective in revitalizing the steel industry, and the new steel Commissioner, Vicomte Etienne Davignon, put into effect a new plan which included obligatory price minima on concrete reinforcing bars, voluntary price minima on other steel products, and a system of import licensing. Later in the year, the minima on some products were raised. It was evident by yearend that these measures were insufficient, and a new system of minimum guideline prices to apply within the EC, as well as base prices on imports, was announced to take effect on January 1, 1978. Minimum prices were to be compulsory on hot-rolled coils, mechanical bars, and reinforcing bars, and voluntary on other products. Base prices on imports were similar to U.S. reference prices, in that material imported below those prices would be subject to antidumping procedures.

Some observers noted that minimum price and import controls would bring only temporary relief to the EC steel industry, which was faced with the problems of overcapacity, high production costs, and loss of export markets to third nations, and that the only permanent solution would be restructuring of the industry, involving reduction of excess capacity and closing of obsolete plants.

Belgium.—Raw steel production declined 15.8% to 11.3 million tons in 1977. SA Cockerill-Ougrée-Providence et Espérance-Longdoz (Cockerill) sustained a loss of $109 million in the first half of 1977. The Belgian Government granted loans of $128 million to Cockerill and $77 million to Société Métallurgiue Hainaut-Sambre SA. The Government commissioned a study of the entire Belgian steel industry, which also included the two major Luxembourg steel companies because of their extensive interests in Belgian companies.

France.—The French steel industry, like that of most of the EC nations, returned to the depressed condition begun in 1975, after having shown a slight recovery at the beginning of 1976. Raw steel production in 1977 was 24 million tons, about 5% less than in 1976. The French steel industry, through its trade association, the Chambre Syndicale de la Sidérurgie Francaise (CSSF), proposed a plan for restructuring the steel industry, which would be essentially completed by 1980. Under the plan, about 25% of the steelmaking capacity that is obsolete would be shut down, involving a reduction of employment from 154,000 to 134,000. Most of the plants to be closed are in the Lorraine region, and 70% of the 20,000 excess jobs are also in this region. It was hoped that most job reductions could be accomplished by early retirement and natural attrition. Investment of $1.75 to $2 billion by 1980 for modernization of the remaining plants will be needed, and a portion of this will come from government loans. Closing of Usinor's Thionville plant was completed in December when the blast furnace was shut down. The French Government created a department to maintain surveillance of the steel industry for 5 years. The main purpose of the department will be to monitor expenditures and utilization of loans for restructuring the industry. Total government loans over the next 5 years are expected to amount to $1.4 billion.

Germany, Federal Republic of.—The West German steel industry remained in a depressed state in 1977. Raw steel production fell to 43.0 million tons, the lowest since 1967; it was 8% below that of 1976 and 3.5% below that of 1975. Production of rolled steel, at 31.7 million tons, was the lowest since 1971 and 3.5% below that of 1976. Employment in the steel industry dropped by 16,000 workers to 307,967, the lowest since 1961. Imports of steel accounted for an increasing proportion of the market. For the third consecutive year steel producers incurred substantial financial losses. Some companies were able to offset losses from steel production by their other activities.

Italy.—Although raw steel production remained at about the same level as in 1976, the industry was operating at only about 60% of capacity in 1977. Italsider SpA, the large integrated steel company, lost $384 million in the first half of 1977.

Plans to build a large steelworks at Gioia Tauro in Calabria, southern Italy, were abandoned. The decision was based primarily on financial considerations. However, it was determined earlier that the area was seismically unstable and could not support blast furnace structures, and the plan had been modified to employ electric furnace steelmaking.

Egam, the state-owned steel, mining, and engineering conglomerate, was dissolved, and its steelmaking subsidiaries were taken over by Industrial Reconstruction Holding (IRI). Two of the specialty steel companies involved, Stà Nazionale Cogne and Breda Siderurgica SpA, will be merged into Acciaierie di Piombino SpA, which is jointly owned by Fiat and Italsider SpA.

The minimill reinforcing-bar producers in Brescia and vicinity, the so-called Bresciani, were criticized by other EC steel producers for selling their product at prices below the minimum set by the EC.

Luxembourg.—Steel production continued the decline begun in 1975, falling to 4.8 million tons, 5.2% below that of 1976. The major steel company, Aciéries Réunies de Burbach-Eich-Dudelange SA (ARBED), lost $62 million during the first half of 1977.

A "rescue plan" for Métallurgique et Miniére de Rodange-Athus (MMRA) was announced, subject to approval by the Belgian and Luxembourg Governments and the EC Commission. The plan included (1) restructuring of MMRA by progressive integration with ARBED, (2) reduction of employment by 700 by attrition, (3) nonreplacement of blast furnaces and cancellation of construction plans for a new rolling mill at Rodange, (4) an increase of the capitalization of the company to about $31 million, and (5) participation by the Luxembourg Government National Credit and Investment Society.

United Kingdom.—The BSC sustained a loss of $173 million in fiscal 1976-77, compared with a loss of $459 million in fiscal 1975-76. Delayed closing of obsolete plants contributed to the loss. The corporation produced 21.7 million tons of raw steel, 15% more than in the previous year. Employment was 207,900, 1% less than in 1975-76, and capital expenditures were up 10% to $1,054 million. BSC instituted a policy of greater decentralization, which placed more responsibility on divisional and works managers.

The Government approved plans for a major expansion at BSC's Port Talbot Works, at a cost of $1.44 billion. Raw steel production was to be increased to 4.4 million tons by 1982 and 6.6 million tons by 1986. Import penetration of the steel market continued, and antidumping action was taken against imports from Spain and Japan.

A three-part program that would influence decisionmaking in the BSC was proposed. It would consist of a contract with the unions for resolving problems, a steel council consisting of members from BSC management and the unions, and a steel policy board that would include members from government, consumers, competitors and other businessmen in addition to BSC and union officials.

A new stainless plate finishing facility was commissioned by BSC Stainless in Sheffield. Also planned were a new electric-arc furnace, an argon-oxygen-decarburization (AOD) refining vessel, and a slab caster.

In the private sector, GKN Rolled and Bright Steel Ltd. opened a new wire-rod mill in Cardiff, Wales, replacing a mill dating from 1950. Billets from the mill were to be provided by GKN's new minimill at Tremorfa.

Alphasteel Ltd., a cold-metal mill in South Wales owned by an international consortium, began operation in July. The plant equipment includes four 100-ton, 50-megavolt-ampere electric-arc furnaces, three slab casters, and a semicontinuous hot strip mill. When fully operational, the plant was to have a capacity of almost 1 million tons of raw steel and was to produce sheet, strip, and plate.

Plans to build an 800,000-ton-per-year direct-reduction plant at Tyneside utilizing the Thyssen Purofer process were postponed by the multinational North Sea Iron Co. consortium. At Hunterston, Scotland, construction of the first of two 400,000-ton Midrex direct-reduction plants was nearing completion.

Other Western Europe.—*Austria.*—Despite a decline of nearly 9% in raw steel production and a continuing downtrend in incoming orders, the Austrian steel industry was generally considered to be less affected by the current world steel slump than were the steel industries of many other countries. A major reason for this was the diversification of the Austrian steel industry. Capacity utilization in the industry's finishing departments was maintained between 75% and 80%, compared with 65% for raw steel production facilities. The working force was not reduced other than by attrition; however, up to 15,000 workers went on short time late in December.

Spain.—Raw steel production decreased slightly to 12.0 million tons in 1977. The economic situation, characterized by rapid inflation, balance of payments deficits, rising unemployment, and a 25% devaluation of the peseta in July, retarded the expansion plans of the Spanish steel industry. This especially affected the concerted action program, which was intended to nearly double the capacity of nonintegrated steel works and which included the construction of two direct-reduction plants, one in the north and one in the south. The integrated section of the private sector consisted of Altos Hornos de Vizcaya, SA (AHV) and its subsidiary, Altos Hornos de Mediterraneo (AHM). United States Steel Corp. had a 27% share in AHV and a 15% direct interest in AHM. The construction of the second phase of AHM's plant at Sagunto, in Valencia on the Mediterranean coast, was also affected by the economic situation. Possible solutions, apparently including nationalization of AHM, were under consideration at yearend.

Sweden.—The iron and steel industry remained in a depressed condition throughout 1977. A low rate of demand in the machinery and engineering, shipbuilding, and building and construction industries held down demand for steel. Raw steel production was 4.2 million tons; the decline of 25.9% compared with 1976 was greater than that of any Western nation. The decline in demand for steel was also reflected in the import figures. In 1977, finished steel imports declined 24% to 1.8 million tons. However, exports increased 7% to 1.8 million tons, mainly because of the industry's need to liquidate large inventories built up during 1975 and 1976 under the Government's stockpiling program.

As a result of an official investigation by the Swedish steel industry, a merger of Sweden's three largest nonspecialty steel producers was agreed upon subject to approval by the Swedish Parliament early in 1978. The new company, Svenskt Stål AB, will include the State-owned Norbottens Järnverk AB (NJA), the Oxelösund Steel Works of Gränges, AB (Gränges), and the Domnarvet steelworks of Stora Kopparbergs Bergslags AB (Stora), as well as the iron mining and railroad operations of the latter two companies. The company ownership was to be 50% by the Government and 25% each by Gränges and Stora.

Another official investigation recommended restructuring of the specialty steel industry, which would involve the merger of some mills and shutting down of others.

Stålverk 80, the large government steel project orignally planned at Luleå (adjacent to the NJA steelworks), was indefinitely suspended.

Eastern Europe.—*Hungary.*—The Lenin Metallurgical Works at Diosgyör commissioned the West German firm of Demag AG to supply a new LD steelmaking shop as part of its expansion to 1 million tons per year. The melting shop, with a capacity of 770,000 tons per year, will produce mostly carbon steel, but also some specialty steels, and is expected to be in production by 1980.

Poland.—A new blast furnace (No. 2) commissioned at Katowice Works in November, increased Polish steel production to about 2 million tons in 1977 and is expected to increase production in 1978 to 4.5 million tons. In addition, new billet, slabbing, and medium-products mills are under construction.

Romania.—Expansion programs are being implemented at several Romanian iron and steel plants, and construction was to begin at the new center at Calarasi. The new complex is designed to eventually reach the same size as the plant at Galati, which now produces about 8.0 million tons of raw steel per year and is projected to produce 11 million tons per year by 1980.

U.S.S.R.—Raw steel production, at 162 million tons, increased by 2.4 million tons over 1976 production but was 5.5 million tons below the planned production, despite the fact that 6.6 million tons of additional capacity was installed during the year. There were reported losses in pig iron production because of blast furnace downtime.

The firm of Salzgitter AG in the Federal Republic of Germany received an $85 million order for an iron ore pelletizing plant to be built at the proposed steel complex at Kursk. This follows a $232 million order to Korf Stahl AG of the Federal Republic of Germany for four Midrex direct-reduction units for the complex. When finally completed, the plant is to have a capacity of up to 4 million tons of rolled steel per year.

AFRICA

Morocco.—A steelmaking complex is planned at a location about 9 miles south of Nador, where port facilities are nearing completion. The steel plant is to have an initial capacity of 1 million tons per year, with eventual expansion to 2.5 million tons per year. Initially, it is expected that all of the plant's output will be used in Morocco, which now imports all of its steel, primarily from Spain.

Nigeria.—A contract was signed in October for the engineering and construction of a 1.1-million-ton-per-year integrated steelmaking complex, near the port of Warri in the State of Bendel, about 250 miles southeast of Lagos. The plant will include two

Midrex direct-reduction modules. Engineering and construction will be done by a six-member West German-Austrian consortium.

ASIA

China, People's Republic of.—Major additions were made during the year to steelworks at Anshan (including a blast furnace with a 1.7-million-ton-per-year capacity), Wuhan, and Penhsi, but these additions became operational too late to affect the annual steel output significantly. Imports of steel from Japan were 5 million tons, 29% higher than in 1976. China also imported about 800,000 tons of pig iron during the year, mainly from Japan and Australia.

It was reported that China intended to order a large integrated steel complex, to be erected in Shanghai, from Nippon Steel Corp. of Japan.

India.—Raw steel production increased 6% to 11.0 million tons in 1977. In the 1976-77 fiscal year, India became a net exporter of steel for the first time. Exports exceeded imports by approximately $111 million. Total exports of Indian iron and steel amounted to 2.6 million tons.

The Indian Government terminated the contract with the U.S.S.R. for construction of the second stage of the Bokaro steel plant in the eastern State of Bihar. The expansion would be done by a consortium of three State-owned Indian engineering concerns, with technical assistance from U.S. firms. In another development, the Indian Government and the U.S.S.R. signed an agreement for the construction of a steel plant in Orissa State on the east coast of India. Under the terms of the agreement, most of the output of the proposed plant would be exported to the U.S.S.R.

Indonesia.—On July 27, President Suharto inaugurated the first phase of the State-owned steel project, P.T. Krakatau Steel. The mill consists of an angles mill with a capacity of 100,000 tons per year and a bar mill, opened earlier in the year, with a capacity of 150,000 tons per year. Billets for the two rolling mills are imported from Australia. Phase 1 is to be completed in 1979 with the addition of a sponge iron plant.

Japan.—At the end of 1977, approximately 20 of a total of 66 blast furnaces in Japan were idle. Most of these were large furnaces. However, pig iron production declined by only 0.8% below 1976 production, to 94.7 million tons, because three of the world's largest blast furnaces began operation in Japan late in 1976. Raw steel production declined 4.6% to 112.9 million tons. Most of this was attributed to declines at nonintegrated steel plants. Following recommendations of a government research group, about 2.2 million tons of electric-arc furnace capacity, mostly at nonintegrated plants, was shut down. The nonintegrated steel operators formed the National Small Bar Industry Association to control the production and price of steel bars.

Apparent domestic consumption of steel declined 3.7% to 62.8 million tons, while exports declined 5.5% to 38.6 million tons. As a result of recessionary conditions, the profits of the major steel companies declined an average of 6.1% for the 6 months ending September 30, and investment in plant and equipment dropped approximately 32%.

OCEANIA

Australia.—The Australian Iron and Steel Pty. Ltd., a subsidiary of Broken Hill Proprietary Co. Ltd., shut down its No. 1 open-hearth shop at Port Kembla, New South Wales, affecting 2,000 workers. It was originally planned to phase out the shop in the early 1980's; however, poor business conditions necessitated the earlier closing.

TECHNOLOGY

Most steel industry changes during the year were evolutionary in nature or involved rounding out of existing facilities. Emphasis was on maximum use of facilities, further application of known technology, increased efficiency, reduced energy consumption, improved yield, and continued installation of pollution control equipment. Three large, new-generation blast furnaces were under construction at Bethlehem Steel's Sparrow's Point (Md.) plant, United States Steel's Fairfield (Ala.) plant, and Inland Steel Co. at Indiana Harbor (Ind.). Republic Steel Corp. installed two bottom-blown basic oxygen process (Q-BOP) vessels at its South Chicago (Ill.) plant. Continuous-casting equipment installed included the slab caster at Great Lakes Steel Div. of National Steel Corp. in Detroit, reportedly the world's widest, with the capability of casting slabs 104 inches wide and 12 inches thick.

Several new installations for desulfurization of hot metal or of steel were made during the year. Installation of the AOD process reached the point where about 90% of all stainless steel in the United States was produced by this process. More electric-arc furnaces were using water-cooled sidewalls and oxyfuel burners for more rapid melting. Both vacuum-arc remelting (VAR) and electroslag remelting (ESR) found greater use in producing high-purity steels. Several plants added other new equipment such as coke ovens, rolling mills, and galvanizing lines.

Because of the emphasis on weight reduction in the automotive industry, there was increased use of high-strength low-alloy (HSLA) steels in automobile manufacturing. There was greater use of coatings for corrosion resistance, particularly one-side galvanized steel sheet. Coatings of aluminum-zinc and nickel-zinc alloys also found some use. Low-sulfur steels were used in offshore oil-drilling rigs as well as in ships, bridges, and building construction. Work continued on development of stainless and alloy steels with lower alloy content.

Bureau of Mines Research.—The Bureau of Mines conducted research related to iron and steel at its various metallurgy research centers, which included development of corrosion-resistant iron-based alloys with smaller quantities of critical alloying materials, surface alloying of steel by ion implantation to produce a corrosion-resistant surface, and vacuum cladding of stainless steel and other alloys to a carbon steel base. Research was conducted on electroslag incremental casting for improved performance or for preparation of composite ingots, on preparation of low-sulfur steel by the electroslag process, and on improved ductile and gray cast iron for elevated-temperature use with minimal amounts of chromium and nickel. Work continued on development of ferrous damping alloys for noise suppression, preparation of iron-base alloys with chromium and nickel by powder-metallurgy methods, and activated sintering of unpressed powder-metallurgy preforms. Studies were conducted on substitutes for coke in cupola melting of cast iron, and on substitutes for fluorspar as a flux in steelmaking slags.

Contract research sponsored by the Bureau of Mines included a study of mathematical modelling of raw materials and energy needs of the iron and steel industry of the United States, and analysis of stainless steel supply and demand in the United States.

---

[1]Physical scientist, Division of Ferrous Metals.
[2]Tons in this chapter refer to short tons of 2,000 pounds.
[3]Steel production and shipments from Annual Statistical Report 1977 - American Iron and Steel Institute; inventories from Current Industrial Reports, Inventories of Steel Mill Shapes, Summary for 1977, U.S. Department of Commerce, Bureau of the Census.

Table 2.—Pig iron produced and shipped in the United States in 1977, by State

(Thousand short tons and thousand dollars)

State	Production	Shipped from furnaces		Average value at furnace, dollars per ton
		Quantity	Value	
Alabama	3,133	3,227	598,365	$185.42
Illinois	6,226	6,255	1,155,931	184.80
Indiana	16,490	16,585	2,994,065	180.53
Ohio	14,693	14,752	2,695,155	182.70
Pennsylvania	16,643	17,288	3,104,427	179.57
California, Colorado, Utah	4,733	4,719	724,315	153.49
Kentucky, Maryland, Texas, West Virginia	9,226	9,246	1,648,477	178.29
Michigan	6,809	6,808	1,252,821	184.02
New York	3,541	3,512	666,254	189.71
Total	81,494	82,392	14,839,810	180.11

Table 3.—Foreign iron ore and manganiferous iron ore (excluding agglomerates) consumed in manufacturing pig iron in the United States, by source of ore

(Thousand short tons)

Source	1976[1]	1977[2]
Australia	715	175
Brazil	2,546	1,238
Canada	993	1,312
Chile	505	580
Peru	10	--
Venezuela	3,081	3,634
Other countries	900	926
Total	8,750	7,865

[1]Excludes 16,883,000 tons used in making agglomerates.
[2]Excludes 15,953,000 tons used in making agglomerates.

Table 4.—Pig iron shipped from blast furnaces in the United States, by grade[1]

(Thousand short tons and thousand dollars)

Grade	1976			1977		
	Quantity	Value		Quantity	Value	
		Total	Average per ton		Total	Average per ton
Foundry	8,383	1,560,636	$186.17	9,143	1,730,714	$189.29
Basic	75,550	13,464,631	178.22	69,931	12,502,990	178.79
Bessemer	1,119	210,923	188.49	1,183	225,127	190.30
Low-phosphorus	102	18,902	185.31	170	30,085	176.97
Malleable	1,208	222,954	184.56	1,098	196,990	179.41
All other (not ferroalloys)	331	51,888	156.76	867	153,904	177.51
Total	86,693	15,529,934	179.14	82,392	14,839,810	180.11

[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 State

State	Jan. 1, 1977			Jan. 1, 1978		
	In blast	Out of blast	Total	In blast	Out of blast	Total
Alabama	7	2	9	9	--	9
California	3	1	4	3	1	4
Colorado	3	1	4	4	--	4
Illinois	8	11	19	11	5	16
Indiana	16	11	27	21	4	25
Kentucky	2	--	2	2	--	2
Maryland	3	7	10	5	3	8
Michigan	8	1	9	8	1	9
New York	5	6	11	7	2	9
Ohio	21	18	39	27	11	38
Pennsylvania	22	27	49	28	18	46
Texas	2	--	2	2	--	2
Utah	3	--	3	3	--	3
West Virginia	3	1	4	4	--	4
Total	106	86	192	134	45	179
Ferroalloy blast furnaces	1	--	1	--	--	--
Grand total	107	86	193	134	45	179

Source: American Iron and Steel Institute.

Table 6.—Iron ore and other metallic materials, coke, and fluxes consumed, and pig iron produced in the United States, by State

(Thousand short tons unless otherwise specified)

State	Metalliferous materials consumed: Iron and manganiferous ores							Net coke	Fluxes	Pig iron produced	Metalliferous materials consumed per ton of pig iron (short tons)				Coke and fluxes consumed per ton of pig iron (short tons)	
	Domestic	Foreign	Agglomerates	Net ores and agglomerates[1]	Net scrap[2]	Miscellaneous[3]	Net total				Net ores and agglomerates[1]	Net scrap[2]	Miscellaneous[3]	Total	Net coke	Fluxes
1976:																
Alabama	W	1,552	3,990	5,504	45	63	5,612	2,216	450	3,297	1.669	0.014	0.019	1.702	0.672	0.136
Illinois	W	4	9,938	10,071	263	249	10,584	3,187	705	6,429	1.566	.041	.039	1.646	.496	.110
Indiana and Michigan	922	428	37,579	38,474	928	1,606	41,008	13,497	[r]2,785	24,825	1.550	.037	.065	1.652	.544	[r].112
New York	647	W	5,974	6,812	167	108	7,086	2,971	603	4,362	1.562	.038	.025	1.624	.681	.138
Ohio	2,425	1,801	20,099	23,938	359	979	25,276	10,474	3,046	15,762	1.519	.023	.062	1.604	.665	.193
Pennsylvania	2,135	[r]2,952	24,181	[r]28,744	932	707	[r]30,382	10,974	2,102	18,007	1.596	.052	.039	1.687	.609	.117
California, Colorado, Utah	1,561	W	6,233	7,815	173	97	8,085	2,708	904	4,694	1.665	.037	.021	1.722	.577	.193
Maryland, West Virginia, Kentucky, Texas	310	1,555	13,470	14,889	245	502	15,637	5,680	1,028	9,472	1.572	.026	.053	1.651	.600	.109
Total	8,228	[r]8,749	121,464	[r]136,247	3,112	4,311	[r]143,670	51,707	[r][4]11,623	86,848	1.569	.036	.050	1.654	.595	[r].134
1977:																
Alabama	W	1,518	3,562	4,999	51	57	5,108	2,033	466	3,133	1.596	.016	.018	1.630	.649	.149
Illinois	W	8	9,164	9,633	276	263	10,172	3,763	817	6,226	1.547	.044	.042	1.634	.604	.131
Indiana and Michigan	1,037	684	34,796	36,018	1,229	1,300	38,547	12,990	1,828	23,299	1.546	.053	.056	1.654	.558	.078
New York	470	W	5,008	5,526	120	167	5,813	2,297	468	3,541	1.561	.034	.047	1.642	.649	.132
Ohio	1,689	1,020	19,915	22,282	337	1,008	23,628	9,017	2,966	14,693	1.517	.023	.069	1.608	.614	.202
Pennsylvania	2,463	3,124	21,110	26,179	850	663	27,692	10,220	1,891	16,643	1.573	.051	.040	1.664	.614	.114
California, Colorado, Utah	1,860	W	6,042	7,904	179	103	8,185	2,822	986	4,733	1.670	.038	.022	1.729	.596	.208
Maryland, West Virginia, Kentucky, Texas	358	1,248	12,902	14,111	349	468	14,928	5,263	725	9,226	1.529	.038	.051	1.618	.570	.079
Total	8,417	7,865	112,499	126,652	3,391	4,029	134,073	48,405	[5]10,147	81,494	1.554	.042	.049	1.645	.594	.125

[r]Revised. W Withheld to avoid disclosing individual company confidential data; included with "Total."
[1]Net ores and agglomerates equal ore 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 the following: 4,831 limestone, 209 burnt lime, [r]6,174 dolomite, and 408 other fluxes excluding 4,384 limestone, 20 burnt lime, [r]3,576 dolomite, and 68 other fluxes used in agglomerate production at or near steel plants and an unknown quantity used in making agglomerates at mines.
[5]Fluxes consisted of the following: 3,956 limestone, 14 burnt lime, 5,688 dolomite, and 488 other fluxes excluding 4,281 limestone, 15 burnt lime, 4,032 dolomite, and 69 other fluxes used in agglomerate production at or near steel plants and an unknown quantity used in making agglomerates at mines.

Table 7.—Steel production in the United States, by type of furnace[1]

(Thousand short tons)

Year	Open hearth	Basic oxygen converter	Electric	Total
1973	39,780	83,260	27,759	150,799
1974	35,499	81,552	28,669	145,720
1975	22,161	71,801	22,680	116,642
1976	23,470	79,918	24,612	128,000
1977	20,043	77,408	27,882	125,333

[1]Excludes 1.7 million tons of finished steel castings produced by foundries not covered by AISI.

Source: American Iron and Steel Institute.

Table 8.—Metalliferous materials consumed in steel furnaces[1] in the United States

(Thousand short tons)

Year	Iron ore[2]		Agglomerates[2]		Pig iron	Ferro-alloys[3]	Iron and steel scrap
	Domestic	Foreign	Domestic	Foreign			
1973	163	1,320	656	243	94,398	1,907	76,352
1974	153	1,126	272	302	90,031	1,950	75,329
1975	92	515	553	189	74,518	1,450	58,071
1976	66	593	584	195	81,926	1,495	63,554
1977	112	372	123	102	77,086	1,519	64,231

[1]Basic oxygen converter, open-hearth, and electric furnace.
[2]Consumed in integrated steel plants only.
[3]Includes ferromanganese, spiegeleisen, silicomanganese, manganese metal, ferrosilicon, ferrochromium, and ferromolybdenum.

Table 9.—Consumption of pig iron in the United States, by type of furnace or other use

Type of furnace or other use	1975		1976		1977	
	Thousand short tons	Percent of total	Thousand short tons	Percent of total	Thousand short tons	Percent of total
Basic oxygen converter	59,210	74.3	66,138	76.0	63,877	77.9
Open hearth	14,554	18.3	15,410	17.7	12,531	15.3
Electric	1,019	1.3	638	.7	993	1.2
Cupola	1,362	1.7	1,197	1.4	1,241	1.5
Air and other furnaces[1]	483	.6	406	.5	354	.4
Direct castings[2]	3,010	3.8	3,255	3.7	3,007	3.7
Total	79,638	100.0	[3]87,045	100.0	82,003	100.0

[1]Includes vacuum melting furnaces and miscellaneous melting processes.
[2]Castings made directly from blast furnace hot metal. Includes ingot molds and stools.
[3]Data do not add to total shown because of independent rounding.

Table 10.—Consumption of pig iron[1] in the United States, by State

(Thousand short tons)

State	1977
Alabama	3,077
Arkansas	3
California	1,881
Connecticut	12
Georgia	3
Illinois	6,223
Indiana	16,587
Iowa	31
Kansas	6
Kentucky	1,639
Maine	(2)
Maryland	3,799
Massachusetts	18
Michigan	7,097
Minnesota	35
Missouri	11
Nevada	(2)
New Jersey	25
New York	3,314
North Carolina	7
Ohio	14,566
Oklahoma	9
Pennsylvania	16,832
Rhode Island	3
Tennessee	59
Texas	1,225
Utah	1,930
Virginia	112
Washington	1
West Virginia	2,511
Wisconsin	72
Undistributed[3]	915
Total	82,003

[1]Includes molten pig iron used for ingot molds and direct castings.

[2]Less than 1/2 unit.

[3]Includes Colorado, Florida, New Hampshire, Oregon, and South Carolina.

Table 11.—U.S. exports of major iron and steel products

Products	1973 Quantity (short tons)	1973 Value (thousands)	1974 Quantity (short tons)	1974 Value (thousands)	1975 Quantity (short tons)	1975 Value (thousands)	1976 Quantity (short tons)	1976 Value (thousands)	1977 Quantity (short tons)	1977 Value (thousands)
SEMIMANUFACTURED										
Ingots and other primary forms:										
Puddled bars and pilings, blocks, lump, other primary forms of iron or steel, n.e.c	38	$18	1,223	$653	320	$83	322	$95	39	$9
Blooms, billets, ingots, slabs, sheet bars, roughly forged pieces	546,991	63,023	804,768	147,730	323,320	58,727	260,682	42,063	248,036	37,414
Coils for rerolling	43,702	10,732	149,643	38,760	8,550	4,328	11,607	4,371	11,613	5,246
Blanks for tubes and pipes, iron or steel	3,737	394	2,654	420	1,628	160	977	82	391	49
Total	594,468	74,167	958,288	187,563	333,818	63,298	273,588	46,611	260,079	42,718
Bars, rods, angles, shapes, sections:										
Wire rods	89,786	15,303	65,847	17,469	40,616	10,826	112,869	20,949	83,934	16,922
Bars, rods, hollow-drill steel	239,617	70,368	402,996	144,384	174,826	83,264	175,383	74,365	145,849	67,637
Concrete reinforcing bars	151,535	29,788	320,272	86,036	65,323	17,175	2,830	1,313	75,967	14,576
Angles, shapes, sections	272,519	58,708	397,560	109,130	209,998	69,740	121,756	39,824	106,418	41,327
Plates and sheets:										
Steel plates	29,392	17,405	54,791	32,204	29,358	26,923	26,827	25,629	15,713	18,032
Steel sheets	658,430	152,935	1,027,369	293,110	191,943	85,168	309,197	105,066	153,214	70,317
Black plate	95,272	16,344	81,297	18,708	13,086	2,709	28,026	5,101	23,547	4,335
Iron and steel plates, n.e.c	473,911	97,176	536,337	166,602	278,599	101,980	155,277	32,554	130,748	54,952
Tinplate and terneplate	419,275	95,344	500,939	173,742	266,627	109,671	385,484	137,966	341,944	121,472
Tinplate, circles, cobbles, strip, scroil	24,151	2,678	17,395	2,654	2,837	437	16,843	1,949	23,561	2,821
Hoop and strip	268,762	83,076	394,738	141,894	83,925	62,311	248,493	100,799	83,598	70,413
Total	2,722,650	639,125	3,799,541	1,185,933	1,357,138	570,204	1,582,985	545,515	1,184,493	482,804
MANUFACTURED										
Rails and railway track construction materials:										
Rails	108,965	19,184	128,631	26,221	150,670	45,011	146,892	49,988	95,188	22,420
Joints and tie plates	14,302	3,667	34,610	9,301	43,669	14,509	17,296	5,733	20,244	4,052
Sleeper and track material of iron or steel, n.e.c	4,253	2,044	10,002	5,096	15,177	11,038	5,878	5,857	14,110	12,953
Wire, cables, ropes, bands, slings	88,469	58,639	127,622	98,844	114,932	106,046	130,007	141,402	126,984	113,134
Tubes, pipes, fittings:										
Cast-iron pressure pipe and fittings	27,897	13,575	38,857	29,244	38,635	34,632	33,166	27,168	52,495	38,845
Cast-iron soil pipe and fittings	6,208	2,894	13,358	8,496	39,929	29,719	38,516	28,027	21,111	15,112
Steel tube and pipe fittings, unions, flanges	21,451	40,176	32,055	68,698	30,203	86,498	27,286	96,764	24,714	89,052

Table 11.—U.S. exports of major iron and steel products —Continued

Products	1973 Quantity (short tons)	1973 Value (thousands)	1974 Quantity (short tons)	1974 Value (thousands)	1975 Quantity (short tons)	1975 Value (thousands)	1976 Quantity (short tons)	1976 Value (thousands)	1977 Quantity (short tons)	1977 Value (thousands)
MANUFACTURED —Continued										
Tubes, pipes, fittings —Continued										
Steel tube and pipe fittings, welded	7,621	15,186	12,304	27,668	12,944	42,869	10,881	40,753	7,826	27,996
Malleable iron tube and pipe fittings, n.e.c	3,747	5,449	4,104	5,907	2,300	4,610	3,852	6,451	5,746	8,026
Electrical conduit fittings of iron or steel	4,611	6,710	7,006	10,911	6,548	13,360	9,376	17,540	8,190	20,008
Iron tube and pipe fittings, n.e.c	11,315	20,827	14,150	30,986	19,478	50,427	15,478	41,001	15,457	39,529
Seamless tubes and pipe	376,997	162,263	628,082	513,862	793,638	934,225	371,148	400,871	296,982	336,151
Welded, clinched, or riveted tubes and pipe	207,893	77,658	268,353	156,551	255,678	215,608	144,932	117,965	123,065	102,233
Finished structural iron and steel	219,228	153,914	294,345	251,688	220,736	312,554	219,747	356,417	199,529	384,055
Castings and forgings	439,298	173,576	481,091	230,540	407,715	269,923	488,543	348,236	479,936	353,852
Storage tanks, lined or unlined	14,804	11,764	29,826	25,153	19,652	20,879	23,426	29,874	22,387	27,094
Nails, tacks, staples, spikes, n.e.c	12,822	10,928	16,172	14,358	13,740	12,949	15,131	14,882	14,818	14,704
Bolts	31,394	31,677	38,851	44,287	42,800	52,178	48,994	53,911	55,521	56,975
Nuts	10,865	14,613	15,901	22,536	21,740	23,321	23,596	23,930	26,031	27,152
Screws, rivets, washers	32,272	42,850	38,880	58,194	33,859	55,985	40,631	63,511	43,094	65,489
Total	1,644,412	867,594	2,234,200	1,638,541	2,284,043	2,336,341	1,814,776	1,870,281	1,653,428	1,758,832
Grand total	4,961,530	1,580,886	6,992,029	3,012,037	3,974,999	2,969,843	3,671,349	2,462,407	3,098,000	2,284,354

Table 12.—U.S. imports for consumption of pig iron, by country

Country	1975 Quantity (short tons)	1975 Value (thousands)	1976 Quantity[r] (short tons)	1976 Value (thousands)	1977 Quantity (short tons)	1977 Value (thousands)
Australia	17,545	$3,038	17,909	$2,858	11,945	$1,998
Belgium-Luxembourg	111	26	--	--	--	--
Brazil	25,232	2,717	128,410	10,846	122,678	10,955
Canada	224,379	35,393	225,527	33,791	188,860	27,288
Colombia	1,981	269	--	--	--	--
France	--	--	--	--	6,169	832
Germany, Federal Republic of	5,592	899	--	--	--	--
Hungary	55,652	9,225	--	--	--	--
Japan	104,085	12,575	25,898	1,573	6,097	552
Mexico	--	--	--	--	73	7
Norway	5,512	740	--	--	--	--
Sweden	32,201	3,411	7,892	1,013	29,732	2,364
United Kingdom	5,816	1,023	9,027	1,061	7,213	920
Total	478,106	69,316	414,663	51,142	372,767	44,916

[r]Revised.

Table 13.—U.S. imports for consumption of major iron and steel products

Products	1973 Quantity (short tons)	1973 Value (thousands)	1974 Quantity (short tons)	1974 Value (thousands)	1975 Quantity (short tons)	1975 Value (thousands)	1976 Quantity (short tons)	1976 Value (thousands)	1977 Quantity (short tons)	1977 Value (thousands)
Iron products:										
Cast-iron pipes and tubes	6,248	$1,873	6,593	$3,053	8,264	$3,945	7,906	$5,577	7,678	$4,023
Malleable cast-iron fittings	8,493	6,018	6,643	5,765	7,535	6,941	11,136	10,093	13,845	12,617
Bars of wrought iron	243	84	390	139	200	94	3	1	18	28
Castings and forgings	23,059	11,138	35,898	20,371	31,536	21,319	25,832	16,331	34,217	19,227
Total	38,043	19,113	49,524	29,328	47,535	32,299	44,877	32,002	55,758	35,895
Iron and steel products:										
Ingots, blooms, billets, slabs, sheet bars	172,305	30,801	182,859	42,839	242,833	69,333	240,107	52,812	297,704	63,359
Bars of steel:										
Concrete reinforcement bars	286,428	43,875	477,750	137,286	142,232	26,860	r192,168	r29,962	92,602	14,975
Solid and hollow steel bars	954,286	197,426	866,458	301,733	611,503	243,926	r578,029	r193,723	1,004,365	306,835
Hollow drill steel	2,637	1,376	2,929	1,819	2,797	2,418	1,746	1,428	2,737	2,308
Plates and sheets:										
Black plate	3,323	651	8,333	2,352	6,445	1,574	12,596	3,422	16,939	5,456
Steel plate	1,348,767	216,255	1,729,001	499,862	1,394,484	404,646	r1,735,930	r683,068	2,116,137	472,992
Steel sheets	5,837,588	986,676	5,689,737	1,621,105	4,411,404	1,136,183	5,527,122	1,394,298	8,046,768	2,144,601
Plates and sheets of iron or steel	709	549	527	350	696	1,142	556	916	2,299	3,017
Plates, sheets and strip of iron or steel[1]	71,737	16,976	61,407	21,249	65,002	25,527	66,584	23,018	122,914	42,878
Strip of iron or steel	116,415	52,306	98,058	60,834	71,506	54,690	75,794	47,210	94,901	68,379
Tinplate and terneplate	470,345	105,630	318,996	98,349	408,414	170,191	r311,874	r108,308	448,200	162,661
Structural iron and steel	1,375,223	228,419	1,229,375	358,640	903,343	274,985	1,433,809	326,115	1,872,205	439,244
Angles, shapes, sections	457,457	63,044	521,622	156,371	167,284	48,719	r309,880	r33,338	263,585	50,737
Wire rods of steel	1,416,256	229,258	1,950,628	581,611	1,112,794	349,577	r1,120,731	r288,502	1,341,492	345,039
Sheet piling	81,248	12,303	84,162	19,295	63,734	17,375	63,088	13,626	73,955	17,370
Pipes, tubes, fittings	1,681,112	383,372	1,952,523	748,934	1,778,608	1,021,002	1,958,512	746,004	2,531,136	971,783
Bail ties of iron or steel	15,334	3,011	27,452	9,530	16,610	6,272	--	--	--	--
Steel castings and forgings	19,020	7,137	13,555	8,358	15,952	11,953	11,741	7,514	106,261	24,455
Rails and railway track construction materials	77,697	14,741	117,478	34,025	175,418	68,018	r113,674	r34,978	207,185	65,121
Wire:										
Round wire	525,893	173,701	608,888	317,361	381,289	232,687	380,130	203,702	498,168	277,807
Other wire	87,740	32,217	93,538	55,230	52,265	38,704	70,990	41,254	58,155	40,266
Nails	345,121	97,332	355,815	167,201	220,934	100,267	358,217	139,266	421,954	175,888
Total	15,346,641	2,897,056	16,391,091	5,244,334	12,245,547	4,306,049	r14,563,278	r4,372,464	19,619,662	5,695,171
Advanced manufactures:										
Bolts, nuts, rivets, washers	223,192	129,043	305,418	309,044	194,779	169,142	430,282	179,961	254,974	204,493
Grand total	15,607,876	3,045,212	16,746,033	5,582,706	12,487,861	4,507,490	r15,038,437	r4,584,427	19,930,394	5,935,559

r Revised.

[1] Includes plates, sheets and strips of iron or steel, electrolytically coated or plated: 1973, 63,787 tons ($14,020); 1974, 48,945 tons ($14,957); 1975, 56,789 tons ($21,405); 1976, 59,559 tons ($19,852); 1977, 103,877 tons ($34,909).

Table 14.—Pig iron:[1] World production, by country

(Thousand short tons)

Country[2]	1975	1976	1977[p]
North America:			
Canada	10,086	10,803	10,649
Mexico[3]	3,265	3,889	4,762
United States	79,721	86,848	81,494
South America:			
Argentina	1,144	1,454	1,527
Brazil	7,774	9,006	10,788
Chile	459	445	476
Colombia	323	315	246
Peru	332	246	269
Venezuela	589	471	548
Europe:			
Austria	3,368	3,658	3,268
Belgium	9,996	10,875	[e]9,815
Bulgaria	1,663	1,717	[e]1,786
Czechoslovakia	10,200	10,443	[e 4]10,710
Finland	1,495	1,456	1,944
France	19,284	20,566	19,705
German Democratic Republic[4]	2,707	2,787	[e]2,888
Germany, Federal Republic of	32,853	34,765	31,633
Greece	595	441	441
Hungary	2,446	2,448	[e]2,500
Italy	12,512	12,821	12,578
Luxembourg[4]	4,287	4,140	3,933
Netherlands	4,376	4,702	4,323
Norway	703	723	605
Poland	8,381	8,721	[e]10,505
Portugal	361	379	393
Romania	7,277	8,174	[e]8,820
Spain	[r]7,542	7,302	[e]7,300
Sweden[3]	3,854	3,523	2,745
Switzerland	39	25	[e]30
U.S.S.R	112,390	116,166	[e]117,065
United Kingdom	[r]13,278	15,116	[e]13,120
Yugoslavia	2,205	2,114	2,136
Africa:			
Algeria	440	[r e]446	[e]500
Egypt	463	627	82
Morocco	13	[e]13	[e]13
Rhodesia, Southern[e]	[r]330	[r]330	300
South Africa, Republic of	5,707	6,388	6,740
Tunisia	[r]159	119	146
Asia:			
China, People's Republic of[e 5]	35,000	33,000	33,000
India	[r]9,138	10,776	11,133
Iran[e]	1,100	1,100	1,100
Israel[e]	44	44	44
Japan	95,765	95,434	94,673
Korea, North[e 5]	[r]3,100	3,300	3,400
Korea, Republic of	1,308	2,136	2,674
Malaysia[e]	200	210	210
Taiwan	74	116	80
Thailand	14	13	21
Turkey	1,498	2,196	1,904
Oceania:			
Australia	8,240	8,176	7,444
New Zealand[e 3]	[r]200	[r]230	230
Total	[r]528,298	551,193	542,696

[e]Estimate. [p]Preliminary. [r]Revised.

[1]Table excludes all ferroalloy production except where otherwise noted.

[2]In addition to the countries listed, Vietnam and Zaire have facilities to produce pig iron and may have produced limited quantities during 1975-1977, but output is not reported and available general information is inadequate to permit formulation of reliable estimates of output levels.

[3]Includes sponge iron output as follows in thousand short tons: Mexico: 1975—1,007; 1976—1,229; 1977—[e]1,400; Sweden: 1975—193; 1976—206; 1977—[e]155; New Zealand, total figure for all years.

[4]May include blast furnace ferroalloys.

[5]Includes ferroalloys.

Table 15.—Raw steel:[1] World production by country

(Thousand short tons)

Country[2]	1975	1976	1977[p]
North and Central America:			
Canada	14,357	14,690	15,026
Cuba[e]	[r]330	275	330
El Salvador	12	[e]12	15
Mexico	5,812	5,840	6,113
United States[3]	116,642	128,000	125,333
South America:			
Argentina	2,500	2,657	2,950
Brazil	9,158	10,107	12,183
Chile	538	531	604
Colombia	407	397	360
Peru	476	385	418
Uruguay	18	17	19
Venezuela	1,185	1,033	942
Europe:			
Austria	4,484	4,935	4,511
Belgium	12,773	13,392	11,270
Bulgaria	2,497	2,712	[e]2,860
Czechoslovakia	15,789	16,196	[e]16,600
Denmark	616	796	756
Finland	1,784	1,812	2,420
France	23,733	25,597	24,350
German Democratic Republic	7,135	7,421	7,551
Germany, Federal Republic of	44,550	46,754	42,974
Greece	[r]795	[r] [e]500	496
Hungary	4,049	4,026	[e]4,020
Ireland	89	64	53
Italy	24,070	25,845	25,721
Luxembourg	5,098	5,033	4,772
Netherlands	[r]5,320	5,717	5,431
Norway	1,000	990	808
Poland	16,542	17,240	19,670
Portugal	462	511	591
Romania	10,526	11,831	12,787
Spain	[r]12,276	12,026	[e]11,967
Sweden	6,186	5,666	[e]4,200
Switzerland	463	601	[e]770
U.S.S.R	155,784	159,620	162,000
United Kingdom	22,264	24,552	[e]23,340
Yugoslavia	3,215	3,032	4,204
Africa:			
Algeria	[r]244	392	441
Angola	45	42	[e]44
Egypt	384	504	290
Ghana[e]	17	17	17
Kenya[e]	--	11	11
Libya[e]	11	11	11
Morocco[e]	[r]7	[r]7	7
Mozambique[e]	42	44	44
Nigeria[e]	15	17	17
Rhodesia, Southern[e]	330	330	330
South Africa, Republic of	7,163	7,807	[e]8,060
Tunisia	143	113	172
Uganda	17	[r]17	[e]17
Zaire[e]	--	33	33
Asia:			
Bangladesh	107	91	128
Burma[e]	[r]40	45	45
China, People's Republic of[e]	[r]28,000	[r]28,000	30,000
Hong Kong[e]	[r]75	80	80
India	[r]8,809	10,322	10,936
Indonesia	110	110	[e]110
Iran	607	605	[e]605
Iraq[e]	230	220	220
Israel[e]	[r]60	[r]90	110
Japan	112,780	118,387	112,882
Jordan[e]	200	220	220
Korea, North[e]	[r]3,130	3,300	3,400
Korea, Republic of	2,215	2,974	3,017
Lebanon[e]	17	[r]9	9
Malaysia	215	220	[e]220
Philippines[e]	[r]310	[r]330	330
Saudi Arabia[e]	175	175	175
Singapore[e]	[r]206	220	[e]220
Syria[e]	150	165	165
Taiwan	573	658	710
Thailand	[r]284	309	[e]330

See footnotes at end of table.

Table 15.—Raw steel:[1] World production by country —Continued

(Thousand short tons)

Country[2]	1975	1976	1977[p]
Asia —Continued			
Turkey	1,607	1,606	1,540
Vietnam	4	4	6
Oceania:			
Australia	8,645	8,569	8,061
New Zealand	204	236	[e]220
Total	[r]710,106	747,103	741,648

[e]Estimate. [p]Preliminary. [r]Revised.

[1]Steel formed in first solid state after melting, suitable for further processing or sale; for some countries, includes material reported as "liquid steel," presumably measured in the molten state prior to cooling in any specific form.

[2]In addition to the countries listed, Vietnam produces steel, but output is not reported and available general information is inadequate to permit formulation of reliable estimates of output levels.

[3]Data from American Iron and Steet Institute (AISI). Excludes steel produced by foundries not reporting output to AISI but reported to Bureau of the Census as follows (in thousand short tons): 1975—1,937; 1976—1,804; 1977—1,718.

Iron and Steel Scrap

By K. W. Palmer[1]

Reflecting the relatively small total change in the economy, domestic consumption of iron and steel scrap in 1977 increased only 2.6% over that of 1976. Net receipts of scrap by users, however, decreased by 6.7%, while yearend stocks decreased by 6.3% to 9.4 million tons.[2]

Scrap consumption closely paralleled last year's pattern, with the 1977 maximum again occurring in May. Monthly consumption rose, following the trend in raw steel production, from 6.7 million tons in January to a peak of 8.6 million tons in May. Consumption then fell by stages to a low of 7.4 million tons in December, accompanied by a marked decline in price.

Reported consumption of direct-reduced iron (prereduced iron ore), used as a scrap substitute by a few smaller steelworks was 426,000 tons, or 21% more than in 1976.

U.S. exports of scrap declined for a second straight year and were 26% below those of 1976, reflecting the depressed world steel market. No. 1 heavy melting grade regained its leading position over shredded scrap as the principal grade exported.

Research was continued by the Bureau of Mines on coke substitutes in cupola furnace operations as well as the use of urban raw ferrous refuse to replace part of the charge and to calculate the economic effects. The pilot plant built and operated by the Bureau of Mines at Hyattsville, Md., was used by several communities to process their refuse experimentally and evaluate the recovery of various components. The ferrous scrap fraction showed the most economic promise in all experiments and trial runs with this refuse.

Table 1.—Salient iron and steel scrap and pig iron statistics in the United States

(Thousand short tons and thousand dollars)

	1976	1977
Stocks Dec. 31:		
Scrap at consumer plants	9,988	9,363
Pig iron at consumer and supplier plants	1,519	1,322
Total	11,507	10,685
Consumption:		
Scrap	89,910	92,198
Pig iron	87,045	82,003
Exports:		
Scrap (excludes rerolling material and ships, boats, and other vessels for scrapping)	7,877	5,854
Value	$601,826	$381,041
Imports for consumption:		
Scrap (includes tinplate and terneplate scrap)	507	614
Value	$35,120	$40,501

Legislation and Government Programs.—On February 1, 1977, the Interstate Commerce Commission (ICC) rejected an appeal by National Association of Recycling Industries (NARI) and by implication, a parallel appeal by Institute of Scrap Iron and Steel (ISIS), which asked for reversal of an earlier ICC decision rejecting the removal of freight-rate discrimination against scrap as a recyclable material. The appeals of NARI and ISIS were supported by briefs filed in September by the Justice Department and the Federal Energy Administration (FEA) asking that the earlier order be vacated and remanded as not complying fully with the congressional mandate for Section 204 of the Railroad Revitalization and Regulatory Reform Act of 1976, (the section calling for the encouragement of recycling). A group of railroads filed briefs in November challenging the ISIS and NARI briefs. The ICC had not added its rebuttals by yearend.

In April, the ICC determined in its Ex-Parte 252 (Sub-No. 2) proceedings "that the Nation's plain gondola car supply is inadequate to meet the future needs of commerce." The ICC analysis was rejected by ISIS for several reasons, mainly that the ICC was using carefully selected historical data which treated supply of gondolas rather than demand.

In November 1976, ISIS petitioned for a revision of the industrial classification for scrap processors from wholesaler to processor. Cited were advantages in zoning, taxing, fuel allocation, and inventory. In May 1977 this was rejected by an interagency committee of the Government, the Technical Committee on Industrial Classification, on the grounds that it would be too difficult to separate processors from collectors and sorters.

AVAILABLE SUPPLY

The new supply of iron and steel scrap, available for consumption at consumers' plants in 1977, totaled 91.4 million tons, the same amount as in 1976. It consisted of 49.5 million tons of home scrap and 41.9 million tons of purchased scrap (net receipts). These quantities were 1% lower and 1% higher, respectively, than in 1976.

CONSUMPTION

Consumption of iron and steel scrap in 1977 was 92.2 million tons, or 2% more than in 1976. Manufacturers of pig iron, raw steel, and castings consumed 69.3 million tons (75%); iron foundries and miscellaneous users consumed 20.0 million tons (22%); and steel foundries consumed the remainder. Shredded scrap consumed domestically or exported in 1977 totaled 4.8 million tons or 8% less than in 1976. The proportion of shredded scrap consumed domestically or exported declined from 5.8% to 5.2% of total scrap consumption.

STOCKS

Consumers' stocks reported on hand as of December 31, 1977, totaled 9.4 million tons or 6% less than those at yearend 1976.

PRICES

At approximately $66 per long ton, the Iron Age composite price for No. 1 heavy melting steel scrap at the end of 1977 was $4 lower than at the beginning of the year. The weekly composite price for No. 1 heavy melting steel scrap rose from $72.17 per long ton on January 2 to a 1977 high in late March of $74.50, then declined slowly to a low of $46.83 in November (lowest since 1973), recovering to $66.17[3] at yearend. This resulted in an average annual price for No. 1 heavy melting steel scrap of $62.95,[3] 19% below the average price of $77.79 for 1976. These price trends were reflected in prices of other grades of ferrous scrap.

FOREIGN TRADE

Exports of iron and steel scrap, excluding rerolling material and vessels for scrapping, amounted to 5.9 million tons in 1977, 26% less than the 7.9 million tons exported in

1976. The decline reflected the depressed condition of the steel industries of the major scrap importing countries, except for the Republic of Korea.

The Republic of Korea replaced Spain as the principal destination of U.S. scrap, with 25% of the total in 1977, followed by Japan, with 18%; Spain, with 13%; and Canada, with 9%. The tonnage exported to Japan was the lowest since 1958.

No. 1 heavy melting steel scrap (30% of total scrap exported) regained its position as the leading export grade, followed by shredded and fragmentized scrap (27%).[3]

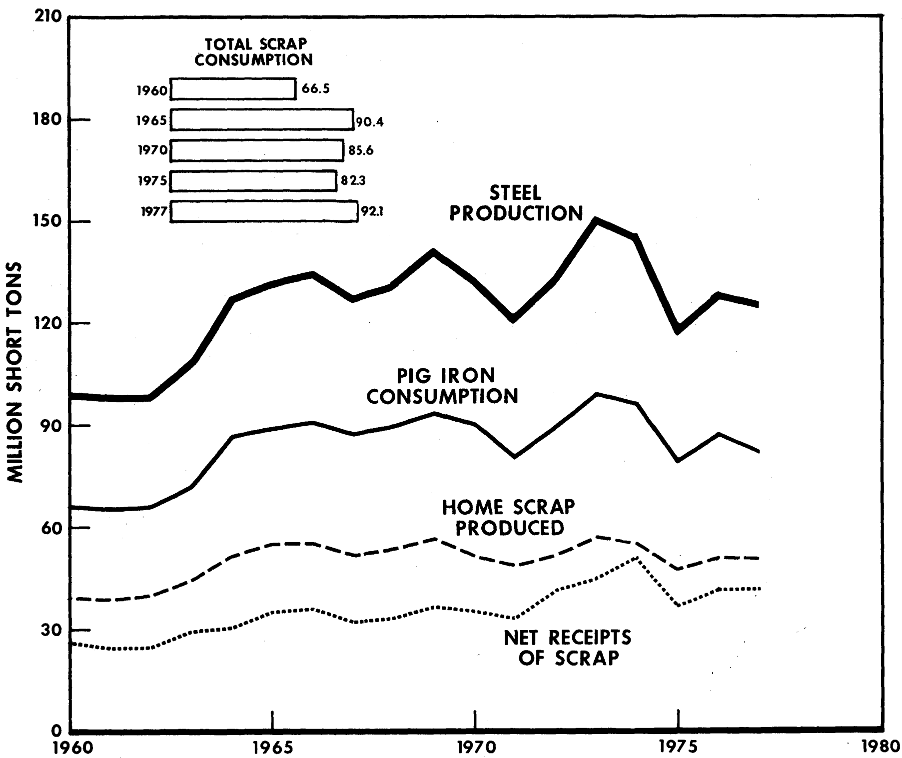


Figure 1.—Steel production (AISI), total iron and steel scrap consumption, pig iron consumption, home scrap production, and net scrap receipts.

WORLD REVIEW

Apparent world consumption of ferrous scrap in 1977, as estimated from data available for the principal consuming countries, appeared to be about the same as in 1976, reflecting the lack of change in total world raw steel production. The United States remained the largest exporter of iron and steel scrap to world markets in 1977, while Italy remained the world's leading importer.

Relationships between apparent consumption of scrap and production of raw steel differs from country to country because of differences in metallurgical practice, magnitude of foundry consumption, availability of scrap, and other factors. For example, relatively large proportions of the raw steel output of Italy and Spain were produced from scrap in electric furnaces, whereas steel produced in France and Japan was made largely in converters using hot metal and relatively low proportions of scrap. Foundry consumption of scrap in comparison to total consumption of scrap in the United States and the United Kingdom was proportionately larger than in most other countries. However total consumption of scrap in the United Kingdom appeared to be relatively low, partly because of more extensive use of pig iron in open-hearth furnaces.

In world trade, France exported over 3 million net tons of scrap in 1977 and was the leading exporter outside of the United States. Net exports of scrap by the Federal Republic of Germany amounted to 2.7 million tons. Imports of scrap by Italy totaled 6.4 million tons, with France being the largest supplier. Spain imported only 2.2 million tons compared with 2.9 million tons in 1976; the reduction in imports occurred despite the fact that Spanish steel production was unchanged. The drop in imports by Spain was at the expense of imports from the United States, which declined from 63% of Spain's imports in 1976 to 38% in 1977. Because of a static economy the United Kingdom, which imported 507,000 tons from the United States in 1976, imported only 51,000 tons from the United States in 1977, while becoming a net exporter of nearly 900,000 tons.

Japanese imports of U.S. ferrous scrap continued a second straight year of decline to 1.5 million tons, although imports from the United States increased slightly as a percent of total Japanese imports of scrap, according to the Japanese. This was the lowest level of imports from the United States since the 1950's and, combined with the drop in U.S. exports to the United Kingdom and Spain, probably contributed to the low price of U.S. scrap in the last half of 1977 and to an increase in exports of scrap to Japan in December, although there was no increase in Japanese raw steel production during this period.

Much lower imports from the United States by Spain, the United Kingdom, and Italy, even though partly offset by a large increase in exports to the Republic of Korea, was the main reason for the 2-million-ton drop in U.S. exports and contributed to the lower domestic price in 1977.[4]

In the United Kingdom, the depressed situation of the scrap industry at the end of 1976 continued to worsen. The 1976 average price of $54 per ton for No. 1 grade (equivalent to U.S. No. 1 heavy melting steel scrap) declined to an average of $44 in 1977, causing some business failures and mergers in the British iron and steel scrap industry.

TECHNOLOGY

A new type of eddy-current system to segregate nonferrous scrap was developed by Raytheon Inc., of Lexington, Mass. A plant is being installed near Rochester, N.Y., to handle 2,000 tons of municipal refuse per day. The system might be applied to ferrous scrap shredders with a saving in electric power usage through reduced use of high magnetic flux magnets.

In May, Resource Recovery Systems of Branford, Conn., began a 6-month trial of recycling metal scrap from municipal waste. The system employs a vibrating hopper with sorter belts and a magnetized rotary drum to extract ferrous scrap. Results were not available at yearend.

The Fiber Baler Div. of American Hoist and Derrick Co., St. Paul, Minn., developed a new baler with heavy duty construction for a 48-cubic-foot metal bale. Initially it will be used on nonferrous scrap.

American Can Co.'s $18 million joint venture with the City of Milwaukee opened a facility in May to handle at least 250,000 tons of municipal refuse annually. When full production is reached the operator (American Can Co.) expects to recover 12,500 to 17,000 tons of iron and steel scrap annually.

During the year there was a definite trend in the scrap industry towards bigger hydraulic crawler and pedestal-mounted cranes.

Apparently due to the lower price of scrap and higher price of pig iron, the average percentage of scrap in an open-hearth charge was increased by 2.4% over that in 1976. This fact, together with higher electric furnace and foundry consumption, resulted in an increase in total scrap consumption from 103% of pig iron consumed in 1976 to 112% in 1977.

Under a contract with the Bureau of Mines, the Massachusetts Institute of Technology continued work on "Mathematical Modeling of Raw Materials & Energy Needs of the Iron & Steel Industry" and phases 3 and 4 were completed in 1977. A fifth phase was to be completed in 1978.

At the Bureau of Mines Twin Cities (Minn.) Metallurgy Research Center, work continued on substituting various fuels for a portion of the coke in cupola operations. Tests indicated that charcoal briquets or shredded rubber tires could replace up to 20% of the coke charge, and Kentucky bituminous coal or anthracite were satisfactory at the 40% level. The metallic charge consisted of 100% shredded scrap.

At the Bureau's Rolla (Mo.) Metallurgy Research Center, work continued on reclaiming chromium and nickel from inplant wastes in Bureau-operated furnaces. A commercial-size heat was also made in cooperation with a private specialty mill.

At the Bureau's Avondale (Md.) Metallurgy Research Center, work continued on the pilot plant at nearby Edmonston, Md., for treatment of raw urban refuse. A 1,500-ton-per-day plant in Baltimore County, Md., using technology developed at the Bureau's pilot plant, was about to come onstream at yearend. The 2,000-ton-per-day plant near Rochester, N.Y., uses similar technology and is scheduled for startup in late 1978.

---

[1]Physical scientist, Division of Ferrous Metals.
[2]All quantities are in short tons unless otherwise noted.
[3]Preliminary.
[4]Source: Iron Age.

Table 2.—U.S. consumer receipts, production, consumption, shipments and stocks of iron and steel scrap in 1977, by grade

(Thousand short tons)

Grade of scrap	Receipts of scrap: From brokers, dealers, and other outside sources	Receipts of scrap: From other own-company plants	Production of home scrap: Recirculating scrap resulting from current operations	Production of home scrap: Obsolete scrap (includes ingot molds, stools, and scrap from old equipment, obsolete buildings, etc.)	Consumption of both purchased and home scrap (includes recirculating scrap)	Shipments of scrap	Ending stocks Dec. 31
MANUFACTURERS OF PIG IRON AND RAW STEEL AND CASTINGS[1]							
Carbon steel:							
Low-phosphorus plate and punchings	532	10	35	9	516	41	108
Cut structural and plate	271	8	271	(2)	535	(2)	60
No. 1 heavy melting steel	5,556	3,059	17,854	129	24,220	2,608	2,428
No. 2 heavy melting steel	2,066	126	1,065	3	3,374	20	492
No. 1 and electric furnace bundles	5,942	645	2,632	6	9,101	157	1,636
No. 2 and all other bundles	1,731	78	295	--	2,044	119	280
Electric furnace 1 foot and under (not bundles)	21	--	55	--	79	--	4
Railroad rails	94	1	(2)	--	91	(2)	4
Turnings and borings	1,281	76	339	1	1,594	108	107
Slag scrap (Fe content 70%)	1,425	48	2,634	2	4,090	115	170
Shredded or fragmentized	1,776	381	5	--	2,100	--	220
No. 1 busheling	1,423	34	34	--	1,505	11	178
All other carbon steel scrap	1,900	206	10,486	347	12,134	690	960
Stainless steel scrap	397	41	645	(2)	1,025	49	93
Alloy steel (except stainless)	204	207	1,568	5	1,778	173	308
Ingot mold and stool scrap	276	658	964	1,845	3,380	782	674
Machinery and cupola cast iron	12	--	--	(2)	10	--	4
Cast iron borings	219	98	300	61	596	85	78
Motor blocks	7	--	(2)	--	8	(2)	2
Other iron scrap	232	188	556	23	650	364	129
Other mixed scrap	328	51	206	(2)	473	129	60
Total scrap[3]	25,696	5,916	39,944	2,431	69,301	5,451	7,995
MANUFACTURERS OF STEEL CASTINGS[4]							
Carbon steel:							
Low-phosphorus plate and punchings	543	9	179	1	751	(2)	60
Cut structural and plate	181	23	25	--	226	1	23
No. 1 heavy melting steel	132	1	63	(2)	193	(2)	31
No. 2 heavy melting steel	55	--	19	--	74	--	1

No. 1 and electric furnace bundles	64	1	2	--	63	--	4
No. 2 and all other bundles	5	(2)	--	--	3	--	2
Electric furnace 1 foot and under (not bundles)	57	(2)	18	--	74	1	5
Railroad rails	(2)	(2)	--	--	(2)	--	(2)
Turnings and borings	57	7	27	--	80	9	6
Slag scrap (Fe content 70%)	4	1	5	--	10	(2)	(2)
Shredded or fragmentized	75	20	--	--	96	--	6
No. 1 busheling	47	8	10	--	60	--	10
All other carbon steel scrap	478	28	345	14	855	1	52
Stainless steel scrap	22	6	23	--	49	3	5
Alloy steel (except stainless)	54	11	124	--	151	(2)	22
Ingot mold and stool scrap	5	--	(2)	--	5	(2)	1
Machinery and cupola cast iron	7	(2)	10	--	17	--	2
Cast iron borings	49	(2)	63	--	110	(2)	5
Motor blocks	1	--	--	--	1	--	(2)
Other iron scrap	33	(2)	72	(2)	101	3	21
Other mixed scrap	(2)	--	4	--	4	--	(2)
Total scrap[3]	1,867	116	989	16	2,924	19	257
IRON FOUNDRIES AND MISCELLANEOUS USERS							
Carbon steel:							
Low-phosphorus plate and punchings	735	113	77	1	922	6	66
Cut structural and plate	1,440	121	149	2	1,721	4	87
No. 1 heavy melting steel	265	143	70	(2)	445	44	56
No. 2 heavy melting steel	57	5	21	1	79	3	7
No. 1 and electric furnace bundles	175	200	66	(2)	444	--	10
No. 2 and all other bundles	579	159	1	--	717	2	57
Electric furnace 1 foot and under (not bundles)	69	1	20	--	87	--	6
Railroad rails	112	(2)	(2)	--	104	1	16
Turnings and borings	594	105	41	(2)	710	32	80
Slag scrap (Fe content 70%)	76	16	1	--	83	1	32
Shredded or fragmentized	843	131	--	--	960	1	53
No. 1 busheling	440	140	31	--	610	--	15
All other carbon steel scrap	1,048	885	147	(2)	2,067	11	125
Stainless steel scrap	5	3	7	(2)	16	1	9
Alloy steel (except stainless)	83	1	4	1	79	1	10
Ingot mold and stool scrap	145	--	103	6	247	10	34
Machinery and cupola cast iron	870	138	769	2	1,776	15	85
Cast iron borings	599	669	399	1	1,624	53	90
Motor blocks	669	58	458	(2)	1,168	(2)	56
Other iron scrap	1,034	132	3,327	86	4,457	114	177
Other mixed scrap	404	853	341	5	1,656	6	40
Total scrap[3]	10,242	3,871	6,032	105	19,973	304	1,111

See footnotes at end of table.

Table 2.—U.S. consumer receipts, production, consumption, shipments and stocks of iron and steel scrap in 1977, by grade —Continued

(Thousand short tons)

Grade of scrap	Receipts of scrap: From brokers, dealers, and other outside sources	Receipts of scrap: From other own-company plants	Production of home scrap: Recirculating scrap resulting from current operations	Production of home scrap: Obsolete scrap (includes ingot molds, stools, and scrap from old equipment, obsolete buildings, etc.)	Consumption of both purchased and home scrap (includes recirculating scrap)	Shipments of scrap	Ending stocks Dec. 31
TOTAL—ALL TYPES OF MANUFACTURERS							
Carbon steel:							
Low-phosphorus plate and punchings	1,810	132	291	11	2,189	47	234
Cut structural and plate	1,891	153	445	2	2,482	5	170
No. 1 heavy melting steel	5,953	3,203	17,987	130	24,858	2,653	2,515
No. 2 heavy melting steel	2,178	131	1,105	4	3,527	23	500
No. 1 and electric furnace bundles	6,181	846	2,701	6	9,608	157	1,650
No. 2 and all other bundles	2,315	237	296	--	2,764	121	340
Electric furnace 1 foot and under (not bundles)	147	1	92	--	240	1	15
Railroad rails	206	1	(2)	--	195	1	20
Turnings and borings	1,933	188	407	2	2,383	149	194
Slag scrap (Fe content 70%)	1,505	66	2,639	2	4,183	116	202
Shredded or fragmentized	2,694	532	5	--	3,156	1	279
No. 1 busheling	1,910	182	74	--	2,175	11	203
All other carbon steel scrap	3,426	1,119	10,977	361	15,056	701	1,137
Stainless steel scrap	424	50	676	(2)	1,090	53	107
Alloy steel (except stainless)	341	219	1,697	5	2,007	174	340
Ingot mold and stool scrap	425	658	1,067	1,851	3,631	793	708
Machinery and cupola cast iron	889	138	779	2	1,804	15	92
Cast iron borings	867	767	762	62	2,331	138	172
Motor blocks	677	58	458	(2)	1,177	1	58
Other iron scrap	1,299	320	3,955	108	5,209	481	328
Other mixed scrap	732	904	552	5	2,133	135	100
Total scrap[3]	37,804	9,903	46,965	2,552	92,198	5,774	9,363

[1] Includes only those castings made by companies producing raw steel.
[2] Less than 1/2 unit.
[3] Data may not add to totals shown because of independent rounding.
[4] Excludes companies that produce both steel ingots and steel castings.

Table 3.—U.S. consumer receipts, production, consumption, shipments, and stocks of pig iron and direct-reduced iron in 1977

(Thousand short tons)

	Receipts	Production	Consumption	Shipments	Stocks Dec. 31
MANUFACTURERS OF PIG IRON AND RAW STEEL AND CASTINGS					
Pig iron	5,615	81,494	79,390	7,963	1,187
MANUFACTURERS OF STEEL CASTINGS					
Pig iron	46	--	46	(1)	6
IRON FOUNDRIES AND MISCELLANEOUS USERS					
Pig iron	2,577	--	2,567	7	129
TOTAL—ALL TYPES OF MANUFACTURERS[2]					
Pig iron	8,238	81,494	82,003	7,971	1,322
Direct-reduced or prereduced iron	422	--	421	W	2

W Withheld to avoid disclosing company proprietary data.
[1]Less than 1/2 unit.
[2]Data may not add to totals shown because of independent rounding.

Table 4.—Consumption of iron and steel scrap and pig iron in the United States in 1977, by type of consumer and type of furnace, or other use

(Thousand short tons)

Type of furnace or other use	Manufacturers of pig iron and raw steel and castings		Manufacturers of steel castings		Iron foundries and miscellaneous users		Total all types[1]	
	Scrap	Pig iron	Scrap	Pig iron	Scrap	Pig iron	Scrap	Pig iron
Blast furnace[2]	3,771	--	--	--	--	--	3,771	--
Basic oxygen process[3]	25,034	63,877	--	--	--	--	25,034	63,877
Open-hearth furnace	11,009	12,525	78	6	--	--	11,087	12,531
Electric furnace	28,188	685	2,653	35	5,573	273	36,414	993
Cupola furnace	361	262	167	1	13,797	978	14,325	1,241
Other (including air furnace)[4]	938	315	26	4	603	36	1,567	354
Direct castings[5]	--	1,727	--	--	--	1,280	--	3,007
Total[1]	69,301	79,390	2,924	46	19,973	2,567	92,198	82,003

[1]Data may not add to totals shown because of independent rounding.
[2]Includes consumption in all blast furnaces producing pig iron.
[3]Includes scrap and pig iron processed in metallurgical blast cupolas and used in oxygen converters.
[4]Includes vacuum melting furnaces and miscellaneous uses.
[5]Includes ingot molds and stools.

Table 5.—Proportion of iron and steel scrap and pig iron used in furnaces in 1977 in the United States

(Percent)

Type of furnace	Scrap	Pig iron
Basic oxygen process	28.2	71.8
Open-hearth furnace	46.9	53.1
Electric furnace	97.3	2.7
Cupola furnace	92.0	8.0
Other (including air furnace)	81.6	18.4

Table 6.—Iron and steel scrap supply[1] available for consumption in 1977, by State and region

(Thousand short tons)

State and region	Receipts of scrap: From brokers, dealers, and other outside sources	Receipts of scrap: From other own-company plants	Production of home scrap: Recirculating scrap resulting from current operations	Production of home scrap: Obsolete scrap (includes ingot molds, stools, and scrap from old equipment, buildings, etc.)	Total new supply[2]	Shipments of scrap[3]	New supply available for consumption
New England and Middle Atlantic:							
Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, Vermont	1,508	272	1,810	31	3,621	261	3,360
Pennsylvania	4,797	2,354	10,319	663	18,133	2,214	15,920
Total[2]	6,305	2,626	12,130	693	21,754	2,475	19,279
North Central:							
Illinois	4,400	859	3,680	528	9,466	329	9,137
Indiana	2,450	148	8,038	414	11,050	1,032	10,018
Michigan, Iowa, Minnesota, Nebraska, Kansas, Missouri	6,133	3,228	4,533	170	14,064	184	13,881
Ohio	5,514	1,806	7,846	232	15,399	912	14,487
Wisconsin	721	41	575	(4)	1,337	22	1,315
Total[2]	19,219	6,082	24,672	1,344	51,317	2,478	48,838
South Atlantic:							
Delaware, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, West Virginia	3,141	242	3,126	296	6,805	68	6,738
South Central:							
Alabama, Arkansas, Kentucky, Louisiana, Mississippi, Oklahoma, Tennessee, Texas	6,095	624	4,526	93	11,338	607	10,731
Mountain and Pacific:							
Arizona, California, Colorado, Montana, Nevada, Oregon, Utah, Washington	3,044	329	2,511	125	6,009	147	5,862
U.S. total[2]	37,804	9,903	46,965	2,552	97,223	5,774	91,449

[1]New supply available for consumption is a net figure computed by adding production to receipts and deducting scrap shipped during the year. The plus or minus difference in stock levels at the beginning and end of year is not taken into consideration.
[2]Data may not add to totals shown because of independent rounding.
[3]Includes scrap shipped, transferred, or otherwise disposed of during the year.
[4]Less than 1/2 unit.

Table 7.—Consumption of iron and steel scrap and pig iron[1] by State and region, by type of manufacturer in 1977

(Thousand short tons)

State and region	Pig iron and raw steel and castings		Steel castings		Iron foundries and miscellaneous users		Total[2]	
	Scrap	Pig iron	Scrap	Pig iron	Scrap	Pig iron	Scrap	Pig iron
New England and Middle Atlantic:								
Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, Vermont	1,905	3,085	163	6	1,203	284	3,271	3,375
Pennsylvania	14,962	16,313	333	14	852	505	16,147	16,832
Total[2]	16,867	19,398	496	20	2,055	789	19,418	20,207
North Central:								
Illinois	7,082	5,958	468	1	1,685	264	9,235	6,223
Indiana	9,234	16,486	226	1	907	100	10,366	16,587
Michigan, Iowa, Minnesota, Nebraska, Kansas, Missouri	6,855	6,693	414	1	6,759	485	14,028	7,179
Ohio	11,155	14,037	256	12	3,204	518	14,615	14,566
Wisconsin	--	--	275	1	1,052	72	1,327	72
Total[2]	34,325	43,174	1,638	16	13,607	1,438	49,571	44,627
South Atlantic:								
Delaware, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, West Virginia	5,806	W	54	1	856	138	6,717	139
South Central:								
Alabama, Arkansas, Kentucky, Louisiana, Mississippi, Oklahoma, Tennessee, Texas	7,509	[3]12,123	386	4	2,776	184	10,670	12,311
Mountain and Pacific:								
Arizona, California, Colorado, Montana, Nevada, Oregon, Utah, Washington	4,793	4,695	350	4	678	19	5,821	4,718
U.S. total[2]	69,301	79,390	2,924	46	19,973	2,567	92,198	82,003

W Withheld to avoid disclosing company proprietary data. Included in South Central Region.
[1]Includes molten pig iron used for ingot molds and direct castings.
[2]Data may not add to totals shown because of independent rounding.
[3]Includes South Atlantic Region.

Table 8.—Consumer stocks of iron and steel scrap, by grade, and pig iron, Dec. 31, 1977, by State and region

(Thousand short tons)

State and region	Carbon steel (excludes rerolling rails)	Stainless steel	Alloy steel (excludes stainless)	Cast iron (includes borings)	Other grades of scrap	Total scrap stocks[1]	Pig iron stocks
New England and Middle Atlantic:							
Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, Vermont	586	23	16	235	10	870	208
Pennsylvania	1,266	48	149	221	2	1,686	251
Total[1]	1,852	71	165	455	12	2,556	458
North Central:							
Illinois	922	4	7	85	1	1,019	22
Indiana	678	4	33	225	24	964	20
Michigan, Iowa, Minnesota, Nebraska, Kansas, Missouri	837	12	5	178	10	1,041	54
Ohio	1,030	6	84	106	3	1,230	499
Wisconsin	20	1	([2])	12	([2])	33	10
Total[1]	3,487	27	129	605	38	4,286	604
South Atlantic:							
Delaware, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, West Virginia	511	7	10	55	([2])	583	21
South Central:							
Alabama, Arkansas, Kentucky, Louisiana, Mississippi, Oklahoma, Tennessee, Texas	1,088	1	25	147	27	1,287	189
Mountain and Pacific:							
Arizona, California, Colorado, Montana, Nevada, Oregon, Utah, Washington	519	1	10	97	22	651	48
U.S. total[1]	7,457	107	340	1,358	100	9,363	1,322

[1]Data may not add to totals shown because of independent rounding.
[2]Less than 1/2 unit.

Table 9.—Average monthly price and composite price for No. 1 heavy melting scrap in 1977

(Per long ton)

Month	Chicago	Pittsburgh	Philadelphia	Composite price[1]
January	$69.50	$72.50	$74.50	$72.17
February	69.50	73.00	74.50	72.33
March	71.00	75.50	74.00	73.50
April	70.25	74.00	71.50	71.92
May	64.10	67.30	64.50	65.30
June	58.75	64.50	62.50	61.91
July	57.50	64.50	61.75	61.25
August	57.50	65.50	61.10	61.37
September	55.00	63.00	59.00	58.83
October	47.30	51.90	48.10	49.10
November	45.75	52.50	50.25	49.50
December[e]	59.50	60.50	54.50	58.17
Average 1977[e]	60.47	65.39	63.01	62.95
Average 1976[r]	78.10	78.80	76.47	77.79

[e]Estimate. [r]Revised.
[1]Composite price, Chicago, Pittsburgh, and Philadelphia.

Source: Iron Age, Jan. 2, 1978.

Table 10.—U.S. exports and imports for consumption of iron and steel scrap, by class

(Thousand short tons and thousand dollars)

Class	1973		1974		1975		1976		1977	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Exports:										
No. 1 heavy melting scrap	3,780	207,743	2,565	262,810	2,766	233,784	2,063	150,327	1,750	$107,089
No. 2 heavy melting scrap	1,107	52,817	883	84,826	1,102	85,508	705	46,047	594	33,870
No. 1 bundles	391	21,565	78	8,504	120	9,574	95	7,726	103	2,442
No. 2 bundles	1,221	49,421	1,304	99,652	1,159	71,903	845	48,144	336	14,429
Stainless steel scrap	49	16,731	35	15,351	66	27,463	112	52,516	75	37,154
Shredded steel scrap	2,098	118,133	1,999	225,990	2,406	206,691	2,179	164,922	1,606	97,602
Borings, shovelings, and turnings	521	16,352	544	35,404	597	29,721	644	32,339	476	17,916
Other steel scrap[1]	1,102	57,528	463	40,814	726	63,565	760	65,809	601	49,960
Iron scrap	605	29,721	626	50,369	500	34,767	474	33,996	314	20,579
Total	10,874	570,011	8,497	823,720	9,442	762,976	7,877	601,826	[2]5,854	381,041
Ships, boats, and other vessels (for scrapping)	156	8,056	327	33,140	40	1,742	50	2,280	35	2,613
Rerolling material	382	28,489	199	25,025	160	16,266	241	32,652	321	31,691
Total	11,412	606,556	9,023	881,885	9,642	780,984	8,168	636,758	[2]6,211	415,345
Imports:										
Iron and steel scrap	337	18,716	188	26,166	293	24,464	496	34,524	601	39,723
Tinplate scrap	12	384	13	861	12	786	11	596	13	778
Total	349	19,100	201	27,027	305	25,250	507	35,120	614	40,501

[1]Includes terneplate and tinplate.
[2]Data do not add to total shown because of independent rounding.

Table 11.—U.S. exports of iron and steel scrap, by country

(Thousand short tons and thousand dollars)

Country	1973 Quantity	1973 Value	1974 Quantity	1974 Value	1975 Quantity	1975 Value	1976 Quantity	1976 Value	1977 Quantity	1977 Value
Argentina	261	13,840	148	16,189	332	29,110	r77	5,746	127	7,422
Bangladesh	--	--	16	1,952	57	4,420	16	1,052	28	1,727
Belgium-Luxembourg	3	535	(1)	105	16	1,813	9	3,603	4	2,262
Brazil	5	229	27	3,321	7	1,025	(1)	332	(1)	21
Canada	811	27,097	940	52,296	873	44,676	889	48,140	522	23,847
Chile	15	1,255	23	2,828	(1)	2	14	1,138	10	904
China, People's Republic of	428	23,729	189	12,406	175	13,243	52	4,192	(1)	102
Egypt	--	--	15	1,611	34	2,660	41	2,820	76	4,308
France	30	2,682	16	4,019	7	1,325	3	306	1	163
Germany, Federal Republic of	2	283	4	1,481	14	6,027	27	8,320	16	5,570
Greece	187	9,429	113	12,762	161	12,964	222	17,475	300	17,192
Hong Kong	1	231	1	83	1	207	1	339	1	312
Israel	(1)	6	27	2,857	15	1,134	89	7,242	(1)	10
Italy	353	23,966	485	58,896	613	57,548	634	57,489	208	18,441
Japan	4,666	234,363	2,980	305,223	2,405	198,884	1,256	93,115	1,036	61,927
Korea, Republic of	739	42,429	680	76,754	762	61,842	911	61,561	1,441	88,668
Mexico	1,009	56,063	890	72,432	1,269	103,208	571	44,541	322	22,555
New Zealand	42	2,479	17	2,189	18	1,599	18	1,433	17	932
Pakistan	1	96	r32	r4,254	r30	r2,531	75	6,744	54	3,415
Peru	--	--	23	3,103	93	7,767	1	100	--	--
Philippines	--	--	17	2,167	67	6,225	23	1,441	11	576
Singapore	15	1,179	--	--	81	5,761	(1)	4	--	--
Spain	1,127	58,197	896	89,696	1,709	131,600	1,862	136,093	784	46,909
Sweden	8	2,171	33	5,138	95	11,266	54	6,822	2	1,454
Taiwan	672	39,527	491	44,454	264	24,168	249	22,068	435	35,647
Thailand	139	8,408	34	3,311	37	3,076	18	1,497	13	1,136
Turkey	124	7,212	57	6,323	89	6,645	159	13,461	310	20,044
United Kingdom	142	9,203	117	14,442	78	9,373	507	43,922	51	5,986
Venezuela	76	3,802	183	17,679	72	4,626	20	1,250	1	133
Yugoslavia	--	--	--	--	37	3,258	28	1,909	15	848
Other	18	1,600	43	5,749	31	r4,993	r51	r7,676	68	8,531
Total[2]	10,874	570,011	8,497	823,720	9,442	762,976	7,877	601,826	5,854	381,041

rRevised.
[1]Less than 1/2 unit.
[2]Data may not add to totals shown because of independent rounding.

Table 12.—U.S. exports of rerolling material (scrap), by country

(Thousand short tons and thousand dollars)

Country	1973 Quantity	1973 Value	1974 Quantity	1974 Value	1975 Quantity	1975 Value	1976 Quantity	1976 Value	1977 Quantity	1977 Value
Argentina	--	--	--	--	12	1,055	11	930	--	--
Canada	1	34	7	485	5	408	1	196	1	102
China, People's Republic of	7	485	1	85	--	--	--	--	--	--
Germany, Federal Republic of	--	--	--	--	--	--	2	560	--	--
Italy	2	168	--	--	--	--	--	--	(1)	15
Japan	16	1,209	1	182	--	--	--	--	8	1,015
Korea, Republic of	118	7,014	81	10,504	29	3,189	44	11,098	99	9,371
Mexico	43	2,954	47	5,269	40	4,623	24	2,464	21	2,061
Nigeria	--	--	--	--	--	--	7	1,177	--	--
Pakistan	8	422	4	617	4	402	3	278	18	742
Spain	(1)	7	--	--	17	1,336	7	599	4	251
Taiwan	149	12,712	57	7,712	39	3,478	55	5,435	11	1,214
Thailand	28	2,641	--	--	13	1,518	76	8,426	133	14,078
Turkey	4	292	(1)	40	(1)	61	4	541	16	1,709
Venezuela	3	210	--	--	--	--				
Other	3	341	1	131	1	196	7	948	10	1,133
Total	382	28,489	199	25,025	160	16,266	241	32,652	321	31,691

[1]Less than 1/2 unit.

Table 13.—U.S. exports of ships, boats, and other vessels for scrapping

(Thousand short tons and thousand dollars)

Country	1973		1974		1975		1976		1977	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Canada	2	260	26	1,414	15	406	4	108	--	--
Germany, Federal Republic of	8	257	13	700	(1)	(1)	(1)	--	--	--
Korea, Republic of	9	370	44	5,826	7	237	6	181	--	--
Mexico	1	132	(1)	23	--	--	(1)	2	(1)	2
Spain	22	1,002	93	8,824	10	426	--	--	--	--
Taiwan	114	5,994	139	15,539	8	617	40	1,948	34	2,585
Other	(1)	41	12	814	(1)	56	(1)	40	(1)	25
Total[2]	156	8,056	327	33,140	40	1,742	50	2,280	35	2,613

[1]Less than 1/2 unit.
[2]Data may not add to totals shown because of independent rounding.

Table 14.—U.S. imports for consumption of iron and steel scrap,[1] by country

Country	1976		1977	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Australia	285	$19	--	--
Austria	--	--	141	$546
Bahamas	11,724	472	2,471	49
Belgium-Luxembourg	92	27	1	1
Canada	423,240	32,105	494,289	34,972
Germany, Federal Republic of	80	83	43,942	991
Haiti	346	9	233	12
Indonesia	--	--	386	80
Jamaica	959	35	957	70
Japan	9,159	437	2,976	130
Mexico	6,952	459	31,395	1,865
Netherlands	14,442	155	40	40
Panama	--	--	14,517	265
Sweden	38,837	483	15,566	875
United Kingdom	302	704	[2]7,357	[2]544
Other	r747	r132	71	62
Total[3]	507,165	35,120	[2]614,343	[2]40,501

[1]Includes tinplate.
[2]Adjusted by Bureau of Mines.
[3]Data may not add to totals shown because of independent rounding.

Table 15.—Iron and steel scrap consumption in selected countries[1]

(Thousand short tons)

	1975	1976	1977
European Economic Community:			
Belgium[2]	4,091	4,032	3,728
Denmark[3]	634	854	862
France[3 4 5]	8,307	8,964	8,282
Germany, Federal Republic of[5]	22,495	23,263	22,262
Ireland[6]	100	75	60
Italy[3]	15,023	16,362	[6]16,541
Luxembourg	r1,518	1,577	1,555
Netherlands	1,748	1,957	1,857
United Kingdom[2 5]	17,526	r18,534	e17,050
Total[7]	r71,442	r75,618	72,197
European Free Trade Association:			
Austria	1,881	1,992	1,789
Norway[2 3 5]	618	593	485
Portugal	r284	r219	[6]303
Sweden[2 3]	r3,770	r3,799	[6]2,598
Total[7]	r6,553	r6,603	5,175

See footnotes at end of table.

Table 15.—Iron and steel scrap consumption in selected countries[1] —Continued

(Thousand short tons)

	1975	1976	1977
Other European market economy countries:[8]			
Finland	767	e770	6794
Spain	7,209	r7,406	67,464
Yugoslavia[3 4 5 8]	1,883	1,747	1,921
Total[7]	9,859	r9,923	10,179
European centrally planned economy countries:[8]			
Czechoslovakia[2 4 5]	7,886	8,088	8,216
German Democratic Republic[2 3 4 5]	4,852	5,117	4,730
Hungary[2 4 5]	2,392	2,420	2,467
Poland	e9,370	10,352	11,083
Romania[e 2 3 4 5 9]	3,530	3,600	3,890
U.S.S.R.[2 3 4 5 10]	51,806	51,900	52,700
Total[7]	79,836	81,477	83,086
Latin America:[11]			
Argentina	r1,620	r1,657	1,892
Brazil	4,040	r4,644	5,044
Chile	185	r186	227
Colombia	248	r229	250
Mexico	3,663	3,406	2,690
Peru	192	185	184
Venezuela	581	499	583
Other[12]	r83	101	112
Total[7]	r10,612	r10,907	10,982
Other countries:			
Australia[6]	2,674	2,697	2,105
Canada[6]	r6,368	r6,538	6,787
India	r 131,760	e2,100	e2,200
Japan[5]	37,714	r42,138	38,147
New Zealand[6]	e165	e165	181
South Africa, Republic of[13]	r2,835	r3,098	3,147
Turkey[6]	r445	r443	1,279
United States[14]	82,331	r89,910	92,198
Total[7]	r134,292	r147,089	146,044
Grand total[7]	r312,594	r331,617	327,663

eEstimate. rRevised.

[1]Unless otherwise noted, figures represent consumption of scrap in the production of pig iron, ferroalloys, crude steel, foundry products and rerolled steel, as well as in other unspecified uses by the steel industry, and by other (unspecified) industries. Also, unless otherwise noted, figures are from: United Nations Economic Commission for Europe. Annual Bulletin of Steel Statistics for Europe. V. 5, 1977. New York, 1978, 81 pp.

[2]Excludes scrap consumed in rerolling.

[3]Excludes scrap consumed in foundries.

[4]Excludes scrap consumed within the steel industry for purposes other than the manufacture of pig iron, ferroalloys, crude steel, and foundry products as well as that consumed by steel rerollers.

[5]Excludes scrap consumed outside the steel industry.

[6]Source: Organization for Economic Cooperation and Development. The Iron and Steel Industry in 1976 and 1977. Paris, 1978 and 1979 respectively. 40 pp. each.

[7]Total of listed figures.

[8]Following United Nations practice, Yugoslavia has been included with other market economy nations.

[9]Excludes scrap used in pig iron production.

[10]Excludes scrap used in production of steel by any method of production except open hearth furnace.

[11]Source: Instituto Latinoamericano del Fierro y el Acero. Statistical Yearbook of Steelmaking and Iron Ore Mining in Latin America, 1977. Santiago 1979, 178 pp.

[12]Includes Uruguay, unspecified countries in Central America, and the Dominican Republic, as reported in source (see footnote 11).

[13]Source: United Kingdom Iron and International Steel Statistics Bureau. International Steel Statistics. Various issues covering subject countries for years specified.

[14]Data compiled by U.S. Bureau of Mines.

Table 16.—Iron and steel scrap exports by selected countries[1]

(Thousand short tons)

	1975	1976	1977
European Economic Community:			
Belgium-Luxembourg	586	581	552
Denmark	100	128	63
France	3,097	3,772	3,702
Germany, Federal Republic of	2,432	2,863	2,735
Ireland	9	9	9
Italy	6	26	12
Netherlands	1,032	1,055	1,021
United Kingdom	1,010	660	1,034
Total[2]	8,272	9,094	9,128
European Free Trade Association:			
Austria	57	50	9
Norway	21	20	14
Portugal	2	r3	4
Sweden	12	10	83
Switzerland	129	77	68
Total[2]	221	r160	178
Other European market economy countries:[3]			
Finland	6	4	3
Greece	([4])	([4])	([4])
Iceland	3	4	2
Spain	1	([4])	([4])
Yugoslavia[3]	24	22	46
Total[2]	34	30	51
European centrally planned economy countries:[3]			
Bulgaria	134	149	67
Czechoslovakia	243	e276	e276
German Democratic Republic	1	([4])	NA
Hungary	34	41	78
Poland	313	101	1
U.S.S.R	1,256	2,025	[5]2,412
Total[2]	1,981	r2,592	2,834
Latin America:			
Mexico[5]	3	1	2
Other	r11	r e11	e11
Total[2]	r14	r12	13
Other countries:			
Australia[5]	637	696	e694
Canada[5]	463	r1,248	847
India[5]	139	[6]116	e110
Japan[5]	105	224	233
Korea, Republic of[5]	([4])	21	1
Malaysia	4	18	12
Morocco	--	r55	21
New Zealand	e2	[6]1	e1
Singapore[5]	2	r3	8
South Africa, Republic of[7]	r7	r3	3
Taiwan[5]	39	69	40
United States[5]	10,584	8,949	6,175
Total[2]	r11,982	r11,403	8,145
Grand total[2]	r22,504	r23,291	20,349

eEstimate. rRevised. NA Not available.

[1]Unless otherwise noted, source is United Nations Economic Commission for Europe. Annual Bulletin of Steel Statistics for Europe, v. 5, 1977, New York, 1978, 91 pp.

[2]Total of listed figures.

[3]Following United Nations' practice, Yugoslavia has been included with other market economy nations of Europe.

[4]Less than 1/2 unit.

[5]Source: Official trade returns of subject country.

[6]Partial figure; compiled from export statistics of selected trading partner countries.

[7]Source: United Kingdom Iron and Steel Statistics Bureau. International Steel Statistics, South Africa, 1975, 1976 and 1977. London 1976, 1977 and 1978, respectively.

Table 17.—Iron and steel scrap imports by selected countries[1]

(Thousand short tons)

	1975	1976	1977
European Economic Community:			
Belgium-Luxembourg	779	646	543
Denmark	3	8	14
France	305	302	316
Germany, Federal Republic of	1,896	1,703	1,569
Ireland	4	1	2
Italy	5,967	6,914	6,421
Netherlands	176	177	126
United Kingdom	97	765	110
Total[2]	9,227	10,516	9,101
European Free Trade Association:			
Austria	37	50	88
Norway	60	78	20
Portugal	7	32	105
Sweden	373	[r]151	36
Switzerland	107	37	63
Total[2]	584	[r]348	312
Other European market economy countries:			
Finland	105	60	69
Greece	108	88	[e]110
Spain	2,399	[r]2,930	2,197
Yugoslavia[3]	381	377	451
Total[2]	2,993	[r]3,455	2,827
European centrally planned economy countries:[3]			
Bulgaria	153	136	105
Czechoslovakia	[4]34	[4]34	[e]33
German Democratic Republic	384	596	[e]606
Hungary	1	10	2
Poland	2	52	37
Total[2]	[r]574	[r]828	783
Latin America:			
Argentina	[5]352	[5] [r]79	[e]110
Brazil[5]	20	(6)	[e]11
Chile[e]	10	[r]17	17
Cuba	[4]61	[e]66	[e]66
Mexico[5]	1,283	[r]577	389
Peru[5]	69	[r]24	—
Venezuela	[5]62	[r] [e]66	[e]66
Total[2]	[r]1,857	[r]829	659
Other countries:			
Canada	1,024	907	[5]644
China, People's Republic of	[4]219	[4]52	[e]110
Egypt	NA	[4]41	[e]55
India	22	[e]13	[e]17
Indonesia	18	32	52
Iran	[5]8	[e]11	[e]11
Japan	3,409	1,986	1,587
Hong Kong[5]	62	120	45
Korea, Republic of[5]	930	1,206	1,732
Malaysia[5]	7	3	3
Morocco[5]	(6)	(6)	(6)
Philippines[5]	67	[r]117	68
Singapore[5]	106	61	25
South Africa, Republic of[5]	20	37	33
Taiwan	[5]389	[5]327	[e]353
Thailand[5]	294	304	489
Turkey	[5]94	[5] [r]260	[e]220
United States[5]	305	507	625
Total[2]	[r]6,974	[r]5,984	6,069
Grand total[2]	[r]22,209	[r]21,960	19,751

[e]Estimate. [r]Revised. NA Not available.

[1]Unless otherwise noted, source is United Nations Economic Commission for Europe. Annual Bulletin of Steel Statistics for Europe. V. 5, 1977, New York, 1978, 91 pp. It should be noted that among major steel producing nations, the U.S.S.R. and Romania do not import any substantial quantity of scrap.

[2]Total of listed figures.

[3]Following United Nations practice, Yugoslavia has been included with other market economy nations of Europe.

[4]Partial figure; compiled from export statistics of selected trading partner countries.

[5]Source: Official trade returns of subject country.

[6]Less than 500 tons.

Kyanite and Related Materials

By Michael J. Potter[1]

Kyanite, andalusite, and sillimanite are anhydrous aluminum silicate minerals that are alike in both composition and use patterns and have the same chemical formula, $Al_2O_3 \cdot SiO_2$. Related materials include synthetic mullite, dumortierite, and topaz, also classified as aluminum silicates, although the last two additionally contain substantial proportions of boron and fluorine, respectively. All of these kyanite-group substances can serve as raw materials for manufacturing special high-performance refractories in the high-alumina category, but there has been no record in recent years of significant utilization of either dumortierite or topaz for this purpose in the United States.

Although published statistics are not sufficiently complete to be wholly conclusive, it appears that the United States, India, and the Republic of South Africa are the leading world producers of kyanite-group minerals. It can be presumed that the U.S.S.R. and perhaps a few other industrialized nations also produce significant quantities of these materials.

U.S. kyanite production in 1977 was slightly higher in tonnage and value than in 1976. The amount of kyanite-group material exported decreased compared with that of 1976. The tonnage of imported material continued to be small.

Legislation and Government Programs.— The allowable depletion rates for kyanite, established by the Tax Reform Act of 1969 and unchanged through 1977, were 22% for domestic production and 14% for foreign operations.

On November 17, 1977, the Federal Government announced the offering of 2,816 tons of kyanite for sale on a sealed-bid basis. On December 5, 1977, 150 tons of kyanite was sold to one company at a total sales value of $41,250. The General Services Administration was conducting bid openings for the sale of the kyanite on the fourth Tuesday of each month.

DOMESTIC PRODUCTION

Kyanite was produced in the United States in 1977 at three open pit mines, two in Virginia and one in Georgia. Kyanite Mining Corp. operated the Willis Mountain mine in Buckingham County, Va., and the Baker Mountain mine in adjoining Prince Edward County, Va. C-E Minerals, Inc., operated the Graves Mountain mine in Lincoln County, Ga.

Domestic kyanite output in 1977 was slightly higher in tonnage and value than in 1976. Kyanite production statistics for 1977 (as well as for all previous years since 1949) are withheld to avoid disclosing company proprietary data.

Synthetic mullite production showed a slight decrease in both tonnage and value compared with the 1976 figures, and output was largely of the high-temperature sintered variety. The four producers of this material were A. P. Green Refractories Co. at Philadelphia, Pa.; C-E Minerals, Inc., at Americus, Ga.; Harbison-Walker Refractories Co. at Eufala, Ala.; and Taylor Refractories Division, NL Industries, Inc., at Greenup, Ky. Electric-furnace-fused mullite was produced by The Carborundum Co. at Niagara Falls, N.Y.

Table 1.—Synthetic mullite production in the United States

Year	Quantity (short tons)	Value
1973	r58,180	$5,211,000
1974	r41,510	5,895,000
1975	r24,150	3,350,000
1976	r42,230	5,453,000
1977	40,280	5,283,000

rRevised.

CONSUMPTION AND USES

Conforming to established end use patterns, kyanite and related materials were consumed in 1977 mostly in the manufacture of high-alumina or mullite-class refractories and in lesser quantities as ingredients in some ceramic compositions. Domestic kyanite, already ground to minus 35 mesh as required by the flotation process used in its separation and recovery, was marketed in the raw form or after heat treatment; that is, as mullite, which was sometimes further reduced in particle size before use. In the 35- to 48-mesh range, the mineral was used mostly in monolithic refractory applications such as for high-temperature mortars or cements, ramming mixes, and castable refractories, or with clays and other ingredients in refractory compositions for making kiln furniture, insulating brick, firebrick, and a wide variety of other articles. More finely ground material, minus 200 mesh, for example, was used in body mixes for sanitary porcelains, wall tile, precision-casting molds, and miscellaneous special-purpose ceramics.

PRICES

Engineering and Mining Journal, December 1977, listed prices for kyanite, f.o.b. Georgia, ranging from $63 to $106 per short ton for bulk shipments and $9 more per ton for bagged material.

Price ranges quoted for kyanite-group materials in Ceramic Industry magazine, January 1978, follow:

	Per short ton
Andalusite	$30-$60
Kyanite	64-116
Mullite, calcined	302-313
Mullite, fused	160-450

The December 1977 issue of Industrial Minerals (London) quoted kyanite-group price ranges approximately equivalent to the following (converted from pounds sterling per metric ton to dollars per short ton):

	Per short ton
Andalusite, Transvaal, c.i.f. main European port	$146
Kyanite, Indian, f.o.b	$109- 127
Sillimanite, Indian, natural, bagged, f.o.b	177
Kyanite, Indian, calcined, f.o.b. Calcutta	181

FOREIGN TRADE

The quantity of kyanite-group materials exported in 1977 showed a substantial decrease compared with that of 1976 exports. The greater part of the material currently being exported by the United States is probably mullite. (The Bureau of the Census export figures, which are used in table 2, do not distinguish between synthetic mullite and materials that are in part mullite.)

The tonnage of imported material continued to be small. Because of this, the Bureau of the Census is expected to stop collecting data on kyanite imports as a separate category.

Table 2.—U.S. exports and imports for consumption of kyanite and related minerals

	1975		1976		1977	
	Quantity (short tons)	Value	Quantity (short tons)	Value	Quantity (short tons)	Value
Exports:						
Argentina	160	$14,926	325	$22,686	149	$30,330
Australia	9,918	615,663	14,886	1,087,338	345	31,311
Belgium-Luxembourg	221	58,062	1,049	94,541	223	41,871
Brazil	582	29,700	309	32,788	371	28,900
Canada	5,175	361,361	4,857	362,709	10,242	731,084
Colombia	301	20,869	58	2,934	--	--
Denmark	134	11,919	--	--	--	--
France	600	69,973	300	45,234	676	79,490
Germany, Federal Republic of	65,487	3,582,084	14,181	1,011,056	4,351	499,491
Haiti	--	--	--	--	80	4,093
Hong Kong	48	7,262	--	--	19	2,934
Israel	200	11,255	--	--	--	--
Italy	13,066	921,974	6,907	600,611	3,903	403,630
Japan	30,666	1,796,826	5,406	428,012	5,323	391,737
Mexico	3,045	318,374	4,130	391,763	3,256	287,030
Netherlands	1,120	84,598	131	11,057	63	4,245
New Zealand	20	1,690	21	1,851	59	5,238
Philippines	12	2,205	219	24,874	473	55,885
South Africa, Republic of	3	1,168	2	1,126	19	3,874
Spain	--	--	21	1,735	42	3,480
Sweden	5,755	385,925	3,028	261,251	2,186	210,376
Taiwan	49	3,542	--	--	88	2,335
U.S.S.R	1,734	170,182	--	--	--	--
United Kingdom	11,110	739,346	6,940	509,519	5,993	503,448
Venezuela	850	137,230	481	45,904	882	82,265
Other	113	9,277	78	4,699	89	13,882
Total	150,369	9,355,411	63,329	4,941,688	38,832	3,416,929
Imports:						
El Salvador	--	--	--	--	1	495
France	--	--	--	--	2	1,183
India	65	2,849	--	--	--	--
Mexico	--	--	65	7,225	--	--
South Africa, Republic of	--	--	45	5,172	50	5,786
Total	65	2,849	110	12,397	53	7,464

WORLD REVIEW

Australia.—The only production of sillimanite was at Mount Crawford, South Australia. Most of the material being mined was kaolinized sillimanite, with only a comparatively small amount of sillimanite rock being produced as a coproduct. In the Eneabba-Jurien Bay area of Western Australia, some 25,000 tons per year of fine-grained kyanite was being thrown onto tailings dumps. The kyanite is removed from the zircon fraction of the mineral sands. Although it might be recovered economically in the future, it is presently considered to be an impurity.[2]

Brazil.—Initial production of kyanite began in mid-1977 at Andrelandia, in Minas Gerais State. Output was expected to be around 15,000 tons per year with an increase in production to around 30,000 tons per year by 1978.[3]

Some activity was taking place at a lump kyanite operation in Goias State, not far from the Federal capital of Brasilia. Reserves were estimated at around 2 million tons of pure lump kyanite averaging 60% Al_2O_3 and 10 million tons of a kyanite-quartz rock with the kyanite content ranging from 70% to 90%. Boulders of the pure kyanite were being broken up and stockpiled at a crushing station onsite, and lump material was being transported to the ports of Santos and Rio de Janeiro for shipment. The operating company, Cianita-Serra das Araras Ltda., is controlled by Finapa Assessoria Commercial e Industrial Ltda. of São Paulo in conjunction with an Italian company, Italmineraria S.p.A., which was also providing technical assistance on the project. Methods were being investigated for beneficiating the mixed kyanite-quartz material.[4]

India.—Reserves of high-alumina lump kyanite at Lapso Buru were said to be quite limited, and the Indian Government reportedly banned exports of kyanite containing more than 60% Al_2O_3.

The Khasi sillimanite deposits in Assam were originally mined by Assam Sillimanite Ltd. but were later taken over by the Government. In recent years, supplies of the lump material had fallen off considerably, but production seemed to be underway again, although the reserve situation was difficult to assess. During the monsoon periods, it is almost impossible to get material to the ports.

Maharashtra State also possesses some high-grade massive kyanite deposits. Material is quarried by hand picking and sorting, as it is at the other deposits. Reserves are difficult to assess.

Apart from the high-grade material, India has large reserves of lower grade quartz-kyanite schists and sillimanite schists, and research was underway to find ways of beneficiating these.[5]

South Africa, Republic of.—Andalusite occurs in three main areas, all in Transvaal Province: Groot Marico/Zeerust, northern Lydenburg, and Thabazimbi. Reserves are very large.

One of the three producers in the Groot Marico area, Exandula (Pty.) Ltd., which is owned by Cullinan Minerals (Pty.) Ltd., was producing about 13,000 tons per year. The firm was planning to increase capacity to 22,000 tons per year to meet increased local demand. Another mine, owned by Export Minerals (Pty.) Ltd., was producing from 2,700 to 10,600 tons per year. In spite of excess capacity, plans were underway to increase production capacity to 17,600 tons per year in 1977. The andalusite, with an alumina content of 56% and less than 1% Fe_2O_3 in the concentrate, meets requirements for refractory producers in the United Kingdom and Japan.

In the Lydenburg district there were four established andalusite mines, and a fifth was expected to come into operation in mid-1977. One of the established mines, owned by Marico Minerals, had been operating at about 75% of its capacity of 40,000 tons per year in recent years. Plans call for increasing the capacity to about 55,000 tons per year by 1980. Hudson Mining Co. operated a large mine at Annesley, where production capacity was 44,000 tons per year, although actual output had been running at 75% of capacity. During 1977 the company was planning to increase the capacity to 50,000 tons per year, with further increases by 1980 and 1985. At Hudson Mining's other mine it was planned to increase production to 6,600 tons per year in 1977, followed by an increase to 11,000 tons per year by 1980 and 15,000 tons per year by 1985. The mine owned by Hoogenoog Andalusite (Pty.) Ltd. has been in operation only since March 1976. The production capacity of 12,000 tons per year was to be increased to 22,000 tons per year, with most of the output destined for Japan and Australia.[6] Cullinan Minerals was in the process of opening up a large andalusite deposit at Klipfontein in eastern Transvaal. Plant construction started in June 1976; initial capacity was to be around 20,000 tons per year, rising to 40,000 tons per year in the following years.[7] Two grades (both containing less than 1% Fe_2O_3) were to be produced: A standard grade with over 54% Al_2O_3 for local consumption, and a premium grade with over 58% Al_2O_3 for the export market.

In the Thabazimi area, Weedons Minerals was hoping to open its first andalusite mine. Target production was put at 22,000 tons per year of high-grade material, with an unusually low iron content for South African andalusite.

Sillimanite production amounted to 28,000 tons in 1976. There were only two operating mines. Reserves are limited and will only last until 1982 unless new deposits are found.[8]

Spain.—Production of kyanite has been around 6,600 tons in recent years. Total reserves were estimated at about 3 million tons. Mining of kyanite was to be expanded to 20,000 tons per year late in 1977, and a new plant was to be installed.[9]

Table 3.—Kyanite, sillimanite and related materials: World production, by country[1]

(Short tons)

Country and commodity[2]	1975	1976	1977[p]
Australia: Sillimanite[3]	648	625	1,098
Brazil: Kyanite	254	282	[e]290
France: Kyanite and andalusite[e]	11,000	11,000	11,000
India:			
Kyanite	[r]57,721	53,276	47,214
Sillimanite	[r]9,125	16,379	16,418
Korea, Republic of: Andalusite	117	573	127
South Africa, Republic of:			
Andalusite	85,042	85,389	124,645
Sillimanite	18,641	28,366	17,036
Spain: Andalusite	5,558	[e]6,600	[e]6,600
United States:			
Kyanite	W	W	W
Synthetic mullite	[r]24,150	[r]42,230	40,280

[e]Estimate. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data.

[1]Owing to incomplete reporting, the table has not been totaled.

[2]In addition to the countries listed, a number of other countries presumably produced kyanite and related minerals, but output data are not reported and no basis is available for estimates of output levels.

[3]In addition, sillimanite clay (also called kaolinized sillimanite) is produced, but output is not reported quantitatively, and available information is inadequate for the formulation of reliable estimates of output levels.

TECHNOLOGY

A patent was granted for extracting alumina from kyanite, aluminous clay, low-grade bauxite, or like material. The source material is slurried in concentrated sulfuric acid, heated to form a hard, anhydrous mass containing aluminum sulfate and silica, decomposed in the presence of a carbonaceous reductant at 700°C to 800°C to form an alkali-soluble alumina, and subjected to alkali leaching.[10]

The high strength potential of single-phase mullite under compressive stress-strain and creep testing conditions at 1,400° and 1,500°C was investigated.[11] Although the strength properties of mullite-containing fire clay refractories have been studied extensively, studies on mullite itself have been limited. This work was made possible by recently developed techniques of hot-pressing mullite powders to form a dense polycrystalline mullitic material. Previous materials invariably contained a glass phase, formed during mullitization, which adversely affected strength and creep values.

[1]Physical scientist, Division of Nonmetallic Minerals.

[2]Industrial Minerals (London). Sillimanite Minerals-Synthetics Encroaching on Markets. No. 117, June 1977, p. 50.

[3]Page 53 of work cited in footnote 2.

[4]Industrial Minerals (London). World of Minerals (Goias Kyanite). No. 121, October 1977, p. 11.

[5]Pages 47-48 of work cited in footnote 2.

[6]Pages 42-45 of work cited in footnote 2.

[7]Manos, A. Industrial Minerals of South Africa. Industrial Minerals (London). No. 122, November 1977, p. 25.

[8]Pages 45-46 of work cited in footnote 2.

[9]Page 50 of work cited in footnote 2.

[10]Lowenstein, H. M., and A. M. Lowenstein. Alumina Production. Canadian Pat. 1,017,578, Sept. 20, 1977.

[11]Dokko, P. C., J. A. Pask, and K. S. Mazdiyasni. High-Temperature Mechanical Properties of Mullite Under Compression. J. Am. Ceram. Soc., v. 60, No. 3-4, March-April 1977, pp. 150-155.

Lead

By J. Patrick Ryan,[1] John M. Hague,[1] and John A. Rathjen[2]

World mine production of lead in concentrates increased about 2% in 1977, to 3.8 million tons. Primary metal production from world smelters and refineries increased slightly to 3.85 million tons, 0.9% more than in 1976. World metal consumption increased 4% in 1977, to almost 4.9 million tons. World producer stocks outside centrally planned economy countries declined. Consumer stocks rose moderately during the year in Europe and the United States, but were virtually unchanged in Japan and in London Metal Exchange (LME) warehouses from a year earlier.

The U.S. producer price of lead advanced from 26 cents to 31 cents per pound in the first quarter, increasing again in November to 32 cents and in December to 33 cents per pound. In terms of U.S. currency, the LME monthly average cash price ranged from 25.3 cents in January to a high of 31.9 cents in March, then declined to about 25.0 cents in August, rising again to 31.1 cents in December. In 1977, the U.S. producer price averaged 30.7 cents, 2.7 cents more than the average LME price.

U.S. mine output of recoverable lead dropped 3% in 1977, to 592,491 tons, accounting for 16% of world mine production, approximately the same proportion as in 1976. Primary refinery output of lead, including lead in antimonial lead, from domestic and foreign concentrates declined 8% to 608,131 tons, largely reflecting curtailment of operations by labor strikes. Secondary smelter production increased 15% to 835,102 tons and accounted for 58% of total U.S. production.

U.S. stocks of refined and antimonial lead at primary plants dropped to 15,400 tons at yearend, the lowest level since 1968. Consumer stocks of soft lead, lead in antimonial lead, and lead in alloys increased 3% to 132,189 tons at yearend.

Legislation and Government Programs.—On October 7 the General Services Administration (GSA) reaffirmed the stockpile goal of 865,000 tons for lead established in 1976.

On December 14 the Environmental Protection Agency (EPA), in response to a court order, published its proposed national ambient air quality standard for lead of 1.5 micrograms of lead per cubic meter of air, based on a monthly average. Following promulgation of the standard, States will be required to develop implementation plans for EPA approval that demonstrate how the standard will be attained by 1982. A public hearing concerning the feasibility of achieving the proposed standard was scheduled to be held on January 17, 1978; the final standard is to be promulgated by June 1978. According to EPA, the standard is intended to establish a level of airborne lead that can be regarded as consistent with protecting the public health over a lifetime of exposure.

The Consumer Product Safety Commission (CPSC) promulgated regulations in September that banned (1) paint and other surface coating materials containing more than 0.06% lead, (2) toys and other articles intended for use by children that contain paint or other similar surface coating material containing more than 0.06% lead, and (3) furniture coated with materials containing more than 0.06% lead.

The International Lead and Zinc Study Group (ILZSG) held its 21st session in Geneva, Switzerland, September 8-16, 1977, to review the current situation in lead and zinc, the outlook for 1978, and long-term lead and zinc trends. ILZSG provided estimates of production and consumption in market-economy countries and trade with centrally planned economy countries, excluding Yugoslavia, which reflected continued strong demand for lead in 1977-78. A review of new mine and smelter projects showed that several mine projects have come into production including Navan in Ireland, Rubiales in Spain, and Nanisivik in Canada. The review also noted that mining at the large Aggeneys zinc-lead deposit in the Republic of South Africa was expected to begin in the early 1980's.

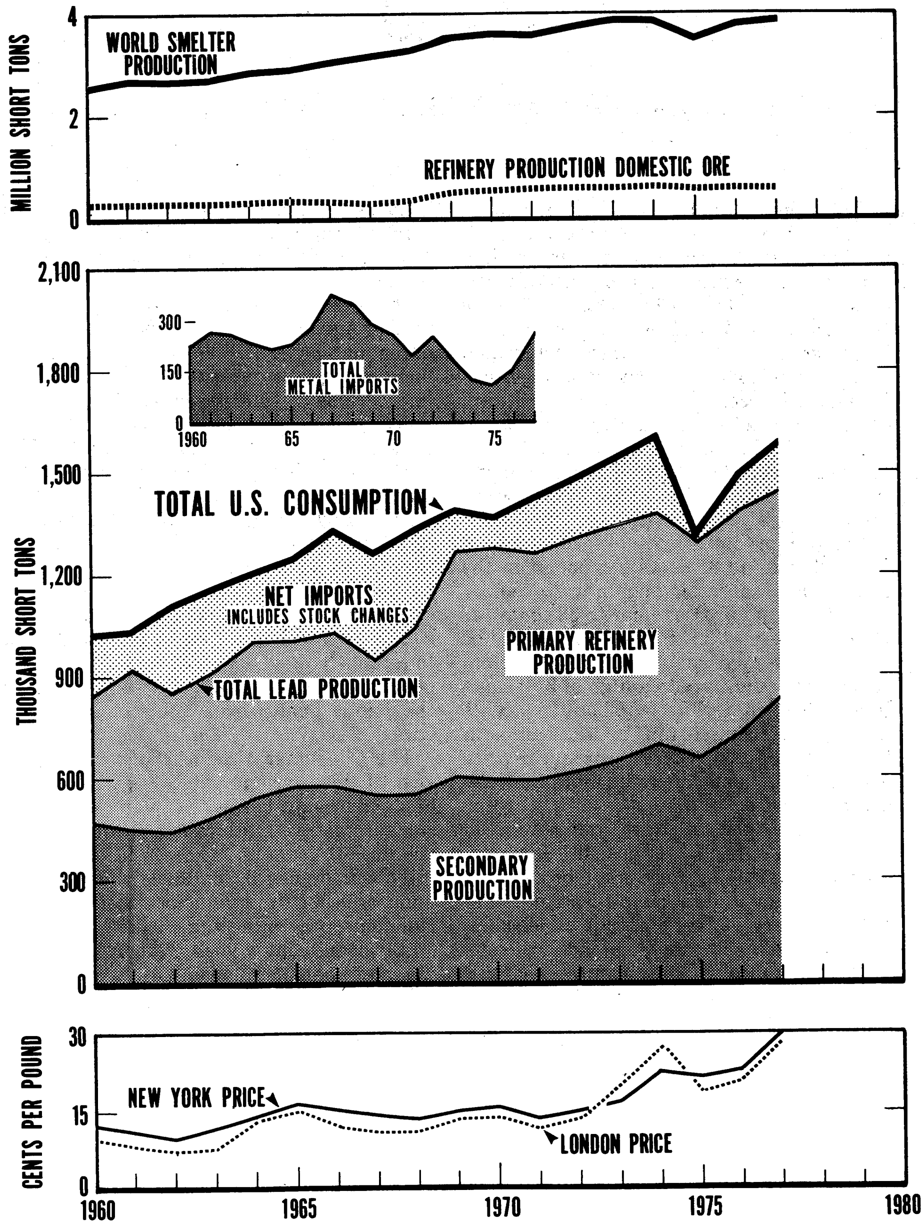


Figure 1.—Trends in the lead industry in the United States.

Table 1.—Salient lead statistics

(Short tons unless otherwise specified)

	1973	1974	1975	1976	1977
United States:					
Production:					
Domestic ores, recoverable lead content	603,024	663,870	621,464	609,546	592,491
Value thousands	$196,465	$298,742	$267,230	$281,613	$363,789
Primary lead (refined):					
From domestic ores and base bullion	567,256	580,078	530,215	568,536	536,449
From foreign ores and base bullion	107,260	92,946	105,907	84,341	68,389
Antimonial lead (primary lead content)	13,223	9,867	2,125	4,642	3,293
Secondary lead (lead content)	654,286	698,698	658,456	726,569	835,102
Exports of lead materials excluding scrap	66,576	61,982	21,256	5,877	9,845
Imports, general:					
Lead in ore and matte	109,947	94,299	87,560	76,365	73,340
Lead in base bullion	4	831	462	2,334	8,068
Lead in pigs, bars, and reclaimed scrap	181,486	119,579	105,876	150,345	268,042
Stocks December 31 (lead content):					
At primary smelters and refineries	89,847	121,051	156,530	r121,702	100,435
At consumers and secondary smelters	124,121	166,589	133,315	129,610	133,806
Consumption of metal, primary and secondary	1,541,209	1,599,427	1,297,098	1,490,072	1,582,338
Price: Common lead, average, cents per pound[1]	16.29	22.53	21.53	23.10	30.70
World:					
Production:					
Mine	3,843,723	3,762,489	r3,783,287	r3,677,118	3,758,805
Smelter[2]	3,837,864	3,828,701	r3,633,088	r3,810,873	3,846,788
Price: London, common lead, average, cents per pound	19.47	26.83	18.73	20.46	28.00

rRevised.
[1]Quotation on a nationwide, delivered basis.
[2]Primary metal production only. Includes secondary metal production where inseparably included in country total.

DOMESTIC PRODUCTION

MINE PRODUCTION

U.S. mine output of recoverable lead dropped 3% in 1977 to 592,491 tons, the third consecutive decline from the record high level of nearly 664,000 tons achieved in 1974. Monthly production ranged from a high of 56,800 tons in March to a low of 41,900 tons in July when production was curtailed due to vacation furloughs. Production from Missouri mines decreased slightly to 500,255 tons and accounted for 84% of the Nation's total output of lead. Production in Idaho, which provided 8% of the total, was down 12% from the 1976 level. Colorado's lead production dropped 14% largely due to curtailed operations at the Idarado and Leadville Unit (Resurrection) mines. After rising in the 2 preceding years, Utah's mine output of lead dropped 34% in 1977, to a level near the 70-year low reached in 1974. The sharp falloff in Utah's production reflected curtailment in output at the Ontario mine near Park City operated by The Anaconda Company, because of the decline in the price of zinc, and to lower output at Kennecott Copper Corp.'s Burgin mine.

As in the preceding 6 years, the Buick mine, jointly owned by AMAX Lead Co. of Missouri and Homestake Lead Co., was again the Nation's leading lead producer. Tonnage of ore milled in 1977 totaled 1.61 million tons averaging 8.6% lead and 3.4% zinc. Although the quantity of ore milled was about equal to that of 1976, concentrate production was down 13% because of a decrease in grade of ore mined. Lead concentrate produced totaled 176,788 tons and zinc concentrate production was 83,386 tons. Refined lead output was 60,894 tons. Ore reserves declined 1.5 million tons to about 53.6 million tons at yearend. Average grade of the reserves was 7% lead and 1.9% zinc.

St. Joe Lead Co., a subsidiary of St. Joe Minerals Corp. the Nation's largest lead-producing company, operated five mines and four mill complexes in southeast Missouri during the year and accounted for about 39% of the total domestic mine production in 1977. The company reported that its mines produced 342,570 tons of lead concentrate yielding 228,780 tons of lead metal in 1977, compared with 316,570 tons of concentrate and 222,480 tons of metal in 1976.

Hecla Mining Co. reported that its Lucky Friday mine produced 182,412 tons of ore assaying 14.73 ounces of silver per ton, 10.57% lead, and 1.38% zinc in 1977, compared with 186,520 tons of ore assaying 14.41 ounces of silver per ton, 10.91% lead, and 1.47% zinc in 1976. About 19,000 tons of lead, 2.64 million ounces of silver, and 2,360 tons of zinc were contained in the concentrates produced, slightly less lead and zinc and about the same quantity of silver as in 1976. Ore reserves at yearend were 510,000 tons compared with 475,000 tons at yearend 1976. Hecla also reported that production from the Star-Morning mine, jointly owned by Hecla (30%) and The Bunker Hill Co. (70%), totaled 293,466 tons of ore, about 4% more than in 1976. Hecla's share of the 1977 production was 88,040 tons of ore assaying 2.72 ounces of silver, 5.4% lead, and 6.2% zinc. Computed ore reserves were 967,000 tons at the end of 1977, compared with 1.15 million tons at yearend 1976.

The Bunker Hill Co., a subsidiary of Gulf Resources & Chemicals Corp., reported that production from company-owned and controlled mines totaled 29,000 tons of lead, about 7,000 tons less than in 1976. The lower production resulted from a labor strike that curtailed operations from May to September. The company also reported that proven and probable ore reserves in the Bunker Hill mine totaled 2.84 million tons at yearend 1977, compared with 3.09 million tons at the end of 1976. In addition, the company's 70% interest in proven and probable ore at the Star mine declined 72,000 tons to 631,000 tons at yearend 1977.

In Colorado, Idarado Mining Co. mined and milled 301,000 tons of ore averaging 2.22% lead, 3.89% zinc, 0.42% copper, 0.95 ounce of silver, and 0.035 ounce of gold per ton compared with 361,000 tons averaging 2.4% lead, 3.8% zinc, 0.5% copper, 1.37 ounces of silver, and 0.03 ounce of gold per ton in 1976. Ore reserves at yearend 1977 were 3.37 million tons, about 3% less than at yearend 1976. At the Leadville Unit mine, also known as the Resurrection mine, a joint venture of ASARCO Incorporated and Newmont Mining Corp., 186,000 tons of lead-zinc-silver ore was treated, 7% less than in 1976. The average grade of ore milled in 1977 was 4.6% lead, 8.1% zinc, 2.2 ounces of silver, and 0.09 ounce of gold per ton compared with 4.25% lead, 9.2% zinc, 2.2 ounces of silver, and 0.06 ounce of gold per ton in 1976. Ore reserves at yearend 1977 were estimated at 1.92 million tons averaging 5.01% lead, 10.11% zinc, 2.72 ounces of silver, and 0.089 ounce of gold per ton, down slightly from a year ago.

SMELTER AND REFINERY PRODUCTION

Output of primary refined lead and lead in antimonial lead from the five primary refineries in 1977 totaled 611,590 tons, 7% less than in 1976. About 88% of the total output was recovered from domestic ores compared with 87% in 1976. Antimonial lead production at primary refineries increased 12% to 7,557 tons. The average antimony content of the alloy increased from 10.8% to 11.9%. About 86% of the total refined lead produced was corroding grade, the remaining production was in common, chemical, antimonial, and miscellaneous grade metal.

St. Joe Lead Co.'s smelter-refinery at Herculaneum, Mo., continued to operate near capacity during the year and produced 228,780 tons of lead and lead alloys, about 3% more than in 1976. The near-record lead production reflected strong demand, particularly for batteries.

The Bunker Hill smelter-refinery produced 100,000 tons of lead in all forms in 1977, 7% less than in 1976. The smelter processed ore and concentrates from mines in seven States, and from Canada, Mexico, and Peru. The lower production was attributed largely to the effects of a strike that curtailed operations at the company's mine, concentrator, and refinery. Completion in August of a tall stack at the smelter enabled the company to meet Federal air quality standards and will permit the plant to operate near capacity levels in the future.

ASARCO reported that its Omaha, Nebr., and Glover, Mo., refineries produced 158,300 tons of lead in 1977, 20% less than in 1976. The falloff in production was largely attributed to shutdowns because of labor strikes at the El Paso, Tex., and East Helena, Mont., lead smelters which restricted the supply of lead bullion to the Omaha lead refinery causing it to operate at reduced levels. Also, a strike at the Glover lead smelter-refinery that began on September 1, 1976, and ended on June 1, 1977, significantly reduced production. During the strike the plant was operated by supervisory personnel. The company also reported that full production after the strike was delayed by major repairs and a heavy maintenance schedule that caused further interruptions during the remainder of the year. The first phase of major modernization and air-quality-control improvements at the El Paso copper and lead smelters was completed and the second phase of the program was begun in 1977. The modernization program includes a new baghouse to filter out solid particles, construction of an enclosed ore handling system to minimize dust from incoming ore shipments, a new sinter machine, and an 800-ton-per-day sulfuric acid plant using sulfur dioxide liberated during the roasting of copper and lead ores. At the East Helena lead smelter the 500-ton-per-day sulfuric acid plant begun in 1976 was completed and placed in operation. The new facility is expected to eliminate most sulfur dioxide emissions from the smelter. Modernization of an existing blast furnace was planned for 1978.

The AMAX-Homestake smelter-refinery at Boss, Mo., treated 176,787 tons of lead concentrate from the Buick and Magmont mines and produced 127,037 tons of refined lead, 5% less than in 1976.

Secondary smelter production from recycled materials increased 15% reaching a record of 835,102 tons in 1977, accounting for 58% of the total smelter and refinery lead output. Approximately 108 secondary plants were engaged in recovering lead and lead alloys from processing scrap materials during the year. Four plants closed during the year.

Approximately two-fifths of the total secondary lead production was recovered in the form of refined lead metal, and the remainder as antimonial lead and other lead alloy.

RAW MATERIAL SOURCES

Primary smelters and refineries processed ores and concentrates from domestic mines yielding 539,160 tons of refined lead and antimonial lead, 89% of the total primary refinery production. Refined and antimonial lead recovered from imported concentrates smelted during the year totaled 68,971 tons, 17,698 tons less than in 1976. Lead recovered from lead scrap processed at primary plants increased to 3,459 tons, largely contained in antimonial lead.

Scrap materials consumed in 1977 totaled 1,159,913 tons, 156,805 tons more than in 1976. New scrap in the form of purchased drosses and residues from a variety of sources aggregated 192,244 tons, 41,123 tons more than in 1976. New scrap accounted for 17% of the total scrap processed, compared with 15% in 1976. The remainder, old scrap, was largely battery plates with smaller quantities of cable lead, soft and hard lead, type metal, solder, and babbitt. A small quantity of reclaimed scrap totaling 6,769 tons in 1977 was imported for processing in domestic plants.

CONSUMPTION AND USES

Domestic consumption of lead in 1977 increased to 1.58 million tons, 6% more than in 1976. On a monthly basis, consumption ranged from a high of 149,548 tons in March to a low of 108,060 tons in July, when some plant operations were curtailed by vacation furloughs. Lead consumption in the metal products category increased 9% due almost entirely to battery requirements which were up 15%, offsetting declines in most other products. Lead used in ammunition dropped 7% and sheet lead requirements were down 31%, but solder increased 2%.

Lead used in pigments, principally red lead and litharge, was down 9% and lead used in gasoline antiknock compounds declined 3% from the 1976 level. Miscellaneous and other unclassified uses of lead combined increased 7%. According to type of material consumed, soft refined lead represented 65% of the total consumption; antimonial lead, 30%; lead in other alloys and in copper-base scrap, 4% and 1%, respectively, of the total consumption.

The 15% gain in lead requirements for battery grids and oxides was attributed essentially to increased demand for automotive replacement batteries due to severe winter conditions, and to increased requirements for original equipment batteries reflecting an increase of 11% in production of automobiles and trucks in 1977 using batteries for starting, lighting and ignition (SLI). Approximately 69.3 million SLI batteries were produced in 1977, 7.2 million more than in 1976. Of the total battery production, 54.6 million were replacement and 14.7 million were original equipment.

The unexpectedly small decline in the quantity of lead used in antiknock compounds in 1977 was attributed largely to the continued growth in gasoline production and to waivers from the 0.8-gram-per-gallon limit for 1978 granted to certain petroleum refiners. Regulations will require the reduction of lead in gasoline to 0.5 gram per gallon by October 1, 1979. The gasoline pool average lead content in 1977 was approximately 1.5 grams per gallon, slightly less than the average in 1976.

Lead used in battery manufacture accounted for 60% of the total lead consumption. Lead requirements for antiknock compounds represented 15% of the total; pigments, 6%; miscellaneous and other unclassified uses, 4%; and other metal products, 15%.

The domestic supply of lead metal from all sources—primary and secondary production, imports for consumption, and industry stock changes—totaled about 136,800 tons more than reported consumption and exports. The apparent excess supply in 1977 was attributed largely to unreported consumption, incomplete export data, and stock buildup, especially by small producers and dealers that do not report to the Bureau of Mines.

LEAD PIGMENTS

Consumption of pig lead in the manufacture of lead oxides and pigments totaled 564,971 tons, 9% more than in 1976. The quantity of lead used in making black oxide increased 13% and accounted for 75% of the total lead in pigments. Lead used in litharge production was down 1% and accounted for 22% of the total, and lead used in production of red lead increased 2% and accounted for 3% of the total lead used in the manufacture of oxides and pigments. Most of the black oxide and part of the red lead and litharge went to battery manufacturers. Litharge shipments for use in the ceramics industry were 29,940 tons and accounted for 24% of the total litharge shipments.

Prices.—The price of red lead (Pb_3O_4), 98% in carload lots at works, as published in the Chemical Marketing Reporter, increased from 31.75 cents per pound in January to 35.75 cents per pound in February; and in mid-October the price was advanced to 40.5 cents, remaining unchanged to yearend. The quoted price of commercial-grade litharge in carload lots at works was increased from 30.25 cents per pound at the beginning of the year to 33.25 cents in February and to 34 cents in March; it remained unchanged at this level until mid-October when the price increased 3.75 cents to 37.75 cents, remaining firm until late December when the price was increased to 38.75 cents per pound. The quoted price of basic carbonate white lead in carload lots, following the general pattern of price changes for pigments advanced from 38.5 cents per pound in January to 41 cents in February. In mid-October the price was advanced to 45 cents, remaining unchanged to yearend. The price quotation on lead silicate followed the same pattern as for lead carbonate with increases from 24.2 cents per pound in January to 47 cents in February, and to 52.5 cents in October.

Foreign Trade.—Imports for consumption of lead pigments and compounds increased 25% in quantity and 56% in value compared with those in 1976. Receipts of litharge, which comprised 78% of the total imports, were up 27% over last year. Imports of chrome yellow and red lead, together comprising about 18% of the total imports, were 14% more than in 1976. Litharge and red lead imports came from Mexico, whereas most of the chrome yellow came from Canada.

STOCKS

Inventories of refined and antimonial lead at primary refineries declined steadily during the first 9 months, from 43,716 tons at the beginning of the year to 11,100 tons at the end of September, then trended upward to 15,420 tons at yearend, the lowest level of producer stocks in more than 25 years. Stocks of lead in base bullion declined 12% to 5,856 tons, but stocks of lead in ore and matte increased 11% to 79,159 tons.

Stocks of refined lead, lead in antimonial lead, lead in alloys, and copper-base scrap at producer and consumer plants totaled 133,806 tons at yearend. Stocks of new and old scrap at secondary smelters at yearend totaled 112,533 tons, up from 101,670 tons at the end of 1976.

Lead stocks in LME warehouses fluctuated during the year in a range between 75,900 tons and 68,400 tons, and were 69,400 tons at yearend, about 3,000 tons less than a year earlier.

PRICES

The U.S. producer price for common- and corroding-grade pig lead reported by Metals Week on a nationwide delivered basis was at a split price of 25.5 to 26 cents per pound in the first few days of 1977, but on January 5, ASARCO raised its price from 25.5 cents to 26.5 cents. Other producers followed the move to 26.5 cents. ASARCO raised its price again on January 20 to 28 cents and other producers followed quickly. On January 31, Bunker Hill raised its price to 29 cents and other producers went to the same price over a period of several days. On February 28, St. Joe raised its price to 31 cents and other primary and secondary producers followed on March 1. The price remained at 31 cents until October 31, when St. Joe increased its price to 32 cents and was followed by NL Industries, Inc., Bunker Hill, AMAX, ASARCO, Homestake, and later by other producers. On December 5, ASARCO and Cominco Ltd., lifted the quoted price to 33 cents per pound and subsequent increases by other producers made that price industrywide within a few days. The price remained at the record high level through the end of the year. The average price for the year was 30.7 cents per pound.

The cash bid price for lead on the LME in terms of U.S. currency was 22.8 cents per pound at the beginning of the year, and rose steadily to 33.5 cents in early March, a price temporarily above the U.S. producer price. The LME price retreated somewhat in March and April but remained only 1 or 2 cents below the U.S. price, a range that would discourage the movement of European metal to the U.S. market. In June the LME price dropped to the 1977 low of 23.8 cents and stayed in the 24- to 27-cent range through July, August, and September. In October the LME price climbed to 28 cents, in November to 29 cents, and by December had reached 31 cents, approximately 2 cents below the U.S. producer price at that time. The average 1977 LME price for lead was 28 cents per pound. During the last 2 months of 1977, lead brought a higher price per pound than zinc, reversing the relationship that had existed for the last 6 years.

FOREIGN TRADE

Exports of lead metal, lead alloys, and lead scrap in 1977 grew to 95,256 tons, almost double those of 1976. Scrap exports, at 85,411 tons, was the major component of this growth, with Canada receiving 31% and the Federal Republic of Germany 14%. Of the total wrought and unwrought lead and lead alloys exported, Canada, the United Kingdom, and Belgium accounted for 63%. Exports of lead and zinc ores and concentrates were not reported separately in 1977, but the total gross weight of undifferentiated shipments was 128,056 tons valued at $28.8 million, with 39% going to Brazil and 26% to Belgium.

General imports of lead were 349,450 tons (lead content), an increase of 53% over those of 1976. The breakdown of this total, 73,340 tons in ores and concentrates, 8,068 tons in bullion, 261,273 tons in pigs and bars, and 6,769 tons in scrap, shows a slight decrease in ores but substantial increases in each metal category when compared with similar imports in 1976. Imports for consumption were comprised of 97,862 tons in ores and concentrates, 8,068 tons in bullion, 253,608 tons in pigs and bars, and 3,884 tons in scrap. The principal source countries for general imports of concentrates were Honduras, Australia, Canada, and Peru. The principal sources for lead metal were Canada, Mexico, Peru, the Federal Republic of Germany, and Australia.

Basic tariff rates continued through 1977 at 0.75 cent per pound on ore and concentrate and 1.0625 cents per pound on bullion, metal, and dross for favored nations, and at 2.125 cents per pound statutory for other nations.

WORLD REVIEW

World mine production of lead in 1977 increased by 2% to 3.76 million tons and primary refined metal production increased 1% to 3.85 million tons.

The market economy countries mined 2.58 million tons of lead, a 3% increase over production in 1976. Refined primary lead production in market economy countries was 2.64 million tons, almost the same as in 1976. The mine production of lead in centrally planned economy countries was estimated to be about 1.18 million tons, not much changed from the previous year. Smelter production of primary refined lead was up 3% at 1.21 million tons.

The United States was the leading producer of primary refined lead, followed by the U.S.S.R., Australia, Japan, and Canada, all of which produced over 200,000 tons, and France, Mexico, Yugoslavia, Bulgaria, the Federal Republic of Germany, Belgium, and the People's Republic of China, all of which produced over 100,000 tons.

World consumption of refined lead in 1977 was reported by the World Bureau of Metal Statistics as 4.9 million tons, a 4% increase over 1976 consumption. For the most part, this total excluded remelted pig lead and remelted antimonial lead. If all secondary metal consumption were included, the world total would be at least 0.7 million tons greater. The United States consumed 22% and the U.S.S.R. consumed about 14% of the total, excluding secondary.

Australia.—Mine production of lead was 9% greater than in the previous year and reaffirmed Australia's rank as third among lead producing nations. A part of this production was exported as concentrates, part was smelted to bullion and refined elsewhere, and part was produced as refined lead.

M.I.M. Holdings Ltd. (Mount Isa Mines), produced 170,600 tons of lead (content) in the fiscal year ending June 30, 1977. Lead bullion produced at Mount Isa was exported to the United Kingdom for refining by a subsidiary, Britannia Lead Co. Ltd.

The Broken Hill mines, controlled by Conzinc Riotinto of Australia Ltd., produced 176,400 tons of lead in concentrates, a company record. Sulphide Corporation Pty. Ltd., produced 215,000 tons of refined lead.

E-Z Industries Ltd., produced lead concentrates containing about 10,000 tons of lead from the West Coast Mines operations in Tasmania.

The Woodlawn project in New South Wales, shared by Australian Mining & Smelting Ltd., St. Joe Minerals Corp., and Phelps Dodge Corp., was under construction and scheduled for completion in 1978. The plant was designed to treat 3,000 tons of ore per day producing zinc, copper, and lead and silver concentrates.

Bolivia.—The Bolivian Government companies Empresa Nacional de Fundiciones (ENAF) and Corporación Minera de Bolivia (COMIBOL), early in 1977 asked for bids for the construction of a lead smelter near Potosi. The new plant will use the Kivcet process and could begin production in 1980 with a capacity of 24,000 tons of lead annually. The estimated cost was $130 million. Bolivian mines have been exporting lead concentrates during the last 6 years at an average rate of about 20,000 tons of lead per year. The total production of concentrates for export by COMIBOL, medium mines, and small mines in 1977 was about 21,000 tons, presumably containing 13,000 tons of lead.

Brazil.—Three new smelter projects were underway or planned, one by Companhia Brasileira de Chumbo (Cobrac) to increase capacity from 35,000 to 50,000 tons per year; a new secondary plant for Tonolli, Inc., of 44,000 tons per year; and a third project sponsored by the State Government and private owners involving a mine and plant in Morro Agudo with a proposed capacity of 12,000 tons per year.

Canada.—Mine production of lead in ores and concentrates recovered from the low level of 1976. The production of primary refined lead was 206,636 tons, a 7% increase over the output in 1976. Recovery of secondary lead was estimated to be 42,000 tons and total consumption of primary and secondary lead was about 110,000 tons. Hence, a large excess of both concentrate and metal production was available for export. Of 151,600 tons of lead in concentrates exported, 13% went to the United States and 63% to Japan.

Although demand for lead was better than in previous years, many Canadian mines which produced lead as a byproduct of zinc or copper curtailed production as these latter two metals were in a depressed market situation. Mines were producing lead in eight provinces and territories, 28% of the total came from British Columbia, 24% from Yukon Territory, 22% from New Brunswick, 20% from the Northwest Territories, and the balance from Ontario, Newfoundland, Manitoba, and Quebec. Four leading producing mines were closed in 1977: Nigadoo River mine in New Brunswick, Cupre and D'Estrie mines of Sullivan Mining Co. in Quebec, and Ruth Vermont mine in British Columbia. Six new mining projects were under development early in 1977 with production originally scheduled to begin or increase in the 1978 to 1982 period. The scheduled expansion at the Brunswick No. 12 mine in New Brunswick was delayed, the Lyon Lake mine in Ontario was placed on a care and maintenance basis awaiting more favorable market conditions, the Grum deposit near Faro, Yukon Territory was the subject of an evaluation and financing program in 1977, the Howard's Pass prospect of Placer Development Ltd., in the Yukon Territory was being developed with an underground testing program scheduled for 1978, the Gays River deposit in Nova Scotia was scheduled for production late in 1978 by Exxon Corp. that acquired complete control of the project early in 1977, and the Polaris mine of Arvik Mines (75% owned by Cominco) was held in standby condition pending negotiations with the Federal Government.

Major mine producing units were Brunswick Mining and Smelting Corp. Ltd.'s, Bathurst mines, with about 69,400 tons of lead in concentrates, and Cyprus Anvil's Faro mine, with 74,000 tons. Pine Point Mines, Ltd., produced 85,000 tons of lead concentrate and Cominco's mine produced 118,000 tons.

The two Canadian smelters producing refined lead in 1977 were the Cominco plant at Trail, British Columbia, with 150,000 tons of production, and the Brunswick Mining and Smelting Corp., Ltd. Imperial smelting furnace at Belledune, New Brunswick, with 56,000 tons of production.

Greece.—The mines at Laurium of the Compagnie Française des Mines de Laurium were closed after 100 years of operation. The Kassandra mines were closed by a 7-month strike in 1977.

Ireland.—The mine at Silvermines in County Tipperary, operated by Mogul of Ireland Ltd., produced concentrates containing 15,115 tons of lead and 53,733 tons of zinc. Ore reserves at the end of the year were reported to be 5.1 million tons, assaying 2.71% lead and 5.38% zinc. Kerr Addison Mines Ltd., has a 75% interest in the Mogul mine.

Tara Mines Ltd., at Navan, County Meath, started its concentrator in June, almost 7 years after the discovery of the deposit. Although mining was hampered by work stoppage in the fourth quarter and concentrate shipments were hindered by picketing at the port site, the company treated 789,700 tons of ore grading 9.9% zinc and 2% lead, with more than half coming from a stockpile accumulated during development. The concentrates produced totaled 145,800 tons containing 10,700 tons of lead and 71,200 tons of zinc. During the second half of 1977, 16,000 tons of lead concentrates and 90,300 tons of zinc concentrates were shipped to European smelters. When the mine is fully operational, Tara should produce 46,000 tons of lead (content) annually. Ore reserves at the end of 1977 were given as 67 million tons (undiluted), assaying 11% zinc and 2.4% lead.

At the Tynagh mine, County Galway, 616,400 tons of ore was mined yielding 25,053 tons of lead concentrate, 27,491 tons of zinc concentrate, 5,309 tons of bulk concentrate, and 1,648 tons of copper concentrate. The relatively low European prices for zinc and lead in 1977, and a reduction of the quantity of zinc concentrates accepted by European smelters, led to a study on the viability of the Tynagh mine. The indication was that if conditions did not improve, operations at the mine probably would not continue beyond the end of 1979.

Japan.—Production of primary refined lead increased by 1% during 1977 to a total of 244,049 short tons, and an additional 62,276 tons of secondary lead was produced. Over 60,000 tons of lead came from domestic mines and the balance of primary production was from imported concentrates from Canada, Peru, Australia, the Republic of Korea, and the United States. Metal imports were 31,000 tons, about half from North Korea, and exports were 9,100 tons. Consumption of refined lead was 271,000 tons, of which 40% was used for storage batteries.

In October 1977, the Japanese Metal Mining Agency announced that a new lead-zinc deposit had been discovered near Jozankei in western Hokkaido, near a mine operated by Tohoya Mining Co. Drilling yielded samples assaying 20% combined lead and zinc over thicknesses on the order of 40 feet, and exploratory work was to be continued in 1978 to determine the extent of the deposit. No immediate increase was expected in Japanese production of lead and zinc ore as Tohoya would probably use the new deposit, if it is developed, to maintain production at its existing nearby mine plant.

Mexico.—Industrial Minera Mexico, S.A. (IMM), continued expansion of the Santa Barbara mine and began modernization of the lead smelter in Chihuahua. During 1977 it produced 107,200 tons of refined lead plus the lead content in concentrates sold. The company reported 52,400 tons of lead from IMM mines and 86,900 tons of refined lead from the smelter and refinery.

Met-Mex Peñoles, S.A., completed the transfer of some of its lead refining operations from Monterrey to Torreon. Lead production in 1977 was 138,400 short tons, an increase of 23% over 1976 production.

South Africa, Republic of.—The three ore deposits discovered by Phelps Dodge at Aggeneys will be developed by Gold Fields of South Africa Ltd., and Phelps Dodge. They are known as Black Mountain, Broken Hill, and Big Syncline. The first to be developed is expected to be Broken Hill, which was reported to have an ore reserve of 38 million tons averaging 6.35% lead, 2.87% zinc, 0.45% copper, and 2.6 ounces of silver per ton.

Production at Broken Hill is expected to be about 90,000 tons of lead in concentrates.

U.S.S.R.—Primary production of lead in the U.S.S.R. was estimated at 560,000 tons and secondary production was an additional 110,000 tons. Although information was incomplete, imports were probably much lower in 1977, close to 25,000 tons instead of the 100,000 tons purchased from western nations in 1976. Consumption was estimated to be 670,000 tons of refined pig lead and lead content of antimonial lead.

Yugoslavia.—During 1977 about 18 lead-zinc mines and 14 flotation plants were operating in Yugoslavia. Two lead smelters, one at Zvecan, and one Imperial smelting furnace at Titov Veles, contributed to lead production.

Rudarsko Metalurski Kombinat Trepca was the largest lead producer, processing concentrate from the Trepca mines at the Zvecan refinery. The company was developing additional mine levels and constructing a new mill at the Trepca mine. Upon completion in 1980, the mill should be able to process over 1 million tons of crude ore annually, a 40% increase over the 1977 rate. The Rudnik mine in Serbia was also being expanded to increase its production from 187,000 to 253,000 tons of crude ore per year.

TECHNOLOGY

Bureau of Mines metallurgists reported considerable progress in the installation of a process development unit (PDU) at its Reno (Nev.) Metallurgy Research Center to determine the feasibility of the ferric chloride-lead electrolysis procedure for treating galena concentrates to recover lead. The work in progress was an extension of laboratory research in which flotation concentrates are leached with hot ferric chloride-sodium chloride solution to produce lead chloride and elemental sulfur. Dried lead chloride is electrolyzed in a fused-salt bath to produce molten lead, and chlorine, evolved at the anode, is used to regenerate the ferric chloride leach solution. The project, in cooperation with industry, will develop data necessary to design a pilot plant and assess the potential for commercial application of the new hydrometallurgical process.

Most of the industry-sponsored research and development continued to be oriented toward new fields of application for lead and retaining existing applications. In the field of lead materials for batteries the objective of research efforts is to improve efficiency and increase energy density of batteries to meet changing market requirements. Significant progress was achieved in developing better grid materials for low-maintenance or maintenance-free batteries such as low-antimony, calcium-tin, and strontium-lead alloys which will extend the life of lead-acid batteries and improve their competitive position relative to other current or anticipated battery systems.

Battery weight has been decreasing while battery performance has increased. One manufacturer has achieved these improvements by using thinner, lighter grids primarily based on wrought lead strip metal, and smaller, shorter intercell connectors. These more powerful lead-acid batteries probably will extend the markets for lead. Researchers reported that the maintenance-free type battery currently in use in SLI applications likely will be extended to the deep discharge cycling type of industrial applications.

A hydrometallurgical process for recovery of lead and silver from high-grade lead sulfide concentrates by dry chlorination and fused salt electrolysis was developed by Hazen Research Inc. A pilot plant was designed to handle mixed sulfide concentrates and produce high-purity lead in a 2,000-ampere-capacity fused-salt cell. In the process, lead sulfide concentrate is fed to the dry chlorinator where lead chloride is formed along with chlorides of other metals. The metal chlorides are solubilized in a hot brine leach, and tailings containing sulfur and gangue material are separated by filtration. The solution containing lead is treated in a crystallizer to produce solid lead chloride which is fed to an electrolytic cell containing molten lead chloride—sodium chloride electrolyte. High-purity lead is tapped from the cell and cast into ingots, and the chlorine gas produced in the cell is recycled to the dry chlorinator.[3]

The International Lead Zinc Research Organization, Inc., reported that a large part of its research activities during the year were focused on the architectural and automotive fields. Model structures were created and exhibited to demonstrate the advantages of using lead in wall structures and roofs of residential and commercial buildings. Progress was also reported in the production of improved lead oxides to give better performance as the active material in lead-acid storage batteries and in solving the problem of early corrosion of the positive grid and extending battery life.

The competitive position of lead used as a sound-attenuating material was enhanced by coating sheet lead on both sides with highly porous and elastic materials such as polyurethene or mineral wool. Optimum sound insulation is possible with the new laminated combination materials.

---

[1]Physical scientist, Division of Nonferrous Metals.
[2]Mineral specialist, Division of Nonferrous Metals.
[3]Reynolds, J. E., D. N. Goens, and C. W. Kenney. Hazen Research, Inc., Pilot Plant Development of Chloride Processes for Lead-Zinc Concentrates—SME, AIME. Lead-Zinc Update, 1977, pp. 301-325.

Table 2.—Mine production of recoverable lead in the United States, by State

(Short tons)

State	1973	1974	1975	1976	1977
Alaska	6	--	--	14	--
Arizona	763	1,059	420	338	318
California	44	35	66	54	3
Colorado	28,112	24,609	27,088	26,749	22,994
Idaho	61,744	51,717	50,395	53,636	47,258
Illinois	541	493	W	W	W
Kentucky	--	--	(1)	--	--
Maine	204	279	364	216	178
Missouri	487,143	562,097	515,958	500,991	500,255
Montana	176	154	205	92	106
Nevada	--	1,785	2,976	582	743
New Mexico	2,556	2,364	1,931	W	W
New York	2,304	3,076	3,027	3,196	2,778
Oklahoma	--	W	--	W	W
Oregon	--	W	W	--	--
Utah	13,733	10,510	12,679	16,297	10,746
Virginia	2,637	3,106	2,551	1,946	2,203
Washington	2,217	1,299	W	W	1,201
Wisconsin	844	1,285	W	W	W
Other States	--	2	3,804	5,435	3,708
Total	603,024	663,870	621,464	609,546	592,491

W Withheld to avoid disclosing company proprietary data; included in "Other States."
[1]Less than 1/2 unit.

Table 3.—Production of lead and zinc in the United States in 1977, by State and class of ore, from old tailings, etc., in terms of recoverable metal

(Short tons)

State	Lead ore			Zinc ore			Lead-zinc ore		
	Gross weight (dry basis)	Lead content	Zinc content	Gross weight (dry basis)	Lead content	Zinc content	Gross weight (dry basis)	Lead content	Zinc content
Arizona	--	--	--	--	--	--	--	--	--
California	--	--	--	--	--	--	--	--	--
Colorado	1,229	23	--	159,861	1,758	11,767	482,937	12,979	17,042
Idaho	185,872	18,609	2,186	9,680	12	496	764,033	27,879	27,966
Maine	--	--	--	--	--	--	--	--	--
Missouri	8,925,602	500,178	81,689	--	--	--	--	--	--
Montana	2,012	15	2	--	--	--	--	--	--
Nevada	100	4	1	300	6	2	104,679	719	1,668
New Jersey	--	--	--	207,052	--	33,464	--	--	--
New York	--	--	--	1,194,510	2,778	70,839	--	--	--
Pennsylvania	--	--	--	584,274	--	22,825	--	--	--
Tennessee	--	--	--	3,744,422	--	88,669	--	--	--
Utah	--	--	--	--	--	--	339,638	10,746	17,759
Virginia	--	--	--	541,875	2,203	13,272	--	--	--
Washington	--	--	--	--	--	--	153,595	1,200	5,570
Other States[1]	150	7	--	655,729	3,421	24,810	--	--	--
Total	9,114,965	518,836	83,878	7,097,703	10,178	266,144	1,844,882	53,523	70,005
Percent of total lead-zinc	--	87	19	--	2	59	--	9	16

State	Copper-lead, copper-zinc, and copper-lead-zinc ores			All other sources[2]			Total		
	Gross weight (dry basis)	Lead content	Zinc content	Gross weight (dry basis)	Lead content	Zinc content	Gross weight (dry basis)	Lead content	Zinc content
Arizona	40,710	--	4,364	46,360,681	318	16	46,401,391	318	4,380
California	--	--	--	4,240	3	2	4,240	3	2
Colorado	300,750	5,648	10,286	217,206	2,586	1,172	1,161,983	22,994	40,267
Idaho	--	--	--	571,995	758	350	1,531,580	47,258	30,998
Maine	143,177	178	7,269	--	--	--	143,177	178	7,269
Missouri	--	--	--	--	77	--	8,925,602	500,255	81,689
Montana	--	--	--	10,238	91	77	12,250	106	79
Nevada	--	--	--	1,278,032	14	1	1,383,111	743	1,672
New Jersey	--	--	--	--	--	--	207,052	--	33,464
New York	--	--	--	--	--	--	1,194,510	2,778	70,839
Pennsylvania	--	--	--	--	--	--	584,274	--	22,825
Tennessee	1,250,130	--	1,769	--	--	--	4,994,552	--	90,438
Utah	--	--	--	--	--	--	339,638	10,746	17,759
Virginia	--	--	--	--	--	--	541,875	2,203	13,272
Washington	--	--	--	39,805	1	2	193,400	1,201	5,572
Other States[1]	--	--	--	2,356,034	280	4,285	3,011,913	3,708	29,095
Total	1,734,767	5,826	23,688	50,838,231	4,128	5,905	70,630,548	592,491	449,620
Percent of total lead-zinc	--	1	5	--	1	1	--	100	100

[1]Other States includes Illinois, New Mexico, Oklahoma, Washington, and Wisconsin.

[2]Lead and zinc recovered from copper, gold, silver, and fluorspar ores, and from mill tailings and miscellaneous cleanups.

Table 4.—Mine production of recoverable lead in the United States, by month

(Short tons)

Month	1976	1977
January	50,379	45,019
February	51,999	49,171
March	57,751	56,873
April	50,565	53,209
May	50,959	48,323
June	50,560	50,853
July	48,136	41,922
August	50,978	52,613
September	49,200	46,423
October	49,615	49,249
November	48,975	48,555
December	50,429	50,281
Total	609,546	592,491

Table 5.—Twenty-five leading lead-producing mines in the United States in 1977, in order of output

Rank	Mine	County and State	Operator	Source of lead
1	Buick	Iron, Mo	AMAX Lead Co. of Missouri.	Lead ore.
2	Fletcher	Reynolds, Mo	St. Joe Lead Co	Do.
3	Magmont	Iron, Mo	Cominco American, Inc	Do.
4	Ozark	Reynolds, Mo	Ozark Lead Co	Do.
5	Brushy Creek	do	St. Joe Lead Co	Do.
6	Viburnum No. 29	Washington, Mo	do	Do.
7	Viburnum No. 28	Iron, Mo	do	Do.
8	Lucky Friday	Shoshone, Idaho	Hecla Mining Co	Do.
9	Indian Creek	Washington, Mo	St. Joe Lead Co	Do.
10	Star Unit	Shoshone, Idaho	Hecla Mining Co	Lead-zinc and lead ore.
11	Bunker Hill	do	The Bunker Hill Co	Lead-zinc ore.
12	Viburnum No. 27	Crawford, Mo	St. Joe Lead Co	Lead ore.
13	Leadville Unit	Lake, Colo	ASARCO Incorporated	Lead-zinc ore.
14	Ontario	Summit, Utah	Park City Ventures	Do.
15	Idarado	Ouray and San Miguel, Colo	Idarado Mining Co	Copper-lead-zinc ore.
16	Sunnyside	San Juan, Colo	Standard Metals Corp	Lead-zinc ore.
17	Burgin	Utah, Utah	Kennecott Copper Corp	Do.
18	Balmat	St. Lawrence, N.Y	St. Joe Zinc Co	Zinc ore.
19	Ground Hog	Grant, N. Mex	ASARCO Incorporated	Do.
20	Austinville and Ivanhoe	Wythe, Va	The New Jersey Zinc Co.	Do.
21	Bulldog Mountain	Mineral, Colo	Homestake Mining Co	Silver ore.
22	Eagle	Eagle, Colo	The New Jersey Zinc Co.	Zinc and silver ore.
23	Pend Oreille	Pend Oreille, Wash	The Bunker Hill Co	Lead-zinc ore.
24	Pan American	Lincoln, Nev	do	Do.
25	Shullsburg	La Fayette, Wis	Eagle-Picher Industries, Inc.	Zinc ore.

Table 6.—Refined lead produced at primary refineries in the United States, by source material

(Short tons)

	1973	1974	1975	1976	1977
Refined lead:[1]					
From primary sources:					
Domestic ores and base bullion	567,256	580,078	530,215	568,536	536,449
Foreign ores and base bullion	107,260	92,946	105,907	84,341	68,389
Total	674,516	673,024	636,122	652,877	604,838
From secondary sources	--	--	--	29	95
Grand total	674,516	673,024	636,122	652,906	604,933
Calculated value of primary refined lead (thousands)[2]	$219,757	$303,265	$273,914	[r]$301,628	$371,371

[r]Revised.
[1]GSA metal is not included in refined lead production.
[2]Value based on average quoted price and 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
1973	15,455	1,167	7.5	9,020	4,203	1,065	14,288
1974	12,513	1,097	8.8	5,879	3,988	1,549	11,416
1975	6,029	567	9.4	1,658	467	3,337	5,462
1976	6,743	730	10.8	2,314	2,328	1,371	6,013
1977	7,557	900	11.9	2,711	582	3,364	6,657

Table 8.—Stocks and consumption of new and old lead scrap in the United States in 1977

(Short tons, gross weight)

Class of consumer and type of scrap	Stocks Jan. 1	Receipts	Consumption			Stocks Dec. 31
			New scrap	Old scrap	Total	
Smelters and refiners:						
Soft lead	1,969	61,218	--	58,183	58,183	5,004
Hard lead	1,179	35,739	--	35,566	35,566	1,352
Cable lead	3,900	48,079	--	49,510	49,510	2,469
Battery-lead plates	54,357	791,524	--	781,593	781,593	64,288
Mixed common babbitt	255	4,339	--	4,264	4,264	330
Solder and tinny lead	376	13,363	--	13,438	13,438	301
Type metals	2,892	19,254	--	19,078	19,078	3,068
Drosses and residues	36,737	191,186	192,244	--	192,244	35,679
Total	101,665	1,164,702	192,244	961,632	1,153,876	112,491
Foundries and other manufacturers:						
Soft lead	--	--	--	--	--	--
Hard lead	--	--	--	--	--	--
Cable lead	--	--	--	--	--	--
Battery-lead plates	--	--	--	--	--	--
Mixed common babbitt	5	6,074	--	6,037	6,037	42
Solder and tinny lead	--	--	--	--	--	--
Type metals	--	--	--	--	--	--
Drosses and residues	--	--	--	--	--	--
Total	5	6,074	--	6,037	6,037	42
All consumers:						
Soft lead	1,969	61,218	--	58,183	58,183	5,004
Hard lead	1,179	35,739	--	35,566	35,566	1,352
Cable lead	3,900	48,079	--	49,510	49,510	2,469
Battery-lead plates	54,357	791,524	--	781,593	781,593	64,288
Mixed common babbitt	260	10,413	--	10,301	10,301	372
Solder and tinny lead	376	13,363	--	13,438	13,438	301
Type metals	2,892	19,254	--	19,078	19,078	3,068
Drosses and residues	36,737	191,186	192,244	--	192,244	35,679
Grand total	101,670	1,170,776	192,244	967,669	1,159,913	112,533

Table 9.—Secondary metal recovered[1] from lead and tin scrap in the United States in 1977, by type of product

(Short tons)

	Lead	Tin	Antimony	Other	Total
Refined pig lead	257,969	--	--	--	257,969
Remelt lead	76,195	--	--	--	76,195
Total	334,164	--	--	--	334,164
Refined pig tin	--	1,814	--	--	1,814
Remelt tin	--	29	--	--	29
Total	--	1,843	--	--	1,843
Lead and tin alloys:					
Antimonial lead	422,612	623	26,580	470	450,285
Common babbitt	11,147	457	1,018	2	12,624
Genuine babbitt	65	308	8	--	381
Solder	25,698	5,175	952	17	31,842
Type metals	15,907	780	1,950	2	18,639
Cable lead	7,850	--	89	--	7,939
Miscellaneous alloys	788	99	4	--	891
Total	484,067	7,442	30,601	491	522,601
Tin content of chemical products	--	402	--	--	402
Grand total	818,231	9,687	30,601	491	859,010

[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)

	1973	1974	1975	1976	1977
As metal:					
At primary plants	--	--	--	29	95
At other plants	186,124	238,216	271,297	310,981	334,069
Total	186,124	238,216	271,297	311,010	334,164
In antimonial lead:					
At primary plants	1,065	1,549	3,337	1,371	3,364
At other plants	374,713	369,954	311,783	340,596	419,248
Total	375,778	371,503	315,120	341,967	422,612
In other alloys	92,384	88,979	72,039	73,592	78,326
Grand total:					
Quantity	654,286	698,698	658,456	726,569	835,102
Value (thousands)[1]	$213,166	$314,833	$283,531	$335,675	$512,753

[1]Value based on average quoted price of common lead.

Table 11.—Lead recovered from scrap processed in the United States, by kind of scrap and form of recovery

(Short tons)

	1976	1977
Kind of scrap		
New scrap:		
Lead-base	100,750	126,820
Copper-base	3,420	5,695
Tin-base	165	157
Total	104,335	132,672
Old scrap:		
Battery-lead plates	461,391	516,649
All other lead-base	148,981	170,932
Copper-base	11,860	14,847
Tin-base	2	2
Total	622,234	702,430
Grand total	726,569	835,102
Form of recovery		
As soft lead:		
At primary plants	29	95
At other plants	311,010	334,069
Total	311,039	334,164
In antimonial lead[1]	341,967	422,612
In other lead alloys	59,502	61,390
In copper-base alloys	14,025	16,871
In tin-base alloys	36	65
Total	415,530	500,938
Grand total	726,569	835,102

[1]Includes 1,371 tons of lead recovered in antimonial lead from secondary sources at primary plants in 1976 and 3,364 in 1977.

Table 12.—Lead consumption in the United States, by product

(Short tons)

Product	1976	1977
Metal products:		
Ammunition	73,478	68,390
Bearing metals	13,063	11,985
Brass and bronze	15,660	16,698
Cable covering	15,930	15,107
Calking lead	12,475	9,618
Casting metals	6,708	5,983
Collapsible tubes	2,329	2,054
Foil	5,126	3,568
Pipes, traps, bends	13,789	11,635
Sheet lead	24,438	16,761
Solder	63,324	64,286
Storage batteries:		
Battery grids, posts, etc	383,844	459,335
Battery oxides	438,560	486,541
Terne metal	1,595	1,644
Type metal	15,007	12,561
Total	1,085,326	1,186,166
Pigments:		
White lead	2,993	6,612
Red lead and litharge	85,403	78,071
Pigment colors	16,634	14,714
Other[1]	561	585
Total	105,591	99,982
Chemicals:		
Gasoline antiknock additives	239,758	232,910
Miscellaneous chemicals	146	129
Total	239,904	233,039
Miscellaneous uses:		
Annealing	2,893	2,678
Galvanizing	1,252	1,424
Lead plating	386	481
Weights and ballast	22,366	19,092
Total	26,897	23,675
Other, unclassified uses	32,354	39,476
Grand total[2]	1,490,072	1,582,338

[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 month

(Short tons)

Month	1976	1977
January	116,253	132,176
February	123,270	122,099
March	136,065	149,548
April	125,735	138,024
May	123,381	128,314
June	123,335	133,588
July	103,370	108,060
August	120,656	131,550
September	127,399	142,461
October	137,447	141,429
November	128,009	126,154
December	125,152	128,935
Total[1]	1,490,072	1,582,338

[1]Includes lead that went directly from scrap to fabricated products and lead contained in leaded zinc oxide and other pigments.

Table 14.—Lead consumption in the United States in 1977, by class of product and type of material

(Short tons)

Product	Soft lead	Lead in antimonial lead	Lead in alloys	Lead in copper-base scrap	Total
Metal products	114,741	67,613	45,576	12,360	240,290
Storage batteries	536,848	400,154	8,874	--	945,876
Pigments	99,709	273	--	--	99,982
Chemicals	233,039	--	--	--	233,039
Miscellaneous	13,706	9,929	40	--	23,675
Unclassified	35,433	1,085	2,958	--	39,476
Total	1,033,476	479,054	57,448	12,360	[1]1,582,338

[1]Includes lead that went directly from scrap to fabricated products and lead contained in leaded zinc oxide and other pigments.

Table 15.—Lead consumption in the United States in 1977, by State[1]

(Short tons)

State	Refined soft lead	Lead in antimonial lead	Lead in alloys	Lead in copper-base scrap	Total
California	118,485	45,342	5,017	802	169,646
Colorado	733	299	19	--	1,051
Connecticut	12,667	10,567	--	996	24,230
District of Columbia	82	--	--	--	82
Florida	12,551	10,791	649	--	23,991
Georgia	69,054	30,398	2,069	9	101,530
Illinois	81,224	54,392	8,238	1,518	145,372
Indiana	114,940	34,791	2,201	512	152,444
Kansas	27,682	14,847	71	58	42,658
Kentucky	6,966	11,074	2	--	18,042
Maryland	547	1,695	1,575	16	3,833
Massachusetts	840	202	7	94	1,143
Michigan	17,067	18,102	2,537	64	37,770
Missouri	22,093	12,350	1,123	1,005	36,571
Nebraska	1,300	1,627	1,208	1,154	5,289
New Jersey	112,489	8,251	2,711	412	123,863
New York	23,290	6,375	5,038	205	34,908
Ohio	9,847	5,200	3,928	1,612	20,587
Pennsylvania	112,156	56,927	13,673	1,636	184,392
Rhode Island	2,892	80	61	--	3,033
Tennessee	4,777	17,301	84	128	22,290
Virginia	559	2,733	720	432	4,444
Washington	5,470	1,473	--	--	6,943
West Virginia	13,145	--	--	--	13,145
Wisconsin	6,024	13,618	40	323	20,005
Alabama and Mississippi	7,310	9,238	--	723	17,271
Arkansas and Oklahoma	3,621	4,703	--	--	8,324
Hawaii and Oregon	10,965	8,552	13	--	19,530
Iowa and Minnesota	8,094	21,935	1,174	--	31,203
Louisiana and Texas	196,025	45,291	2,244	548	244,108
Montana and Idaho	247	--	--	--	247
New Hampshire, Maine, Vermont, Delaware	12,177	16,213	335	113	28,838
North and South Carolina	18,143	14,470	813	--	33,426
Utah, Nevada, Arizona	14	217	1,898	--	2,129
Total	1,033,476	479,054	57,448	12,360	1,582,338

[1]Includes lead that went directly from scrap to fabricated products and lead contained in leaded zinc oxide and other pigments.

Table 16.—Production and shipments of lead pigments[1] and oxides in the United States

Product	1976				1977			
	Production (short tons)	Shipments			Production (short tons)	Shipments		
		Short tons	Value[2] Total	Value[2] Average per ton		Short tons	Value[2] Total	Value[2] Average per ton
White lead, dry	1,640	1,625	$1,054,436	$649	1,719	1,719	$1,215,516	$707
Red lead	19,608	19,296	11,146,722	578	19,949	19,604	12,661,507	646
Litharge	132,172	122,462	67,190,997	549	131,084	122,658	77,399,953	631
Black oxide	392,911	--	--	--	436,869	--	--	--

[1]Excludes basic lead sulfate; withheld to avoid disclosing company proprietary data.
[2]At plant, exclusive of container.

Table 17.-Lead content of lead and zinc pigments[1] and lead oxides produced by domestic manufacturers, by source

(Short tons)

Product	1976				1977			
	Lead in pigments produced from—			Total lead in pigments	Lead in pigments produced from—			Total lead in pigments
	Ore		Pig lead		Ore		Pig lead	
	Domestic	Foreign			Domestic	Foreign		
White lead	--	--	1,312	1,312	--	--	1,375	1,375
Red lead	--	--	17,775	17,775	--	--	18,154	18,154
Litharge	--	--	122,920	122,920	--	--	121,908	121,908
Black oxide	--	--	374,761	374,761	--	--	423,534	423,534
Total	--	--	516,768	516,768	--	--	564,971	564,971

[1]Excludes lead in basic lead sulfate and leaded zinc oxide; withheld to avoid disclosing company proprietary data.

Table 18.—Distribution of white lead (dry and in oil) shipments,[1] by industry

(Short tons)

Industry	1973	1974	1975	1976	1977
Paints	3,198	--	--	--	--
Ceramics	18	--	--	--	--
Other	6,328	5,905	3,381	1,625	1,719
Total	9,544	5,905	3,381	1,625	1,719

[1]Excludes basic lead sulfate; figures withheld to avoid disclosing company proprietary data.

Table 19.—Distribution of red lead shipments, by industry

(Short tons)

Industry	1973	1974	1975	1976	1977
Paints	6,509	5,344	4,552	7,071	6,519
Storage batteries	W	W	W	W	W
Other	9,514	7,946	10,543	12,225	13,085
Total	16,023	13,290	15,095	19,296	19,604

W Withheld to avoid disclosing company proprietary data; included with "Other."

Table 20.—Distribution of litharge shipments, by industry

(Short tons)

Industry	1973	1974	1975	1976	1977
Ceramics	35,910	46,598	33,941	32,300	29,940
Insecticides	W	W	W	--	--
Oil refining	620	765	W	W	W
Paints	3,112	5,347	3,248	8,354	2,706
Rubber	5,078	6,490	5,850	3,820	3,162
Other	134,424	102,245	77,436	77,988	86,850
Total	179,144	161,445	120,475	122,462	122,658

W Withheld to avoid disclosing company proprietary data; included with "Other."

Table 21.—U.S. imports for consumption of lead pigments and compounds

Kind	1976		1977	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
White lead	134	$156	171	$137
Red lead	881	386	1,270	771
Litharge	13,694	5,662	17,434	9,928
Chrome yellow	2,747	2,935	2,852	3,424
Other lead pigments	91	93	31	62
Other lead compounds	289	230	558	402
Total	17,836	9,462	22,316	14,724

Table 22.—Stocks of lead at primary smelters and refineries in the United States, Dec. 31

(Short tons)

Stocks	1973	1974	1975	1976	1977
Refined pig lead	22,018	34,116	76,713	39,869	13,276
Lead in antimonial lead	4,062	3,138	4,560	3,847	2,144
Lead in base bullion	8,845	5,492	6,748	6,687	5,856
Lead in ore and matte	54,922	78,305	68,509	r71,299	79,159
Total	89,847	121,051	156,530	r121,702	100,435

rRevised.

Table 23.—Stocks of lead at consumers and secondary smelters in the United States, Dec. 31, by type of material

(Short tons, lead content)

Year	Refined soft lead	Lead in antimonial lead	Lead in alloys	Lead in copper-base scrap	Total
1973	84,274	32,226	6,954	667	124,121
1974	106,245	49,504	9,628	1,212	166,589
1975	85,110	41,569	5,059	1,577	133,315
1976	87,774	34,106	6,000	1,730	129,610
1977	81,576	43,262	7,351	1,617	133,806

Table 24.—Average monthly and yearly quoted prices of lead[1]

(Cents per pound)

Month	1976		1977	
	U.S. producer	London Metal Exchange	U.S. producer	London Metal Exchange
January	19.00	15.24	26.86	25.31
February	19.00	15.80	28.69	29.32
March	20.22	17.36	31.00	31.87
April	21.93	20.61	31.00	29.40
May	22.88	21.85	31.00	29.93
June	23.00	21.60	31.00	25.70
July	24.25	23.12	31.00	25.43
August	24.76	21.83	31.00	24.95
September	24.83	21.75	31.00	26.39
October	25.75	21.05	31.02	27.88
November	25.79	20.81	32.00	28.71
December	25.82	21.66	32.85	31.06
Average	23.10	20.46	30.70	28.00

[1]Metals Week. Quotations for United States on a nationwide, delivered basis.

Table 25.—U.S. exports of lead, by country[1]

Destination	1976 Quantity (short tons)	1976 Value (thousands)	1977 Quantity (short tons)	1977 Value (thousands)
Unwrought lead and lead alloys:				
Argentina	43	$17	2	$8
Australia	6	5	23	8
Belgium-Luxembourg	1	1	26	11
Canada	576	279	1,038	478
Chile	18	22	13	40
Colombia	--	--	3	6
Dominican Republic	51	27	71	78
El Salvador	6	13	88	68
Ecuador	14	8	6	3
France	(2)	1	136	51
Germany, Federal Republic of	23	15	78	63
Honduras	4	4	5	6
India	3	19	49	30
Israel	20	19	38	53
Italy	83	50	79	58
Jamaica	21	12	--	--
Japan	101	126	88	167
Korea, Republic of	31	27	93	111
Mexico	1,005	542	163	107
Netherlands	--	--	22	14
Netherlands Antilles	1	2	42	29
Paraguay	6	2	3	2
Philippines	69	49	63	40
Sweden	66	43	86	58
Taiwan	8	11	227	147
Thailand	25	11	26	15
Trinidad and Tobago	1	1	11	12
U.S.S.R	78	143	--	--
United Kingdom	50	89	1,452	1,096
Venezuela	405	220	663	323
Other	r135	r110	92	163
Total	2,850	1,868	4,686	3,245
Wrought lead and lead alloys:				
Australia	24	123	29	52
Austria	13	20	13	16
Belgium-Luxembourg	607	171	1,865	443
Brazil	(2)	26	7	9
Canada	1,088	636	1,724	1,450
Colombia	2	4	8	11
Costa Rica	12	114	29	204
Dominican Republic	16	63	32	72
Ecuador	40	38	54	67
El Salvador	10	28	55	55
Finland	19	23	26	24
France	48	79	105	206
Germany, Federal Republic of	29	139	97	72
Honduras	137	123	58	72
Hong Kong	(2)	4	68	67
Italy	32	35	48	71
Japan	46	166	36	99
Korea, Republic of	99	53	4	18
Leeward and Windward Islands	49	51	--	--
Mexico	165	407	126	393
Netherlands	32	18	49	99
Norway	7	52	35	264
Panama	27	67	37	179
Philippines	19	49	56	103
Saudi Arabia	31	36	29	55
Spain	40	42	34	89
Sweden	24	35	26	53
Taiwan	95	228	52	85
United Kingdom	58	120	146	275
Venezuela	97	154	127	203
Other	r161	r348	184	374
Total	3,027	3,452	5,159	5,180

See footnotes at end of table.

Table 25.—U.S. exports of lead, by country[1] —Continued

Destination	1976 Quantity (short tons)	1976 Value (thousands)	1977 Quantity (short tons)	1977 Value (thousands)
Scrap:				
Belgium-Luxembourg	993	$402	732	$168
Brazil	3,768	860	5,384	1,604
Canada	15,804	2,679	26,715	5,125
Colombia	438	102	381	91
Denmark	1,798	661	1,080	687
Germany, Federal Republic of	2,877	714	11,535	3,554
Hong Kong	39	8	80	52
Italy	1,819	470	291	228
Japan	1,512	691	2,387	1,070
Korea, Republic of	3,208	1,259	8,389	1,833
Mexico	2,833	493	6,367	984
Netherlands	344	187	3,188	1,241
South Africa, Republic of	--	--	2,420	479
Spain	815	205	405	165
Sweden	6	1	338	204
Switzerland	11	18	138	59
Taiwan	4,671	1,007	6,907	1,629
Thailand	--	--	15	17
Turkey	--	--	952	358
United Kingdom	945	470	1,605	1,089
Venezuela	4,805	1,209	4,706	1,183
Yugoslavia	--	--	1,336	586
Other	197	103	60	36
Total	46,883	11,539	85,411	22,442
Grand total	52,760	16,859	95,256	30,867

[r]Revised.
[1]In addition foreign lead was reexported as follows: 1975—Unwrought lead and lead alloys, 213 tons ($12,770); wrought lead and lead alloys, 18 tons ($15,388) and 1976—Unwrought lead and lead alloys, 859 tons ($793,941); wrought lead and lead alloys, 12 tons ($11,724).
[2]Less than 1/2 unit.

Table 26.—U.S. exports of lead, by class

Year	Blocks, pigs, anodes, etc.				Wrought lead and lead alloys				Scrap	
	Unwrought		Unwrought alloys		Sheets, plates, rods, other forms		Foil, powder, flakes			
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
1975	17,455	$7,361	933	$989	2,695	$3,306	173	$385	49,951	$10,063
1976	2,226	1,307	624	561	2,735	2,927	292	525	46,883	11,539
1977	2,025	1,243	2,661	2,002	4,847	4,335	312	845	85,411	22,442

Table 27.—U.S. imports[1] of lead, by country

Country	1975 Quantity (short tons)	1975 Value (thousands)	1976 Quantity (short tons)	1976 Value (thousands)	1977 Quantity (short tons)	1977 Value (thousands)
Ore, flue dust, and residues, n.s.p.f. (lead content):						
Australia	15,916	$4,979	11,215	$3,316	18,289	$8,894
Bolivia	--	--	--	--	902	147
Canada	28,949	8,618	27,673	8,604	17,670	7,400
Colombia	112	42	226	68	146	71
Greenland	6,552	2,031	5,104	1,582	--	--
Honduras	19,153	5,638	22,028	9,219	26,169	13,813
Mexico	--	--	92	28	1,146	206
Nicaragua	1,182	509	762	323	1,746	972
Peru	15,696	5,328	9,263	2,422	7,272	3,158
Other	--	--	2	([2])	--	--
Total	87,560	27,145	76,365	25,562	73,340	34,661
Base bullion (lead content):						
Belgium-Luxembourg	19	7	72	37	110	62
Canada	65	31	730	360	494	291
Germany, Federal Republic of	--	--	--	--	5	23
Mexico	378	145	1,532	558	4,744	2,368
Morocco	--	--	--	--	1,098	561
Peru	--	--	--	--	110	70
South-West Africa, Territory of	--	--	--	--	1,507	869
Total	462	183	2,334	955	8,068	4,244
Pigs and bars (lead content):						
Australia	--	--	[3]6,123	[3]2,389	21,891	12,540
Belgium-Luxembourg	2,058	1,141	168	93	7,615	5,006
Burma	--	--	--	--	167	79
Canada	30,688	14,659	47,612	21,660	83,154	51,749
China, People's Republic of	28	111	--	--	--	--
Denmark	420	450	429	627	193	221
France	29	29	33	27	1,078	544
Germany, Federal Republic of	2,614	1,359	10	54	20,644	12,495
Japan	78	279	3	5	349	271
Mexico	29,637	11,400	44,290	17,090	79,123	44,182
Morocco	--	--	2,756	861	--	--
Netherlands	535	701	2,221	721	110	54
New Zealand	41	21	--	--	--	--
Peru	19,876	9,022	19,733	7,877	33,546	18,674
South Africa, Republic of	--	--	84	20	2,602	1,273
South-West Africa, Territory of	1,120	549	--	--	--	--
Spain	119	162	93	217	--	--
Thailand	437	1,609	408	1,447	275	1,397
United Kingdom	2,638	2,621	2,022	2,352	2,850	2,444
Yugoslavia	10,181	3,054	19,944	6,576	7,594	3,576
Zambia	--	--	--	--	82	39
Other	12	39	3	2	--	--
Total	100,511	47,206	[3]145,932	[3]62,018	261,273	154,544
Reclaimed scrap, etc. (lead content):						
Australia	3,652	1,429	1,943	577	2,935	1,294
Bahamas	20	4	3	1	16	3
Canada	829	259	990	402	2,467	1,226
Germany, Federal Republic of	58	41	70	31	1,098	569
Gilbert Islands	--	--	223	53	--	--
Jamaica	35	8	73	33	49	7
Mexico	735	224	156	56	137	69
Netherlands Antilles	--	--	--	--	49	25
Peru	--	--	901	360	--	--
United Kingdom	35	72	10	25	--	--
Other	1	3	44	12	18	19
Total	5,365	2,040	4,413	1,550	6,769	3,212
Grand total	193,898	76,574	229,044	90,085	349,450	196,661

[1]Data are "general imports;" that is, they include lead imported for immediate consumption plus material entering the country under bond.
[2]Less than 1/2 unit.
[3]Adjusted by Bureau of Mines.

Table 28.—U.S. imports for consumption of lead, by country

Country	1975 Quantity (short tons)	1975 Value (thousands)	1976 Quantity (short tons)	1976 Value (thousands)	1977 Quantity (short tons)	1977 Value (thousands)
Ore, flue dust, and residues, n.s.p.f. (lead content):						
Argentina	4	$1	--	--	--	--
Australia	8,407	2,113	15,312	$4,390	14,621	$5,508
Bolivia	--	--	--	--	902	422
Canada	14,878	3,521	8,556	2,471	9,591	2,812
Colombia	233	56	225	68	306	126
Honduras	7,438	2,330	25,624	10,704	41,798	18,408
Ireland	85	14	--	--	--	--
Japan	--	--	4,449	845	--	--
Mexico	--	--	8,661	3,290	5,952	2,273
Nicaragua	1,381	431	1,781	672	5,248	2,529
Peru	12,598	3,863	24,378	7,052	19,444	7,734
Other	--	--	2	(1)	--	--
Total	45,024	12,329	88,988	29,492	97,862	39,812
Base bullion (lead content):						
Belgium-Luxembourg	19	7	72	37	110	62
Canada	65	31	730	360	494	291
Germany, Federal Republic of	--	--	--	--	5	23
Mexico	378	145	1,532	558	4,744	2,368
Morocco	--	--	--	--	1,098	561
Peru	--	--	--	--	110	70
South-West Africa, Territory of	--	--	--	--	1,507	869
Total	462	183	2,334	955	8,068	4,244
Pigs and bars (lead content):						
Australia	--	--	1,624	442	14,226	7,414
Belgium-Luxembourg	2,058	1,141	168	93	7,615	5,006
Burma	--	--	--	--	167	79
Canada	30,688	14,659	47,612	21,660	83,154	51,749
China, People's Republic of	28	111	--	--	--	--
Denmark	420	450	429	627	193	221
France	29	29	33	27	1,078	544
Germany, Federal Republic of	2,613	1,357	10	54	20,644	12,495
Japan	78	279	3	5	349	271
Mexico	28,728	11,073	44,290	17,090	79,123	44,183
Netherlands	535	701	2,221	721	110	54
New Zealand	41	21	--	--	--	--
Peru	19,876	9,022	19,733	7,877	33,546	18,674
South Africa, Republic of	--	--	84	20	2,602	1,273
South-West Africa, Territory of	1,120	549	--	--	--	--
Spain	119	162	93	217	--	--
Thailand	437	1,609	408	1,447	275	1,397
United Kingdom	2,638	2,621	2,022	2,352	2,850	2,444
Yugoslavia	9,634	2,880	20,491	6,749	7,594	3,576
Other	12	39	2,759	864	82	39
Total	99,054	46,703	141,980	60,245	253,608	149,419
Reclaimed scrap, etc. (lead content):						
Australia	16	6	--	--	50	17
Bahamas	20	4	3	1	16	3
Canada	921	280	990	402	2,467	1,226
Germany, Federal Republic of	58	41	70	31	1,098	569
Gilbert Islands	--	--	223	53	--	--
Jamacia	35	8	73	33	49	7
Mexico	655	203	330	105	137	69
Netherlands Antilles	--	--	--	--	49	25
Peru	--	--	901	360	--	--
United Kingdom	35	72	10	25	--	--
Other	1	3	44	12	18	19
Total	1,741	617	2,644	1,022	3,884	1,935

See footnotes at end of table.

Table 28.—U.S. imports for consumption of lead, by country —Continued

Country	1975		1976		1977	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Sheets, pipe, shot:						
Canada	52	$54	113	$130	676	$465
Denmark	--	--	19	56	57	232
Germany, Federal Republic of	21	28	38	48	48	50
Japan	--	--	--	--	5	13
Mexico	72	12	20	10	22	18
Spain	--	--	65	205	149	636
United Kingdom	2	5	26	39	23	100
Other	--	--	13	7	(1)	2
Total	147	99	294	495	980	1,516
Grand total	146,428	59,931	236,240	92,209	364,402	196,926

[1]Less than 1/2 unit.

Table 29.—U.S. imports for consumption of lead, by class

(Thousand short tons and thousand dollars)

Year	Ore (lead content)		Base bullion (lead content)		Pigs and bars (lead content)		Sheets, plates, strip, other forms	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1975	45	12,329	(1)	183	99	46,703	(1)	91
1976	89	29,492	2	955	142	60,245	(1)	484
1977	98	39,483	8	4,244	252	148,746	1	1,516

Year	Waste and scrap (lead content)		Dross, skimmings, residues, n.s.p.f. (lead content)		Powder and flakes		Total value
	Quantity	Value	Quantity	Value	Quantity	Value	
1975	1	411	(1)	206	(1)	8	59,931
1976	2	821	(1)	201	(1)	11	92,209
1977	3	1,769	(1)	166	(1)	183	196,107

[1]Less than 1/2 unit.

Table 30.—U.S. imports for consumption of miscellaneous products containing lead[1]

Year	Gross weight (short tons)	Lead content (short tons)	Value (thousands)
1975	744	322	$3,575
1976	452	175	1,749
1977	664	283	3,586

[1]Babbitt metal, solder, white metal, and other lead-containing combinations.

Table 31.—Lead: World mine production, by country

(Short tons)

Country[1]	1975	1976	1977[p]
North America:			
Canada	[r]384,853	282,549	313,187
Guatemala	[e]110	[e]110	[2]140
Honduras	25,643	20,492	25,946
Mexico[3]	196,889	220,492	180,205
Nicaragua	1,565	1,403	1,054
United States[4]	621,464	609,546	592,491
South America:			
Argentina	[r]33,116	36,126	36,454
Bolivia	[5]15,755	18,043	20,328
Brazil	24,653	24,929	[e]23,100
Chile	341	2,002	870
Colombia	126	[e]120	126
Ecuador	131	[e]120	237
Peru[4 6]	[r]203,365	176,103	183,058
Europe:			
Austria[4]	[r]5,271	4,820	4,731
Bulgaria	[r]125,663	129,500	126,766
Czechoslovakia	[r]4,525	4,612	[e]4,630
Finland	1,024	1,247	692
France	23,920	30,975	34,833
German Democratic Republic	4,400	4,400	--
Germany, Federal Republic of	35,696	34,916	34,287
Greece	14,202	32,796	19,180
Greenland	26,800	29,750	31,750
Hungary[e]	[r]1,000	[r]1,000	1,900
Ireland	40,010	35,935	45,195
Italy	[r]32,518	32,298	33,951
Norway	3,559	4,303	3,676
Poland[e]	71,700	[r]66,100	60,500
Romania	43,000	46,848	46,297
Spain	64,505	68,561	67,749
Sweden	77,584	89,976	97,149
U.S.S.R.[e]	[r]530,000	[r]550,000	560,000
United Kingdom	[r]7,054	7,826	[e]7,700
Yugoslavia	139,879	134,995	151,300
Africa:			
Algeria	[r]3,527	2,315	990
Congo	2,201	2,300	[e]2,300
Kenya	22	[e]22	--
Morocco	70,150	66,357	102,968
Nigeria[e]	140	140	56
South Africa, Republic of	2,981	--	--
South-West Africa, Territory of[7 e]	[r]58,500	51,100	45,400
Tunisia	[r]14,268	11,424	10,022
Zambia [2]	[r]21,050	14,880	14,660
Asia:			
Burma[e]	11,570	[r]7,830	9,800
China, People's Republic of[e]	110,000	110,000	110,000
India	12,247	14,683	15,900
Iran	[r]55,100	33,600	44,000
Japan[8]	55,739	56,952	60,367
Korea, North[e]	130,000	130,000	120,000
Korea, Republic of	13,409	16,020	18,245
Philippines	3,735	4,993	6,436
Thailand	1,690	996	557
Turkey	[r]7,114	5,430	9,610
Oceania: Australia	[r]449,523	440,183	478,012
Total	[r]3,783,287	3,677,118	3,758,805

[e]Estimate. [p]Preliminary. [r]Revised.

[1]In addition to the countries listed, Uganda and Egypt may produce lead, but available information is inadequate to make estimates.

[2]Smelter production, believed to closely approximate mine output, which is unreported.

[3]Recoverable metal content of lead in concentrates for export plus lead content of domestic products (refined lead, antimonial lead, mixed bars, and other unspecified items).

[4]Recoverable metal.

[5]Production by COMIBOL plus exports by medium, small, and other exporters (excluding COMIBOL exports).

[6]Recoverable content of lead in concentrates for export plus lead content of domestic smelter products (refined lead, antimonial lead, and bismuth-lead bars).

[7]Series revised to reflect estimated calendar output of all producers.

[8]Content of concentrates.

Table 32.—Lead: World smelter production,[1] by country

(Short tons)

Country	1975	1976	1977[p]
North America:			
Canada (refined)	[r]189,063	193,698	206,636
Guatemala[2]	248	121	140
Mexico[2 3]	190,620	209,142	169,698
United States (refined)	636,122	652,877	604,838
South America:			
Argentina	[r]39,700	41,900	49,600
Brazil	41,381	48,140	53,245
Peru[4]	[r]78,422	78,397	87,507
Europe:			
Austria[5]	10,320	8,928	8,050
Belgium[6]	[r]113,500	115,100	114,800
Bulgaria[2]	[r]121,000	124,000	[e]124,000
Czechoslovakia[2]	20,334	21,071	[e]22,000
France	149,233	175,758	190,371
German Democratic Republic[e]	22,000	22,000	22,000
Germany, Federal Republic of	101,679	111,295	115,908
Greece (refined)[2 5]	[r]17,925	20,604	22,487
Hungary[e]	[r]550	2,100	2,200
Italy	36,593	50,721	37,716
Netherlands	26,389	24,130	23,294
Poland (refined)[2]	84,000	88,800	94,100
Portugal (refined)[2]	[r]1,788	1,504	911
Romania[e 2]	43,000	46,300	49,600
Spain	[r]81,456	83,244	98,296
Sweden (refined)	42,265	54,088	57,265
U.S.S.R.[e]	530,000	550,000	560,000
United Kingdom[7]	28,328	18,190	38,597
Yugoslavia (refined)[2]	139,000	122,599	143,179
Africa:			
Morocco	7,716	29,078	38,140
South-West Africa, Territory of (refined)	48,801	43,651	47,069
Tunisia	[r]26,124	25,904	21,718
Zambia (refined)	21,054	14,973	14,450
Asia:			
Burma	[r]10,973	3,672	4,955
China, People's Republic of[e]	110,000	110,000	110,000
India	5,257	5,991	8,364
Iran[e]	330	330	330
Japan	214,087	241,464	244,049
Korea, North[e 2]	90,000	80,000	80,000
Korea, Republic of[2]	6,326	8,556	7,432
Thailand	1,041	909	1,302
Turkey	3,300	3,500	3,300
Oceania: Australia (refined and bullion)[8]	343,163	378,138	369,241
Total	[r]3,633,088	3,810,873	3,846,788

[e]Estimate. [p]Preliminary. [r]Revised.

[1]Primary except as noted. Output of countries with parenthetical note "refined" may have produced a part of the quantity listed from imported bullion.

[2]Includes secondary, if any is produced.

[3]Lead content of refined lead, antimonial lead, and impure bars.

[4]Lead content of refined lead and antimonial lead bars.

[5]Lead content of refined lead plus gross weight of antimonial lead.

[6]Primary soft lead alloy; excludes any primary lead in antimonial lead.

[7]Bullion only; output of refined lead from imported bullion was as follows in short tons: 1975—129,956; 1976—145,678; 1977—153,942.

[8]Of the totals reported, the following quantities in short tons were refined lead (the balance being base bullion): 1975—171,141; 1976—200,555; 1977—198,150.

Table 33.—Lead: World secondary smelter production, by country[1]

(Short tons)

Country	1975	1976	1977[p]
North America:			
Canada[e]	39,000	40,000	42,000
United States	658,456	726,569	835,102
Europe:			
Austria	6,370	8,387	11,713
Belgium-Luxembourg[e 2]	4,400	7,400	6,700
France	16,936	14,325	12,564
German Democratic Republic[e]	18,000	18,000	19,000
Germany, Federal Republic of	185,104	195,484	225,386
Hungary[e]	13,800	12,200	13,200
Italy	62,600	79,600	92,000
Netherlands[e]	36,000	39,000	39,000
Spain	7,071	[e]7,200	[e]7,200
Sweden	365	371	88
U.S.S.R.[e]	105,000	110,000	110,000
United Kingdom[3]	136,022	131,518	137,514
Asia: Japan[4]	46,357	67,060	62,276
Oceania: Australia	37,100	34,800	41,600
Total	1,372,581	1,491,914	1,655,343

[e]Estimate. [p]Preliminary. NA Not available.

[1]Totals presented are incomplete; for the following countries not listed in this table, secondary production is included with primary production because there is no reliable source nor reasonable basis for estimating the proportional total output reclaimed from scrap: Guatemala, Mexico, Bulgaria, Czechoslovakia, Greece, Poland, Portugal, Romania, Yugoslavia, the People's Republic of China, North Korea, and the Republic of Korea. Moreover, the following countries, for which only primary lead production is reported may have also produced some secondary lead: Brazil, India, Iran, and Turkey.

[2]Figures represent lead content of antimonial lead; a small part of each total may be of primary rather than secondary origin.

[3]Secondary refined soft lead only; excludes lead content of secondary antimonial lead produced.

[4]Excludes material identified as remelted lead in Japanese sources; this total is, in short tons: 1975—53,364, 1976—NA, and 1977—NA.

Lime

By J. W. Pressler[1]

Lime output in 1977, including that for Puerto Rico, decreased 1% to 20 million tons. Total value established a new annual record, increasing 9% to $669 million.

Output of most types of lime decreased. Agricultural lime was down 33%; refractory dolomite, 4%; and chemical and industrial lime, 1%. Output of construction lime increased 3%.

Table 1.—Salient lime statistics in the United States[1]

(Thousand short tons and thousand dollars)

	1973	1974	1975	1976	1977
Number of plants	175	172	171	163	161
Sold or used by producers:					
Quicklime	17,230	17,795	15,875	16,924	16,281
Hydrated lime	2,610	2,533	2,344	2,298	2,698
Dead-burned dolomite	1,250	1,278	914	1,007	968
Total	21,090	21,606	19,133	20,229	19,947
Value[2]	$365,849	$473,685	$523,805	$609,010	$666,472
Average value per ton	$17.35	$21.92	$27.38	$30.11	$33.41
Lime sold	14,394	14,640	12,840	14,024	14,202
Lime used	6,696	6,966	6,292	6,205	5,745
Exports[3]	37	32	54	56	33
Imports for consumption[3]	334	416	259	365	423

[1]Excludes regenerated lime. Excludes Puerto Rico.
[2]Selling value, f.o.b. plant, excluding cost of containers.
[3]Bureau of the Census.

DOMESTIC PRODUCTION

Lime producers sold or used 20 million tons, compared with 20.3 million tons in 1976. Sales of lime increased 1% to 14.2 million tons. Captive lime used by producers declined for the third successive year as a result of the depressed conditions in the steel industry, with a 7% reduction in 1977 to 5.7 million tons, the lowest since 1963, and a 21% decrease from the record year of 1971.

Output of quicklime decreased 4% to 16.3 million tons. Production of hydrated lime increased 18% to 2.7 million tons. Output of dead-burned dolomite decreased 4%, 60% below the 1956 record level of 2.4 million tons.

Six States (Ohio, Pennsylvania, Missouri, Texas, Michigan, and Alabama) accounted for 55% of the total output. Production increased 14% in Alabama and 11% in Texas, remained about the same in Missouri, and decreased 16% in Ohio, 7% in Michigan, and 3% in Pennsylvania.

Leading producing companies were Marblehead Lime Co. with two plants in Illinois and one each in Indiana, Michigan, Pennsylvania, and Utah; Mississippi Lime Co. in Missouri; Bethlehem Steel Corp. with two plants in Pennsylvania and one in New York; Allied Chemical Corp. in New York; Martin Marietta Corp.'s Chemical Division in Alabama and Ohio; The Flintkote Co. with two plants in California, two in Nevada, and one each in Arizona, Utah, and

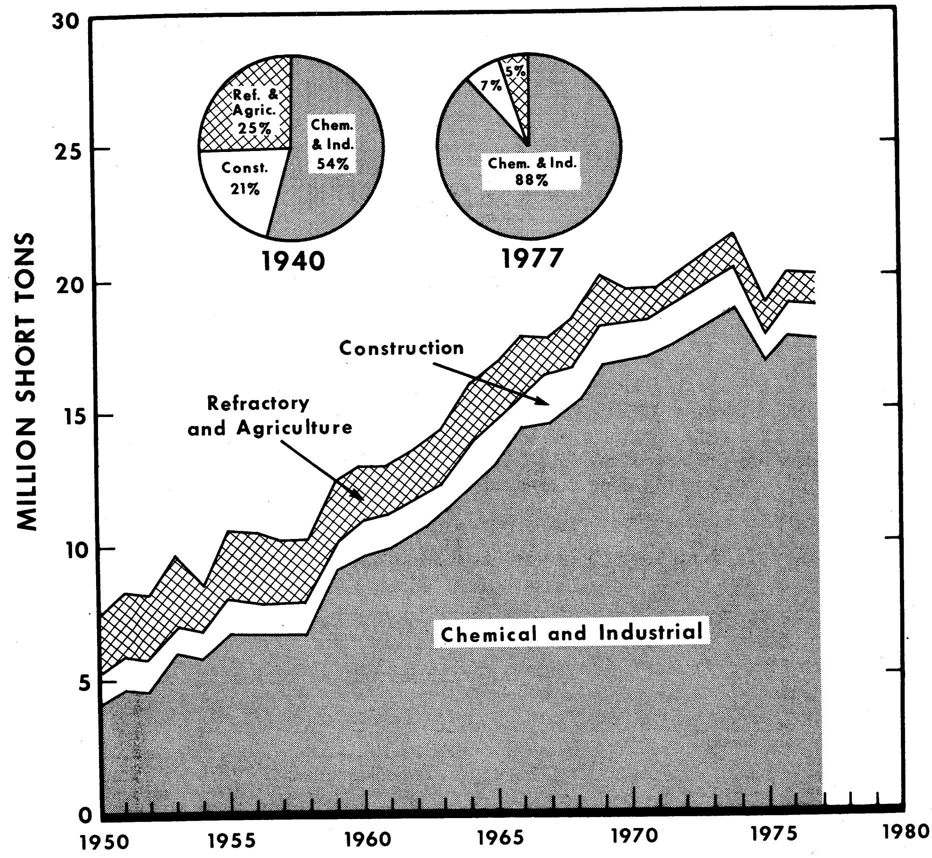


Figure 1.—Trends in major uses of lime.

Virginia; United States Gypsum Co. in Louisiana, Ohio, and Texas; Allied Products Co. with two plants in Alabama; Black River Mining Co. in Kentucky; and Pfizer, Inc., in California, Connecticut, Massachusetts, and Ohio. These 10 companies, operating 30 plants, accounted for 43% of the total lime production.

The eight largest lime plants, each producing more than 400,000 tons, accounted for 27% of the total lime output. Thirty-six plants produced more than 200,000 tons and accounted for 65% of the total.

Leading individual plants were Mississippi Lime's Ste. Genevieve plant, Allied Chemical's Syracuse plant, Marblehead's Buffington plant, Martin Marietta's Woodville plant, and Black River Mining's Carntown plant.

A total of 483 kilns were operational during the year: 251 vertical kilns, 179 rotary kilns, 27 pot kilns (primitive vertical), 15 Calcimatic traveling-hearth kilns, 6 fluidized-bed kilns, 4 Ellernan kilns, and 1 traveling-grate rotary kiln. Hydrators for the production of hydrated lime totaled 117 during the year; 23 were of the batch type and 94 were of the continuous type.

In 1977, the number of lime plants in the United States decreased from 164 to 162, and the average output per plant decreased slightly from 123,500 to 123,400 tons per year. The Dow Chemical Co.'s Freeport plant in Brazoria County, Tex., and Weatherly & Morrison Lime Co.'s McGill plant in White Pine County, Nev., were closed and reported no production in 1977.

New Plants and Expansions.—Dixie Lime & Stone Co., a subsidiary of Rosario Resources Corp., planned to complete a $5 million, 300-ton-per-day kiln expansion at its Sumterville plant in Sumter County, Fla., by yearend 1977. Addition of a second kiln will raise the plant's quicklime capaci-

Table 2.—Lime sold or used by producers in the United States, by State and kind[1]

(Thousand short tons and thousand dollars)

State	1976					1977				
	Plants	Hydrated	Quicklime	Total[2]	Value	Plants	Hydrated	Quicklime	Total[2]	Value
Alabama	5	149	860	1,009	32,753	5	165	985	1,149	39,213
Arizona	6	W	W	546	16,115	6	--	474	474	15,528
Arkansas	3	W	W	182	4,900	3	W	W	152	4,552
California	15	47	591	638	23,324	14	47	551	598	24,074
Colorado	10	W	W	185	4,406	10	W	W	180	5,413
Connecticut	1	12	12	24	1,103	1	12	17	29	1,412
Florida	3	W	W	179	7,798	3	W	W	165	7,350
Hawaii, Idaho, Nevada, Oregon, Washington, Wyoming	17	105	556	661	20,892	15	116	493	609	23,270
Illinois and Indiana	5	86	2,087	2,173	61,313	5	81	2,056	2,137	61,850
Iowa, Kansas, Nebraska, North Dakota, South Dakota,	9	53	232	285	7,889	9	50	233	283	9,036
Kentucky, Tennessee, West Virginia	4	50	475	525	15,536	6	45	774	819	27,901
Louisiana, New Mexico, Oklahoma,	5	128	352	480	13,133	5	113	323	437	14,811
Maryland	1	5	11	16	494	1	5	9	14	449
Massachusetts	2	16	162	178	6,354	2	15	171	187	7,215
Michigan	9	--	1,456	1,456	39,686	9	--	1,347	1,347	42,015
Minnesota	4	--	103	103	2,794	4	--	123	123	4,315
Mississippi	1	--	57	57	1,248	1	--	49	49	1,079
Missouri	3	W	W	1,731	49,907	3	W	W	1,723	51,529
Montana	3	--	224	224	5,980	3	--	223	223	7,705
New Jersey and New York	3	(3)	857	857	23,841	3	18	981	998	33,537
Ohio	17	169	3,619	3,788	114,299	16	163	3,035	3,199	111,100
Pennsylvania	10	340	1,729	2,069	68,356	10	328	1,679	2,007	72,591
Puerto Rico	1	28	(3)	28	2,513	1	38	2	40	3,007
Texas	12	605	850	1,455	43,983	11	932	680	1,612	49,965
Utah	4	W	W	202	6,855	4	W	W	209	8,274
Virginia	r6	53	824	878	25,993	7	97	749	846	28,767
Wisconsin	5	120	206	325	10,058	5	150	228	378	13,521
Other[4]	(5)	360	2,666	(5)	(5)	(5)	361	2,068	(5)	(5)
Total[2]	164	2,326	17,930	20,257	611,523	162	2,736	17,251	19,987	669,479

[r]Revised. W Withheld to avoid disclosing company proprietary data; included in "Other."
[1]Excludes regenerated lime. Includes Puerto Rico.
[2]Data may not add to totals shown because of independent rounding.
[3]Less than 1/2 unit.
[4]Includes States indicated by symbol W and exports.
[5]Included with data for each individual State.

Table 3.—Lime sold or used by producers in the United States, by size of plant[1]

(Thousand short tons)

Size of plant	1976			1977		
	Plants	Quantity	Percent of total	Plants	Quantity	Percent of total
Less than 10,000 tons	24	128	1	22	124	1
10,000 to 25,000 tons	27	464	2	27	462	2
25,000 to 50,000 tons	27	954	5	32	1,158	6
50,000 to 100,000 tons	26	1,835	9	21	1,575	8
100,000 to 200,000 tons	26	3,982	20	24	3,649	18
200,000 to 400,000 tons	26	7,576	37	28	7,640	38
More than 400,000 tons	8	5,319	26	8	5,378	27
Total	164	[2]20,257	100	162	[2]19,987	100

[1]Excludes regenerated lime. Includes Puerto Rico.
[2]Data do not add to totals shown because of independent rounding.

ty to 500 tons per day. Further development and preliminary engineering were reported for a third kiln to be installed, which would bring the total capacity to 1,000 tons per day.[2]

Allied Products Co.'s expansion program at its Montevallo, Ala., plant was scheduled to be completed by yearend 1977. The addition of an Allis-Chalmers 11-1/2- by 350-foot rotary kiln will increase production capacity by 700 tons per day of quicklime.[3]

The U.S. Lime Division of The Flintkote Co. was on schedule in the expansion of its lime plant at Nelson, Ariz., to be onstream by mid-1978. The project included installation of a Kennedy Van Saun 1,000-ton-per-day rotary kiln and related equipment at a cost of $25 million. After completion of the expansion project, total capacity will be 1,800 tons per day of high-calcium lime, making the operation one of the largest suppliers in the United States.[4]

A third Calcimatic lime kiln was being installed in the Portland, Oreg., plant of Ash Grove Cement Co. and was scheduled to be onstream at yearend 1978. This installation will double the capacity of the plant to 150,000 tons per year of quicklime.[5]

Detroit Lime Co. initiated a 1,000-ton-per-day expansion program for its River Rouge plant in Detroit, Mich. The new system will include a Kennedy Van Saun Polygon preheater, rotary kiln, and contact cooler, all fired with pulverized coal. Completion was scheduled for early 1979.[6]

Rangaire Corp. of Cleburne, Tex., initiated a $4 million program to expand two of its lime plant facilities—one in Cleburne and the other in Batesville, Ark. The third rotary kiln added to the Cleburne facilities measures 11-1/2 by 300 feet, and is Texas' largest lime kiln. Its production capacity will be 500 tons per day of quicklime, which will boost the firm's area capacity to 1,200 tons per day. Completion of the program is scheduled for yearend 1978.[7]

Energy.—The lime industry in 1977 made considerable progress in efficient utilization of energy by adding preheaters to kilns and by improving the internal agitation in the kilns. These changes resulted in a 7.8% reduction in energy consumption compared with the base year of 1972. British thermal unit (Btu) consumption per ton of lime produced through the first half of 1977 was 7.43 million, compared with 7.79 million in 1976.

As reported by the National Lime Association, fuel sources for the lime industry through the first half of 1977 were coal and coke, 58.0%; natural gas, 29.7%; oil (No. 2 and No. 6), 9.9%; and electricity, 2.2%. Compared with the base year of 1972, significant improvements were made in 1977 with a 44% reduction in the use of scarce natural gas and a 106% increase in the use of coal and coke.[8]

CONSUMPTION AND USES

Lime was consumed in every State. Leading consuming States were Ohio, Pennsylvania, Michigan, Indiana, Texas, New York, and Illinois, each of which consumed more than 1 million tons. These seven States accounted for 61% of the total lime consumed.

The depressed condition of the steel industry in 1977 led to a decline of 3% in lime consumption for basic oxygen furnace (BOF), open-hearth, and electric steel manufacturing, compared with that of 1976. Record housing and building starts caused a 13% increase in the sales of mason's and finishing lime, making 1976 the best year since 1973.

Leading quicklime-consuming States were Ohio, Pennsylvania, Michigan, Indiana, and New York, each of which consumed more than 1 million tons. These five States accounted for 52% of the total quicklime consumed.

Leading hydrate-consuming States were Texas, Pennsylvania, Louisiana, and Ohio, each of which consumed more than 100,000 tons. These four States accounted for 49% of the total hydrate consumed.

Lime sold by producers was utilized for chemical and industrial uses, 84%; construction, 9%; refractories, 6%; and agriculture, 1%. Captive lime used by producers was 29% of the total, compared with 31% in 1976. Captive lime was used mainly in the production of alkalies, 30%; BOF steel, 29%; and sugar, 15%.

Leading individual uses were for BOF steel, alkalies, water purification, paper and pulp, refractories, and sugar refining, which together accounted for 67% of the total consumption.

Of the main chemical and industrial uses, lime for BOF's was produced principally in Ohio (25%), Indiana and Illinois (combined, 26%), and Pennsylvania (14%). Lime for alkalies was produced mainly in Michigan, New York, and Texas. Lime for water purification was produced mainly in Missouri (28%), Pennsylvania (15%), Texas (13%), and Alabama (8%). Lime used for paper and pulp, excluding regenerated lime, was produced mainly in Alabama (37%), Wisconsin (12%), Virginia (11%), and Texas (8%). Lime for refining sugar was produced mainly in California (22%) and Idaho and Minnesota (combined, 26%).

Mason's lime was produced at 33 plants in 17 States, including Puerto Rico; leading States were Wisconsin (21%) and Pennsylvania (19%) with four plants each. Finishing lime was produced in 11 States at 15 plants; the leading State was Ohio with three plants (49%).

The use of lime in agriculture has decreased from 250,000 tons per year in 1956 to 91,000 tons per year in 1977, indicating a negative annual growth rate of about 4.5%. The attainment of maximum fertilizer utilization and the high cost of energy-intensive lime, compared with that of pulverized limestone, for controlling the adverse acid condition of soil have diverted farmers to the use of the cheaper commodity, even though its reactivity response is considerably less. The use of crushed and pulverized limestone in agriculture has increased from 20 million tons per year in 1956 to about 39 million tons per year in 1977, a growth rate of 2.0% per year.

Table 4.—Destination of shipments of lime sold or used by producers in the United States in 1977, by State[1]

(Thousand short tons)

State	Quicklime	Hydrated lime	Total[2]
Alabama	531	86	616
Alaska	W	W	2
Arizona	391	17	408
Arkansas	154	23	176
California	762	95	857
Colorado	250	19	269
Connecticut	43	12	55
Delaware	14	4	18
District of Columbia	W	W	4
Florida	320	48	368
Georgia	197	32	228
Hawaii	W	W	4
Idaho	131	7	137
Illinois	937	94	1,031
Indiana	1,793	71	1,865
Iowa	72	21	93
Kansas	87	19	107
Kentucky	370	17	387
Louisiana	175	110	285
Maine	W	W	30
Maryland	474	18	492
Massachusetts	58	13	72
Michigan	1,835	41	1,876
Minnesota	239	23	263
Mississippi	134	20	154
Missouri	164	49	213
Montana	W	W	228
Nebraska	62	8	70
Nevada	14	11	25
New Hampshire	W	W	12
New Jersey	71	54	125
New Mexico	91	5	96
New York	1,090	42	1,131
North Carolina	151	31	181
North Dakota	W	W	45
Ohio	2,311	107	2,418
Oklahoma	104	42	146
Oregon	93	15	108
Pennsylvania	1,959	270	2,229
Rhode Island	W	W	7
South Carolina	86	21	107
South Dakota	9	17	26
Tennessee	134	58	192
Texas	902	766	1,667
Utah	101	27	128
Vermont	W	W	9
Virginia	188	27	216
Washington	132	23	155
West Virginia	322	29	351
Wisconsin	128	56	184
Wyoming	39	8	47
Other States[3]	297	75	42
Total United States[2]	17,420	2,531	19,951
Exports:			
Canada	15	10	25
Other countries	7	4	11
Total exports	22	14	36
Grand total	17,442	2,545	19,987

W Withheld to avoid disclosing company proprietary data; included in "Other States."
[1]Excludes regenerated lime. Includes Puerto Rico.
[2]Data may not add to totals shown because of independent rounding.
[3]Includes Puerto Rico, the Virgin Islands, and States indicated by symbol W.

Table 5.—Lime sold or used by producers in the United States, by use[1]

(Thousand short tons and thousand dollars)

Use	1976				1977			
	Sold	Used	Total[2]	Value	Sold	Used	Total[2]	Value
Agriculture	136	--	136	4,759	91	--	91	3,124
Construction:								
Soil stabilization	742	([3])	743	24,597	710	([3])	710	26,118
Mason's lime	351	1	351	11,616	345	41	386	14,204
Finishing lime	132	--	132	4,363	159	--	159	5,854
Other construction uses	35	35	70	2,310	36	42	78	2,878
Total[2]	1,260	35	1,295	42,886	1,251	83	1,334	49,054
Chemical and industrial:								
Steel, BOF	5,800	1,618	7,418	219,306	5,319	1,638	6,958	229,103
Alkalies	7	2,072	2,078	61,434	12	1,746	1,758	57,883
Water purification	1,515	8	1,523	45,026	1,645	7	1,652	54,393
Paper and pulp	946	108	1,054	31,160	1,098	59	1,157	38,094
Sugar refining	76	909	985	29,121	67	849	916	30,159
Steel, electric	707	71	778	23,001	754	89	843	27,755
Copper ore concentration	386	284	670	19,808	327	309	636	20,939
Sewage treatment	548	90	638	18,862	587	26	613	20,182
Steel, open-hearth	340	83	423	12,506	543	38	581	19,128
Aluminum and bauxite	143	152	296	8,751	156	108	264	8,691
Magnesia from seawater	W	W	237	7,007	W	W	262	8,625
Calcium carbide	156	77	232	6,859	175	73	248	8,164
Glass	213	--	213	6,297	217	--	217	7,143
Sulfur removal	30	--	30	887	133	--	133	4,377
Precipitated calcium carbonate	44	36	81	2,395	47	51	98	3,225
Food products	21	35	56	1,656	32	32	64	2,105
Acid mine water	57	([3])	58	1,715	62	([3])	62	2,039
Metallurgy, other	51	--	51	1,508	52	3	56	1,842
Petrochemicals	72	--	72	2,129	47	--	47	1,546
Oil well drilling	47	--	47	1,390	46	--	46	1,513
Magnesium metal	W	W	27	798	W	W	39	1,282
Petroleum refining	42	--	42	1,242	36	--	36	1,183
Tanning	25	--	25	739	24	--	24	788
Ore concentration, other	3	--	3	89	14	--	14	459
Insecticides	9	--	9	266	12	--	12	393
Fertilizer	12	--	12	355	6	--	6	196
Paint	4	--	4	118	4	1	6	196
Rubber	4	--	4	118	4	--	4	130
Brick, sand-lime	W	W	W	W	4	--	4	130
Wire drawing	2	([3])	2	59	1	([3])	2	64
Other uses[4]	457	559	751	22,199	580	559	838	27,582
Total[2]	11,717	6,102	17,819	526,801	12,007	5,586	17,594	579,309
Refractory dolomite	938	68	1,007	37,079	892	75	968	37,992
Grand total[2]	14,052	6,205	20,257	611,523	14,242	5,745	19,987	669,479

W Withheld to avoid disclosing company proprietary data; included in "Other uses."

[1]Excludes regenerated lime. Includes Puerto Rico.

[2]Data may not add to totals shown because of independent rounding.

[3]Less than 1/2 unit.

[4]Includes magnesite, plastics, lithium, explosives, chrome, adhesives, silica brick, manganese (1977), coke (1977), other uses, and uses indicated by symbol W.

PRICES

The average value of lime sold or used by producers in 1977 was $33.50 per ton, an increase of 11% over the 1976 price of $30.19 and an increase of 92% over the 1973 price of $17.42. Values ranged from $32.93 for chemical and industrial lime to $36.77 for construction lime, $39.25 for refractory dolomite, and $34.33 for lime used in agriculture.

Values for quicklime sold ranged from $32.12 for chemical lime to $37.69 for construction lime, $31.30 for lime used in agriculture, and $39.20 for dead-burned dolomite, and averaged $32.71, an increase of 10% over the 1976 value.

Values for hydrated lime ranged from $36.85 for construction lime to $36.22 for chemical lime and $35.08 for lime used in agriculture, and averaged $36.48, an increase of 7% over the 1976 price.

FOREIGN TRADE

Exports of lime decreased 41% to 33,000 tons, 52% below the 1968 record. Of the total exports, Canada received 71%, Guyana received 6%, Mexico received 5%, and Nicaragua, Panama, and Surinam received 3% each. The remaining 9% went to 26 countries, listed in order of shipments as follows: Bahamas, Bermuda, Venezuela, New Zealand, El Salvador, Philippines, the Leeward and Windward Islands, Ireland, Trinidad, Guatemala, Ghana, Brazil, the United Kingdom, Paraguay, Kuwait, Austria, the Netherlands, Peru, Saudi Arabia, Australia, Argentina, Netherlands Antilles, Zaire, India, Japan, and Haiti.

Imports of lime have grown at an average rate of over 6% during the last 10 years. In 1977, imports (mainly from Canada) were 422,900 tons, an increase of 16% compared with that of 1976. Net import reliance, expressed as a percentage of apparent consumption, was 2%.

Table 6.—U.S. exports of lime

Year	Quantity (short tons)	Value (thousands)
1975	53,853	$2,746
1976	55,852	2,981
1977	32,954	2,185

Table 7.—U.S. imports for consumption of lime

	Hydrated lime		Other lime		Total	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
1975	44,637	$1,392	214,311	$4,867	258,948	$6,259
1976	48,461	1,814	316,442	8,816	364,903	10,630
1977	52,875	1,878	370,012	11,192	422,887	13,070

WORLD REVIEW

Lime is produced all over the world, mainly in the heavily industrialized nations. Large quantities of lime are produced in many countries of the world in small, primitive pot and vertical kilns. The quicklime is used in the manufacture of mortar and plaster in the construction of homes and buildings. Production statistics are not reported, and estimates can only be made that the quantities are substantial. Source materials are adequate. The United States, with 16% of the total, ranks second in world production, following the U.S.S.R.

Canada.—During 1977, 17 companies operated 23 lime plants in Canada: 10 in Ontario, 3 in Quebec, 4 in Alberta, 3 in Manitoba, 2 in British Columbia, and 1 in New Brunswick. Of the 85 kilns in operation, 54 were vertical, 27 were rotary, 3 were rotary grate, and 1 was vibratory grate. Total lime output was 2 million tons, of which 418,000 tons, with a customs-declared value of $30.69 per ton, was exported to the United States.

Germany, Federal Republic of.—The Neanderthal limestone quarry in Düsseldorf is the principal raw material source in the production of lime for the steelmaking complex at Duisburg. Approximately 700,000 tons of stone is used per year for burning lime in two Krupp rotary kilns, which measure 11-1/2 by 410 feet each.[9]

New Zealand.—Owing to the increasingly severe recession marking New Zealand's building industry, sales of cement and lime for the year to July 31, 1977, were lower. Lime sales for the 1977 financial year were 128,000 tons, a 4.5% decrease compared with 1976.[10]

South Africa, Republic of.—South Africa's economic slump of several years' standing once again created a mixed year in limestone, lime, and cement production and sales for 1977. Although limestone production declined nearly 9% below the 1976 output to about 17.3 million tons in 1977, lime production increased 7% to about 1.65 million tons in 1977, and local sales volumes and values rose 8% and 26%, respectively.[11]

Switzerland.—In 1977, the Swiss econ-

Table 8.—Quicklime and hydrated lime, including dead-burned dolomite: World production, by country

(Thousand short tons)

Country[1]	1975	1976	1977[p]
North America:			
Canada	1,765	2,039	2,071
Costa Rica	17	6	7
Guatemala	39	50	51
Jamaica	202	269	205
Nicaragua[e]	51	51	51
Puerto Rico	28	29	40
United States (sold or used by producers)	19,133	20,228	19,947
South America:			
Brazil[e]	[r]3,860	[r]4,740	4,960
Chile[e]	660	660	680
Colombia[e]	1,100	1,100	1,430
Paraguay	31	35	58
Peru[e]	(2)	(2)	(2)
Uruguay	51	77	77
Europe:			
Austria	[r]1,145	839	1,068
Belgium	2,778	2,540	2,547
Bulgaria	1,753	[r] [e]1,760	[e]1,820
Czechoslovakia	[r]3,255	3,292	[e]3,300
Denmark	183	255	191
Finland[e]	298	285	266
France	[r]4,892	5,057	[e]4,890
German Democratic Republic	3,340	3,752	[e]3,800
Germany, Federal Republic of	10,114	10,632	[e]10,700
Hungary	787	808	[e]830
Ireland	86	76	[e]80
Italy	1,952	2,122	2,126
Malta	9	7	[e]6
Norway	133	99	[e]110
Poland[3]	9,059	8,940	[e]9,000
Portugal	235	[e]220	[e]240
Romania	3,377	3,660	[e]3,700
Spain	432	[e]440	[e]440
Sweden (sales)	[r]1,022	945	[e]880
Switzerland	80	78	[e]77
U.S.S.R.[e]	25,000	25,000	26,000
Yugoslavia	2,296	2,124	[e]2,300
Africa:			
Algeria[e]	44	44	55
Burundi	(2)	1	1
Egypt[e]	90	90	100
Kenya	[e]33	33	[e]33
Libya	15	358	1,102
Malawi[e]	(2)	(2)	1
Mauritius	8	8	9
Mozambique	591	[e]550	[e]550
South Africa, Republic of (sales)	1,464	1,529	1,659
Tanzania	[r]2	[r] [e]2	[e]2
Tunisia	312	351	373
Uganda[e]	33	33	33
Zaire	165	[r] [e]110	103
Zambia	[e]130	159	[e]165
Asia:			
Cyprus	25	12	23
India[e]	375	375	390
Iran[e]	1,100	1,100	1,200
Israel	265	220	112
Japan	10,110	10,115	9,945
Jordan	3	3	3
Korea, Republic of	[e]110	[e]120	99
Kuwait	[e] (2)	13	[e]13
Lebanon[e]	200	200	180
Mongolia[e]	45	45	55
Nepal	(4)	(4)	--
Philippines	40	30	31
Saudi Arabia[e]	17	17	22
Taiwan	161	181	175
Oceania:			
Australia[e]	1,050	1,050	1,100
Fiji Islands	3	3	2
New Zealand[e]	110	150	165
Total	[r]115,664	119,117	121,649

[e]Estimate. [p]Preliminary. [r]Revised.

[1]Lime is produced in many other countries besides those listed. Mexico, Venezuela, and the United Kingdom are among the more important countries for which official data are unavailable.

[2]Less than 1/2 unit.

[3]Excludes output by small producers.

[4]Revised to zero.

omy experienced gratifying overall recovery, but construction activity remained somewhat depressed. Sales of the Holderbank lime plant, which had risen 16% in 1976, fell 14% to 13,800 tons in 1977.[12]

Tunisia.—Holderbank Management and Consulting Ltd., Engineering Division, of Zurich, Switzerland, received an order for the construction of two lime plants in Tunisia.[13]

United Arab Emirates.—Holderbank Management and Consulting Ltd., Engineering Division, reportedly received a contract for the expansion of the lime plant at Al-Ain, previously reported as under construction in 1976.[14]

TECHNOLOGY

An argillaceous, highly plastic gravel, incapable of being washed, was upgraded and stabilized by adding small percentages of hydrated lime. This produced a quality flexible base material which has met acceptance in the Houston, Tex., market area. A severalfold decrease in plasticity index test values indicated that less plastic and more friable aggregate resulted. After placement and compaction, the cementing reaction between the hydrated lime and the alumina and silica components of the clay hardened the gravel into a strong, stable layer that was relatively impervious to water.[15]

A study indicated that sometimes a longer rotary kiln without preheater is preferable to a preheater lime kiln system. Advantages were lower product sulfur content, more efficient handling of smaller and softer stones, and simpler operation. Comparison of four alternates indicated that a long kiln, fitted with all the heat-exchanging internals, can produce lime at a very attractive fuel expenditure rate, compared with a preheater kiln system.[16]

Woodville Lime and Chemical Co. of Woodville, Ohio, employed an unusual pair of rotary kilns to calcine dolomitic limestone. The kilns produced 250,000 tons per year of dolomitic lime for the steel industry and were constructed with a 1/8-inch layer of ceramic fiber paper between the steel shells and refractory brick linings. The kilns consume 14.6% less fuel than the industry average. Substantial savings were achieved in the process, and substantial protection against thermal shock was provided by the paper. A table was presented indicating how the ceramic insulating paper affected kiln performance.[17]

Fuller Co. presented a preheater-kiln system that produced high-quality lime using as little as 4.5 to 6 million Btu's per ton of quicklime produced. In this system, stone was fed to a stone bin above the preheater, which provided continuous gravity feed to the preheater and sealed the ambient air from infiltrating the system. The system offered two methods (feed-end housing with slope shelf or a knockout box) of collecting the partially calcined stone and directing it into the kiln; the choice of method is contingent upon how much sulfur is allowable in the product. Refractory heat exchangers were also recommended to reduce radiation losses and improve thermal efficiency, including a waste-heat contact-type unit for the calcine. The Fuller system was recommended for stone feed larger than 3/16 inch with good physical strength when partially calcined and low sulfur content in feed and fuel.[18]

---

[1]Physical scientist, Division of Nonmetallic Minerals.
[2]Rock Products. V. 80, No. 12, December 1977, p. 47.
[3]Work cited in footnote 2.
[4]Work cited in footnote 2.
[5]Work cited in footnote 2.
[6]Work cited in footnote 2.
[7]Star Telegram (Fort Worth, Tex.). July 8, 1978, p. 7; Apr. 28, 1978, p. 6.
[8]U.S. Department of Energy. Voluntary Business Energy Conservation Program. Progress Report 6, April 1978, pp. 128-129.
[9]Ironman, R. International Report. Rock Products, v. 80, No. 5, June 1977, p. 90.
[10]Holderbank Financiere Glaris Ltd. (Zurich, Switzerland). Annual Report, 1977. P. 35.
[11]U.S. Embassy, Johannesburg, South Africa. State Department Airgram A-05, Jan. 27, 1978, p. 47.
[12]Page 11 of work cited in footnote 10.
[13]Page 11 of work cited in footnote 10.
[14]Page 11 of work cited in footnote 10.
[15]Gutschick, K. A. Texas Producer Upgrades Gravel With Lime. Pit and Quarry, v. 69, No. 11, May 1977, pp. 78-80.
[16]Kramm, D. J. Save Fuel With Heat Exchanging Internals. Pit and Quarry, v. 69, No. 11, May 1977, pp. 65-67.
[17]Engineering and Mining Journal. Ceramic "Paper" Lining in Rotary Kilns Saves Fuel and Bricks. V. 178, No. 9, September 1977, p. 171.
[18]Kramm, D. J. Preheater Gives More Energy Per Dollar. Rock Products, v. 80, No. 6, June 1977, pp. 42-45.

Lithium

By Stanley K. Haines[1]

Apparent consumption of lithium increased 47% in 1977 to about 4,880 short tons of contained lithium. Shipments from Government inventory and exports both increased in 1977. Demand for lithium carbonate for the aluminum and ceramics industries was strong. The United States continued to produce and consume over one-half of the world's lithium supply.

The United States continued to be a leading exporter of lithium concentrates and chemicals.

Legislation and Government Programs.—Total sales by the General Services Administration (GSA) in 1977 amounted to 253 short tons of contained lithium, or 3.1 million pounds of lithium hydroxide monohydrate. The total disposable inventory as of December 31, 1977, was 53,960 pounds of lithium hydroxide monohydrate, but GSA holds an additional 80 million pounds of surplus material. GSA announced plans to release 28 million pounds of the material to be used in the production of lithium carbonate or lithium carbonate-based products. GSA also sold a separate offering of lithium hydroxide monohydrate of 500,000 pounds on a competitive sealed-bid basis for $1.01 per pound.

Table 1.—Salient statistics on lithium minerals[1]

(Short tons of contained lithium)

	1973	1974	1975	1976	1977
Production	W	W	W	W	W
Imports	130	70	90	10	10
Sales of government stockpile excesses	160	430	61	164	253
Exports[e] [2]	920	1,000	900	1,600	1,800
Apparent consumption	3,850	4,550	3,540	3,320	4,880

[e]Estimated. W Withheld to avoid disclosing company proprietary data.
[1]Includes lithium carbonate produced in Nevada.
[2]Includes lithium compounds.

DOMESTIC PRODUCTION

The two major lithium producers, Foote Mineral Co. and Lithium Corp. of America (Lithcoa), continued to mine and beneficiate spodumene from pegmatite dikes in North Carolina. Foote Mineral, 92% owned by Newmont Mining Corp., continued as the major domestic producer of spodumene concentrate. Foote's new lithium carbonate plant reached design capacity by yearend, after resolution of startup problems.[2]

Foote continued to produce lithium carbonate from subsurface brines at Silver Peak, Nev. Kerr-McGee Corp. produced small quantities of lithium carbonate from Searles Lake brines in California.

Lithcoa reported production of 27.6 million pounds (lithium carbonate equivalent) of lithium products. A program to expand productive capacity from 27 million pounds to 44 million pounds of lithium carbonate equivalent was announced. The initial stage was to be completed in 1981 with a rated capacity of 36 million pounds of lithium carbonate equivalent.[3]

Table 2.—Domestic producers of lithium

Company	Plant location	Estimated capacity (short tons Li_2CO_3 equivalent per year)
Lithium Corp. of America	Bessemer City, N.C	13,500
Foote Mineral Co	Silver Peak, Nev	8,000
	Kings Mountain, N.C.[1]	6,000
Kerr-McGee Corp	Searles Lake, Calif	1,000

[1]Onstream December 1976.

CONSUMPTION AND USES

Apparent domestic consumption increased from 3,320 tons of contained lithium in 1976 to 4,880 tons in 1977. Expanded use of lithium carbonate by the aluminum industry helped push apparent consumption above that of 1974, the record high year. The aluminum industry was expected to further increase its consumption. The use of lithium in ceramics and glass increased, as did pharmaceutical and automotive uses. Lithium chemicals were used to produce vitamin A and in the manufacture of hormones and antihistamines.

Sales of lithium hydroxide for multipurpose greases also improved. During the year Lithcoa announced an agreement with a U.S. company to distribute lithium hypochlorite for use in chlorinating swimming pools and laundry bleach.[4]

A summary of the U.S. lithium market was published in the November 1977 issue of Industrial Minerals (London). The article concentrated on the North Carolina operations of Foote Mineral and Lithcoa and listed the companies in the lithium minerals or chemicals business.[5]

PRICES

The domestic price of ceramic-grade spodumene concentrate declined to $110.40 per ton at yearend according to Ceramic Industry. Price increases were posted for lithium carbonate, lithium hydroxide, and lithium stearate. Table 3 summarizes the domestic prices of various lithium chemicals and shows the gradual increase from 1975 to 1977.

Table 3.—Domestic prices of lithium and lithium compounds

(Dollars per pound)

	1975	1976	1977
Lithium bromide: Anhydrous, drums, delivered	3.00	3.50	3.50
Lithium carbonate: Powdered, bags, delivered	0.755 - .795	0.825 - .84	.88
Lithium chloride:			
Anhydrous, delivered	1.26 - 1.53	1.65	1.65
Solution, drums, delivered	1.47	1.47	1.47
Lithium fluoride: Drums, delivered	2.42	2.52 - 2.70	2.52 - 2.70
Lithium hydride: Delivered	9.25	9.45 - 12.08	9.45 - 12.08
Lithium hydroxide monohydrate: Drums, delivered	1.18	1.27	1.27 - 1.43
Lithium hypochlorite: Works	.52	.52	.52
Lithium metal: 99.9% ingots, thousand-pound lots, delivered	11.10	11.60 - 15.00	11.60 - 15.00
Lithium nitrate: Technical-grade, drums, 100-pound lots	1.41	1.59 - 1.64	1.59 - 1.64
Lithium stearate: 50-pound cartons, freight allowed	.95	0.94 - .95	1.01
Lithium sulfate: Drums, 100-pound lots	1.55	1.43 - 1.75	1.43 - 1.75

Source: Chemical Marketing Reporter.

FOREIGN TRADE

There were no imports of lithium ores in 1977. An estimated 10 tons of contained lithium was imported as various lithium chemicals, mainly from France and Japan.

Reported exports of lithium hydroxide increased 24% to 665,000 pounds in 1977; however, import statistics from receiving countries indicate that these data are incomplete. The major countries of destination were the Federal Republic of Germany, France, and Mexico. There are no data on the exports of lithium carbonate and other lithium compounds.

Table 4.—Lithium metal and chemicals: Apparent U.S. exports[1] to selected countries

(Short tons)

Commodity	Belgium-Luxembourg	France	Germany, Federal Republic of	Italy	Japan	Netherlands	Spain	Total	Total lithium content
1976									
Gross weight:									
Lithium carbonate	r50	r98	r2,706	r25	r1,097	--	r73	r4,049	r761
Lithium hydroxide[2]	24	158	r195	r46	r432	r116	r120	r1,091	r181
Lithium chloride	NA	NA	r19	rNA	1	NA	r3	r23	3
Lithium bromide	NA	NA	NA	NA	[3]1	NA	NA	[3]1	([4])
Lithium metal	--	([4])	14	([4])	r16	--	([4])	r30	r30
Lithium content (total)	14	44	558	13	r293	19	34	r975	r975
1977									
Gross weight:									
Lithium carbonate	83	148	3,468	NA	1,498	665	55	5,917	1,113
Lithium hydroxide[5]	42	179	628	40	221	159	86	1,355	224
Lithium chloride	NA	NA	12	NA	1	NA	3	16	2
Lithium bromide	NA	NA	NA	NA	--	NA	NA	NA	NA
Lithium metal	--	NA	15	NA	18	--	([4])	33	33
Lithium content (total)	23	58	773	7	336	151	24	1,372	1,372

rRevised. NA Not available.

[1]Only in the case of lithium hydroxide are U.S. exports of lithium chemicals reported separately in official U.S. trade statistics. Other lithium compounds as well as lithium metal are reported in basket categories. Data in this table are derived from import statistics of the listed major trading partner countries.

[2]Officially reported U.S. exports total 267 short tons, distributed as follows: Argentina—1, Belgium-Luxembourg—1, Canada—6, France—30, India—10, Israel—11, Japan—77, the Republic of Korea—1, Mexico—31, the Netherlands—39, Spain—41, Switzerland—17, and the United Kingdom—2.

[3]Figures represent estimated gross weight of lithium bromide included in a basket category of lithium bromide and potassium bromide (50% of the total of lithium bromide and potassium bromide is assumed to be lithium bromide).

[4]Less than 1/2 unit.

[5]Officially reported U.S. exports total 333 short tons, distributed as follows: Bolivia—24, Canada—29, France—29, the Federal Republic of Germany—89, Israel—less than 1/2 unit, Japan—31, Mexico—64, the Netherlands—less than 1/2 unit, and Switzerland—17.

Table 5.—U.S. exports of lithium hydroxide

Destination	1976		1977	
	Quantity (pounds)	Value (dollars)	Quantity (pounds)	Value (dollars)
Argentina	2,600	4,032	--	--
Belgium	2,000	3,260	--	--
Bolivia	--	--	47,200	59,944
Canada	12,000	15,532	57,716	58,278
France	60,016	105,030	158,125	183,845
Germany, Federal Republic of	--	--	177,650	159,390
India	20,975	22,865	--	--
Israel	22,000	2,684	50	1,500
Japan	153,617	192,368	62,000	71,358
Korea, Republic of	2,095	3,100	--	--
Mexico	62,000	73,160	128,000	162,560
Netherlands	78,475	91,472	440	622
Spain	82,220	90,007	--	--
Switzerland	33,200	36,012	33,717	32,320
United Kingdom	3,000	34,944	--	--
Total	534,198	674,466	664,898	729,817

Source: U.S. Department of Commerce, Bureau of the Census.

Table 6.—U.S. imports for consumption of lithium-bearing materials

Commodity and country	1976 Gross weight (pounds)	1976 Value (thousand dollars) Customs	1976 Value (thousand dollars) C.I.F.	1977 Gross weight (pounds)	1977 Value (thousand dollars) Customs	1977 Value (thousand dollars) C.I.F.
Lithium ores: Canada	136,000	1	1	--	--	--
Organic acid lithium salts:						
Denmark	23	([1])	([1])	67	2	2
Germany, Federal Republic of	68	1	1	45	7	7
Mexico	12,438	r5	r5	([1])	([1])	([1])
Total	r12,529	6	6	112	9	9
Lithium compounds, n.e.c.:						
Belgium-Luxembourg	--	--	--	2,786	1	1
France	69,839	506	512	19,662	215	217
Germany, Federal Republic of	484	15	15	2,655	70	75
Japan	13,227	87	91	15,442	108	111
Switzerland	1,102	1	1	--	--	--
United Kingdom	100	6	6	1	([1])	([1])
Total	84,752	615	625	40,546	394	404
Lithium stearate:						
Canada	--	--	--	791	1	1
Taiwan	--	--	--	4,000	4	4
Tanzania	--	--	--	858	1	1
Total	--	--	--	5,649	6	6

rRevised.
[1]Less than 1/2 unit.

WORLD REVIEW

In October a Symposium on Lithium Needs and Resources was held in Corning, N.Y. One presentation[6] calculated the reserves and resources of lithium from pegmatite and brine sources and listed them by country and mining method. Total world reserves were calculated to be 2.2 million short tons of contained lithium.

Another paper[7] reviewed the European lithium industry and concluded that any new primary lithium production in Europe is unlikely. The main sources of lithium carbonate are the United States and the U.S.S.R. The paper also stated that lithium reserves are adequate to supply growing demand.

Chile.—Foote Mineral acquired 55% equity in a joint venture with Empressa Minera de Aisen (EMA), a subsidiary of Corfo, a Government-owned company, to study and possibly develop the subsurface brine deposits at Salar de Atacama. The brine contains about 0.15% lithium. The agreement calls for Foote Mineral to furnish all technology for recovering the lithium, to appoint and train Chilean nationals to top posts of the company, and to allow them free access to Foote's facilities in Chile and the United States[8] The venture has rights to produce only lithium and magnesium salts. Rights to produce the other coproduct minerals, primarily potash, and boron and salt remained with the Chilean Government.[9]

Japan.—Japan Lithium Co. disclosed capacity to produce 1,650 tons per year of lithium bromide, 1,320 tons per year of lithium chloride, 33 tons per year of butyllithium, and 7 tons per year of lithium metal.

Table 7.—Lithium minerals: World production, by country

(Short tons)

Country[1] and mineral produced	1975	1976	1977[p]
Argentina (minerals not specified)	276	744	805
Brazil:			
Amblygonite	172	204	[e]210
Lepidolite	516	1,468	[e]1,500
Petalite	4,075	1,067	[e]1,000
Spodumene	873	455	[e]440
Canada, spodumene[2]	--	62	--
China, People's Republic of (minerals not specified)[e 3]	10,000	10,000	11,000
Mozambique:			
Lepidolite[e]	800	800	825
Spodumene[e]	30	30	35
Portugal, lepidolite	1,323	1,213	1,102
Rhodesia, Southern (minerals not specified)[e 3]	[r]10,000	[r]10,000	10,000
Rwanda, amblygonite[e]	30	30	30
South-West Africa, Territory of (minerals not specified)[4]	56,849	6,495	2,809
U.S.S.R. (minerals not specified)[e 3]	50,000	50,000	55,000
United States (minerals not specified)	W	W	W

[e]Estimate. [p]Preliminary. W Withheld to avoid disclosing company proprietary data.

[1]In addition to the countries listed, other nations may produce small quantities of lithium minerals, but output is not reported and no valid basis is available for estimating production levels.

[2]Figures presented are U.S. imports from Canada; official Canadian sources report no production since 1965, but the United States has imported lithium minerals from Canada in most years since that time. It is not clear whether these imports are from: Accumulated stocks, test production quantities not reported in official Canadian statistics, Canadian imports; or a combination of these sources.

[3]These estimates denote only an approximate order of magnitude; no basis for more exacting estimates is available. Outputs by the People's Republic of China and the U.S.S.R. have not been reported since 1964.

[4]Output has not been officially reported since 1966, but presumably has continued since a number of countries record imports from "South Africa," which no longer produces lithium minerals. Data given represent imports by the United States, the EEC, and Spain reported as originating in the Republic of South Africa, but the reader is cautioned that a portion of this material may have been mined in Southern Rhodesia. In 1966 actual output from the Territory of South-West Africa totaled 1,739 short tons, including: amblygonite—30, lepidolite—365, petalite—1,344.

Table 8.—Reported world trade in lithium chemicals[1]

(Short tons of contained lithium)

Importing countries	Source countries									
	United States		U.S.S.R.		Germany, Federal Republic of		Other		Total	
	1976	1977	1976	1977	1976	1977	1976	1977	1976	1977
Belgium-Luxembourg:										
Carbonate	[r]9	16	1	1	--	5	[r](2)	1	[r]10	23
Hydroxide	4	7	--	NA	13	21	[r]4	1	[r]21	29
Chloride	NA	NA	NA	NA	[3]--	[3]--	NA	NA	NA	NA
Metal	--	--	--	NA	(2)	NA	--	(2)	(2)	--
Total	[r]13	23	1	1	13	26	[r]4	2	[r]31	52
France:										
Carbonate	18	28	25	25	36	28	3	6	82	87
Hydroxide	26	30	17	24	25	23	[r]2	3	[r]70	80
Chloride	NA	NA	NA	NA	[3]12	[3]18	NA	--	[3]12	[3]18
Metal	(2)	NA	--	--	6	13	--	11	6	24
Total	44	58	42	49	79	82	[r]5	20	[r]170	209
Germany, Federal Republic of:										
Carbonate	509	652	20	39	XX	XX	[r]24	64	[r]553	755
Hydroxide	32	104	18	19	XX	XX	[r]12	10	[r]62	133
Chloride	3	2	--	--	XX	XX	[r]2	--	[r]5	2
Metal	14	15	[r]5	5	XX	XX	--	1	[r]19	21
Total	558	773	[r]43	63	XX	XX	[r]38	75	[r]639	911
Italy:										
Carbonate	5	NA	1	--	[r]15	39	[r]14	37	[r]35	76
Hydroxide	8	7	--	--	[r]19	43	[r]1	21	[r]28	71
Chloride	--	NA	--	--	[3]7	[3]7	--	--	[3]7	[3]7
Metal	(2)	NA	[r]1	--	3	--	[r](2)	2	[r]4	2
Total	13	7	[r]2	--	[r]44	89	[r]15	60	[r]74	156

See footnotes at end of table.

Table 8.—Reported world trade in lithium chemicals[1] —Continued

(Short tons of contained lithium)

Importing countries	Source countries									
	United States		U.S.S.R.		Germany, Federal Republic of		Other		Total	
	1976	1977	1976	1977	1976	1977	1976	1977	1976	1977
Japan:										
Carbonate	206	282	27	38	--	--	(2)	(2)	233	320
Hydroxide	71	36	22	60	(2)	9	(2)	(2)	93	105
Chloride	(2)	(2)	--	--	(2)	--	--	(2)	(2)	(2)
Bromide	[4](2)	--	--	--	[4](2)	[4](2)	--	--	[4](2)	[4](2)
Metal	[r]16	18	--	(2)	[r](2)	(2)	[r]1	--	[r]17	18
Total	[r]293	336	49	98	(2)	9	[r]1	(2)	[r]343	443
Netherlands:										
Carbonate	--	125	--	10	--	2	--	--	--	137
Hydroxide	19	26	5	14	7	NA	--	2	31	42
Chloride	NA	NA	NA	NA	[3]14	[3]14	NA	NA	[3]14	[3]14
Metal	--	--	--	NA	NA	NA	[r](2)	(2)	(2)	(2)
Total	19	151	5	24	21	16	[r](2)	2	45	193
Spain:										
Carbonate	14	10	--	2	(2)	(2)	--	4	14	16
Hydroxide	20	14	--	4	6	4	(2)	(2)	26	22
Chloride	[r](2)	(2)	--	--	(2)	(2)	(2)	--	(2)	(2)
Metal	(2)	(2)	--	--	(2)	11	(2)	--	(2)	11
Total	34	24	--	6	6	15	(2)	4	40	49
Other countries:										
Carbonate	(2)	NA	NA	NA	[r] [3]6	[3]6	NA	NA	[r] [3]6	[3]6
Hydroxide	NA	NA	NA	NA	[r] [3]24	[3]23	NA	NA	[r] [3]24	[3]23
Chloride	NA	NA	NA	NA	[r] [3]4	[3]10	NA	NA	[r] [3]4	[3]10
Metal	3	NA	NA	NA	[3]5	[3]11	NA	NA	8	[3]11
Total	3	NA	NA	NA	[r]39	50	NA	NA	[r]42	50
Total:[5]										
Carbonate	[r]761	1,113	74	115	[r]57	80	[r]41	112	[r]933	1,420
Hydroxide	180	224	62	121	[r]94	123	[r]19	37	[r]355	505
Chloride	3	2	--	NA	[r]37	49	[r]2	NA	[r]42	51
Bromide	(2)	--	--	--	(2)	(2)	--	--	(2)	(2)
Metal	[r]33	33	[r]6	5	14	35	[r]1	14	[r]54	87
Total	[r]977	1,372	[r]142	241	[r]202	287	[r]63	163	[r]1,384	2,063

[r]Revised. NA Not available. XX Not applicable.

[1]Compiled from import statistics of listed importing countries unless otherwise noted. Conversion from reported metric tons to short tons was accomplished by multiplying metric tons by 1.10231. Conversions to lithium content from reported gross weights were accomplished through the use of the following conversion factors: Lithium carbonate, multiply by 0.188; lithium hydroxide, multiply by 0.165; lithium chloride, multiply by 0.164; lithium bromide, multiply by 0.080. It should be noted that most of the countries provide data for a basket category of "lithium oxide and hydroxide"; this has been assumed to be largely, if not entirely, the monohydrate form of lithium hydroxide ($LiOH \cdot H_2O$), and the factor selected for converting this material to lithium content is based on this assumption.

[2]Less than 1/2 unit.

[3]Source: Federal Republic of Germany official export statistics.

[4]Source publication reports imports of the total of lithium bromide and potassium bromide as a single figure; entry here is an estimate based on the assumption that half of the total is lithium bromide.

[5]Totals are of listed figures only; as such, they are only partial totals in most instances.

Table 9.—Lithium mineral concentrate: Imports of selected countries, by country of origin[1]

(Short tons, gross weight)

Source country	Recipient country											
	Belgium-Luxembourg	Denmark	France	Germany, Federal Republic of	Ireland	Italy	Japan	Netherlands	Spain	United Kingdom	United States	Total
1976												
Producing countries:												
Brazil	--	--	--	--	--	--	[2]1,308	--	--	--	--	[2]1,308
Canada	--	--	--	--	--	--	--	--	--	--	68	68
Mozambique	--	--	--	--	--	--	--	[3]593	--	--	--	593
South Africa, Republic of[4]	1,084	--	1,181	4,130	([5])	r126	--	[3]3,745	100	--	--	r10,366
United States	--	--	463	419	--	--	--	[3]138	--	--	XX	1,020
Nonproducing countries:												
Belgium-Luxembourg	XX	--	--	--	--	--	--	--	--	--	--	--
Germany, Federal Republic of	--	--	--	XX	--	r194	--	--	--	--	--	r194
Greece	--	--	--	--	--	--	--	[3]3,616	--	--	--	3,616
Italy	--	--	--	--	--	XX	--	--	--	--	--	--
Netherlands	346	--	288	200	--	389	--	XX	1	72	--	r1,296
Unspecified countries	14	35	251	--	12	([5])	--	r [3]275	--	--	--	r587
Total	1,444	35	2,183	4,749	12	r709	[2]1,308	[3]8,367	101	72	68	r19,048
1977												
Producing countries:												
Brazil	--	NA	--	--	NA	--	[2]836	--	--	NA	--	[2]836
Canada	--	NA	--	--	NA	--	NA	--	--	NA	--	NA
China, People's Republic of	--	NA	--	--	NA	--	NA	--	28	NA	--	28
Mozambique	--	NA	--	1,510	NA	--	NA	--	--	NA	--	1,510
South Africa, Republic of[4]	--	NA	951	4,160	NA	139	NA	4,597	334	NA	--	10,181
United States	--	NA	772	309	NA	--	NA	--	--	NA	XX	1,081
Non-producing countries:												
Belgium-Luxembourg	XX	NA	--	--	NA	--	NA	593	--	NA	--	593
Germany, Federal Republic of	--	NA	--	XX	NA	--	NA	1,404	--	NA	--	1,404
Greece	--	NA	--	--	NA	--	NA	2,960	--	NA	--	2,960
Italy	--	NA	--	--	NA	XX	NA	--	--	NA	--	NA
Netherlands	--	NA	308	184	NA	1,133	NA	XX	74	NA	--	1,699
Unspecified countries	327	NA	110	78	NA	259	NA	301	44	NA	--	1,119
Total	327	NA	2,141	6,241	NA	1,531	[2]836	9,855	480	NA	--	21,411

r Revised. NA Not available. XX Not applicable.
[1]Compiled from import statistics of listed recipient countries, unless otherwise specified.
[2]Source: Official export statistics of Brazil.
[3]Data may include minerals other than lithium concentrates. Nonexpanded vermiculite, chlorite, and perlite, if any, are included.
[4]Includes materials from the Territory of South-West Africa and possibly Southern Rhodesia.
[5]Revised to none.

TECHNOLOGY

The Bureau of Mines Salt Lake City Metallurgy Research Center initiated a project to investigate methods for recovering lithium from clays and brines. The project team will work in cooperation with the U.S. Geological Survey Lithium Exploration Group in the selection of samples to be investigated.

A patent was assigned to the U.S. Department of Energy for a process to convert lithium borate to lithium borohydrate through diborane. The process is designed to produce hydrogen gas as a fuel and to recycle the valuable lithium and boron components into reusable compounds.[10]

The Department of Energy budget authorization for battery development was increased from $7.5 million in 1976 to $12.7 million in 1977. A lithium-sulfur battery was being developed by Argonne National Laboratory. A prototype for vehicular applications completed 3,300 hours of testing. Its specific energy was 75 to 80 watt-hours per kilogram.[11]

Matsushita Electric Insulation Co. announced plans to make a 3.1 gram, 2.2-millimeter-high, 23-millimeter-diameter lithium battery for calculators. A license was issued to Eagle-Picher Industries, Inc., in Cincinnati, Ohio. The cell has a voltage of 2.8 and a capacity of 140 milliampere-hours, or about 5 years for a calculator with a liquid crystal display.[12]

P. R. Mallory and Co., Inc., developed a lithium D cell battery with an energy density of 150 watt-hours per pound at 30 hours' rate and a storage and operating temperature of -40° C to 160° C. The two main problems of the cells were explosion when abused and voltage delay after storage. The company's research found that the voltage delay was related to the lithium electrode.

---

[1]Physical scientist, Division of Nonmetallic Minerals.
[2]Foote Mineral Corp. 1977 Annual Report. P. 3.
[3]Gulf Resources & Chemical Corp. 1977 Annual Report. Pp. 10-11.
[4]Work cited in footnote 3.
[5]Industrial Minerals (London). Lithium- U. S. Chemical Expansion Insures Supply. No. 122, November 1977, pp. 67-73.
[6]Evans, R. K. Lithium Reserves and Resources. Energy, v. 3, pp. 379-385. Permagon Press.
[7]Bauer, R., Lithium in Europe. Energy, v. 3, p. 241. Summary only. Permagon Press.
[8]Engineering and Mining Journal. Chile and Foote Mineral Study Development of Major Lithium Deposits. V. 178, No. 10, October 1977, p. 145.
[9]U.S. Embassy, Santiago, Chile. State Department Airgram A-103, Aug. 24, 1977, p. 7.
[10]Filby, E. E. (assigned to U.S. Energy Research and Development Administration). Method of Recycling Lithium Borohydride Through Diborane. U.S. Pat. 3,993,732, Nov. 23, 1976.
[11]Chemical and Engineering News. Battery Development Makes Good Progress. V. 55, No. 8, Feb. 21, 1977, pp. 28-30.
[12]Electronics. Matsushita Makes Lithium Cell for Thin Calculators. V. 50, No. 6, Mar. 17, 1977, p. 25.

Magnesium

By Benjamin Petkof[1]

Consumption of magnesium metal declined. Exports increased in both quantity and value and total imports of metal declined in both quantity and value. The quoted price of the metal advanced during the year. World primary metal production (excluding that of the United States) was slightly higher than that of 1976.

Legislation and Government Programs.—The General Services Administration has no stockpile goal for magnesium metal. All material currently in the stockpile has been set aside for Government use. There were no accessions of metal during the year.

Table 1.—Salient magnesium statistics

(Short tons)

	1973	1974	1975	1976	1977
United States:					
Production:					
Primary magnesium	122,431	W	W	W	W
Secondary magnesium	17,636	14,874	27,873	30,553	32,694
Shipments: Primary	137,277	W	W	W	W
Exports	39,585	46,398	32,591	13,444	28,061
Imports for consumption	3,325	5,305	7,903	14,907	5,964
Consumption	115,774	130,048	94,167	104,453	103,576
Price per pound cents	38.25	41.25-75.00	82.00	87.00-92.00	96.00-99.00
World: Primary production	266,441	[1]142,727	[1]138,284	[r] [1]148,506	[1]150,510

[r]Revised. W Withheld to avoid disclosing individual company confidential data.
[1]Excludes United States production.

DOMESTIC PRODUCTION

Domestic primary ingot production remained stable and was almost unchanged from that of 1976. Publication of Bureau of Mines data must be withheld to avoid disclosing individual company confidential data.

All four producers of magnesium ingot were in operation during 1977. The American Magnesium Co. (Snyder, Tex.),The Dow Chemical Co. (Freeport, Tex.), and NL Industries, Inc. (Rowley, Utah), produced magnesium from magnesium chloride solution obtained from brine by the electrolytic method. Northwest Alloys, Inc. (Addy, Wash.) produced magnesium from dolomite using the silicothermic process. The nominal annual production capacities of these producing plants remained unchanged from 1976.

Magnesium obtained by secondary recovery continued to furnish a significant portion of our domestic supply of this metal. Secondary recovery increased during the year.

Table 2.—Magnesium recovered from scrap processed in the United States, by kind of scrap and form of recovery

(Short tons)

	1973	1974	1975	1976	1977
Kind of scrap:					
New scrap:					
Magnesium-base	7,417	3,357	4,076	2,838	3,363
Aluminum-base	6,118	5,798	14,014	16,186	16,807
Total	13,535	9,155	18,090	19,024	20,170
Old scrap:					
Magnesium-base	2,529	4,161	4,873	5,500	5,255
Aluminum-base	1,572	1,558	4,910	6,029	7,269
Total	4,101	5,719	9,783	11,529	12,524
Grand total	17,636	14,874	27,873	30,553	32,694
Form of recovery:					
Magnesium alloy ingot[1]	2,606	2,703	2,796	3,569	3,785
Magnesium alloy castings (gross weight)	12	14	750	836	859
Magnesium alloy shapes	169	4	1,262	335	932
Aluminum alloys	9,206	9,316	20,328	23,595	25,211
Zinc and other alloys	31	16	12	15	21
Chemical and other dissipative uses	567	44	44	28	43
Cathodic protection	5,045	2,777	2,681	2,175	1,843
Total	17,636	14,874	27,873	30,553	32,694

[1]Includes secondary magnesium content of both secondary and primary alloy ingot.

CONSUMPTION AND USES

Total domestic consumption of magnesium metal in 1977 declined less than 1% from that of 1976 and continued to remain below the peak 1974 consumption level. Magnesium metal was used to manufacture structural products that included cast and wrought items and for sacrificial uses where advantage was taken of the metal's excellent chemical and alloying properties. The metal's useful structural properties, such as low specific weight, good machinability, hot formability, and high strength-to-weight ratio resulted in about 19% being used in aircraft, automotive, and other types of transportation equipment, material handling equipment, and the manufacture of items such as power tools. The remaining quantities were used for sacrificial purposes, primarily alloying with other metals (54%); cathodic protection (4%); nodular iron production (7%); chemicals (10%); and reducing agents, for metals such as titanium, zirconium, uranium, and beryllium (5%).

Table 3.—Consumption of primary magnesium in the United States, by use

(Short tons)

	1973	1974	1975	1976	1977
For structural products:					
Castings:					
Die	9,999	11,804	6,392	4,759	5,011
Permanent mold	812	1,000	1,144	1,059	1,048
Sand	1,326	1,372	1,952	1,233	1,142
Wrought products:					
Extrusions	7,436	7,323	6,215	6,449	(1)
Sheet and plate	(1)	(1)	(1)	(1)	(1)
Other (includes forgings)	5,529	6,025	3,451	3,792	12,632
Total	25,102	27,524	19,154	17,292	19,833
For distributive or sacrificial purposes:					
Alloys:					
Aluminum	51,953	62,152	46,670	54,320	56,086
Copper	503	19	13	14	10
Zinc	30	24	15	29	23
Other	13	16	11	10	8
Cathodic protection (anodes)	9,931	10,439	4,702	7,809	4,083
Chemicals	9,835	9,204	r8,681	r10,140	9,941
Nodular iron	8,724	10,603	r6,775	r7,584	7,297
Scavenger and deoxidizer	50	285	(1)	(1)	(1)
Reducing agent for titanium, zirconium, hafnium, uranium, and beryllium	7,367	7,569	7,007	5,985	5,235
Other, including powder	2,266	2,213	1,139	1,270	1,060
Total	90,672	102,524	75,013	87,161	83,743
Grand total	115,774	130,048	94,167	104,453	103,576

rRevised.
[1]Included with "Other."

PRICES

The price of magnesium ingot increased during the year. As of January 1, 1977 the quoted price was $0.96 per pound. On July 1, it increased to $0.99 per pound. The latter price remained unchanged through the end of the year and the first quarter of 1978.

STOCKS

Producer and consumer stocks of primary magnesium declined 32% to 11,838 tons at yearend 1977. Yearend stocks of primary alloy ingot increased 43% to 1,412 tons. Stocks of primary metal at yearend 1976 were 17,295 tons, and those of alloy ingot were 988 tons. New and old magnesium scrap stocks increased 16%.

Table 4.—Stocks and consumption of new and old magnesium scrap in the United States in 1977

(Short tons)

Item	Stocks Jan. 1r	Receipts	Consumption			Stocks Dec. 31
			New scrap	Old scrap	Total	
Cast scrap	968	6,452	567	5,775	6,342	1,078
Solid wrought scrap[1]	76	936	883	--	883	129
Total	1,044	7,388	1,450	5,775	7,225	1,207

rRevised.
[1]Includes borings, turnings, drosses, etc.

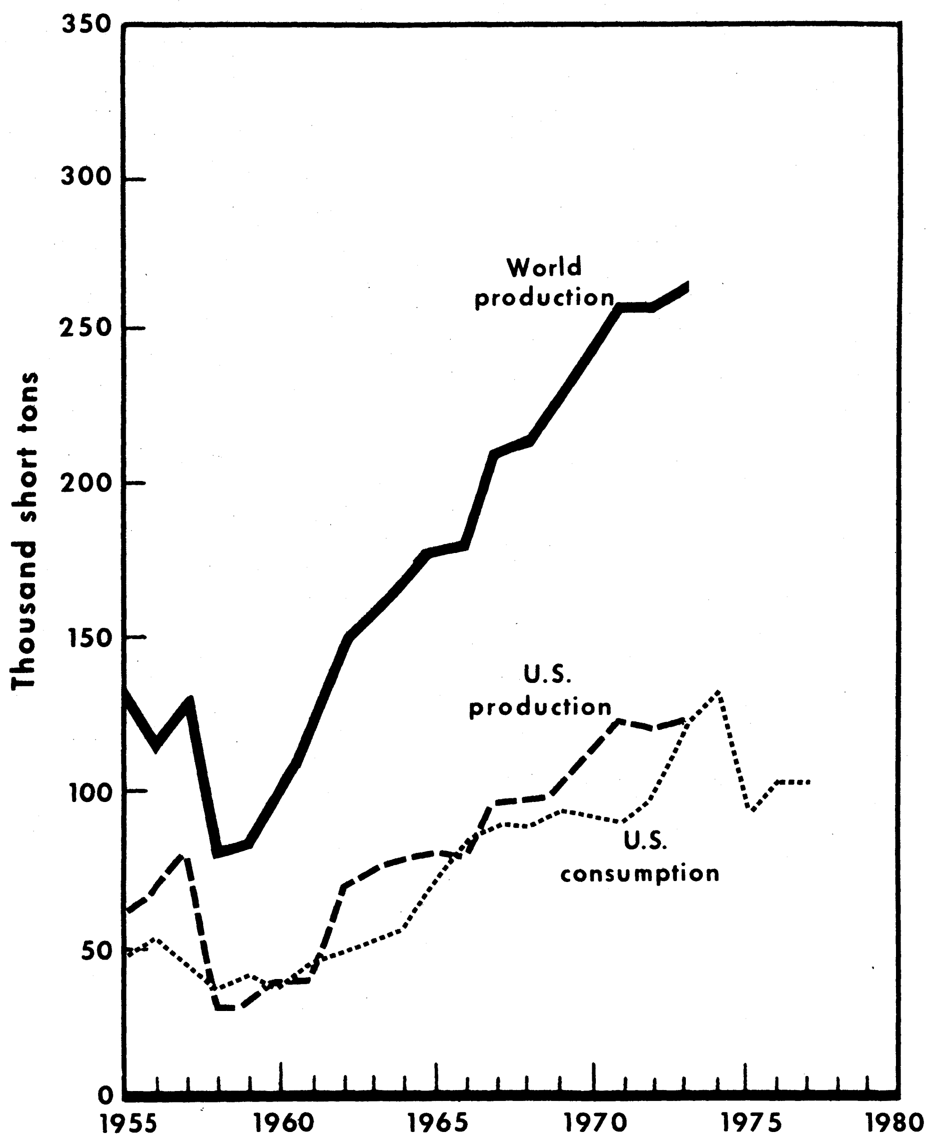


Figure 1.—U.S. and world production, and U.S. consumption of primary magnesium.

FOREIGN TRADE

After declining in the previous year, magnesium exports more than doubled in 1977 and increased from 13,444 tons in 1976 to 28,061 tons in 1977. The value of the exports increased 93% from $26.9 million in 1976 to $51.8 million in 1977. Shipments to the Netherlands, Brazil, Mexico, and the Federal Republic of Germany represented 72% of the total. Most of the metal exported (94%) consisted of primary metal and alloy.

Total imports for consumption of magnesium declined 60% from 14,907 tons, valued at $22.7 million in 1976 to 5,964 tons, valued at $8.0 million in 1977. Imports of metal accounted for 30% of total imports; waste and scrap 64%; and alloys and other forms, 6%. Major sources of magnesium imports were Norway (30%), the Netherlands (25%), and Canada (16%).

Table 5.—U.S. exports and imports for consumption of magnesium

Year	Exports					
	Waste and scrap		Metals and alloys in crude form		Semifabricated forms n.e.c.	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
1975	476	$303	31,047	$44,392	1,068	$3,496
1976	66	130	12,217	21,953	1,161	4,819
1977	105	136	26,309	44,907	1,647	6,805

Year	Imports							
	Waste and scrap		Metal		Alloys (magnesium content)		Powder, sheets, tubing, ribbons, wire, other forms (magnesium content)	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
1975	1,984	$1,564	4,803	$7,735	1,111	$2,215	5	$33
1976	3,376	2,997	9,690	16,023	1,820	3,604	21	38
1977	3,829	3,834	1,770	2,850	299	1,073	66	219

Table 6.—U.S. exports of magnesium, by class and country

Destination	1976						1977					
	Waste and scrap		Primary metals, alloys		Semifabricated forms, n.e.c., including powder		Waste and scrap		Primary metals, alloys		Semifabricated forms, n.e.c., including powder	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Argentina	--	--	248	$476	11	$35	5	$7	491	$985	--	--
Australia	--	--	514	875	20	133	1	2	1,251	2,207	36	$303
Austria	--	--	--	--	5	20	--	--	--	--	13	44
Belgium-Luxembourg	--	--	--	--	3	25	2	3	--	--	33	199
Bolivia	--	--	12	13	--	--	4	1	14	17	--	--
Brazil	--	--	5,039	8,024	5	43	--	--	6,765	11,143	2	9
Canada	37	$52	786	1,167	190	1,281	72	101	1,766	3,386	524	1,462
Colombia	--	--	38	89	--	--	--	--	29	73	4	15
France	--	--	10	40	7	78	--	--	2	4	32	144
Germany, Federal Republic of	--	--	2,719	6,201	492	1,960	--	--	2,748	4,735	425	1,981
Hong Kong	--	--	--	--	--	--	6	8	--	--	--	--
India	--	--	112	146	--	--	--	--	80	127	(1)	2
Israel	8	56	(1)	5	29	93	--	--	4	11	119	461
Italy	--	--	97	344	25	72	--	--	94	348	7	73
Japan	20	19	193	539	143	447	14	13	1,968	3,233	211	1,004
Korea, Republic of	--	--	5	5	2	17	--	--	--	--	18	139
Mexico	--	--	1,851	3,050	75	164	1	1	2,774	4,598	54	120
Netherlands	--	--	5	15	14	65	--	--	7,452	12,500	5	30
New Zealand	--	--	110	159	--	--	--	--	171	181	7	63
Norway	--	--	--	--	1	9	--	--	(1)	2	1	11
South Africa, Republic of	--	--	159	265	4	27	--	--	406	707	10	73
Spain	--	--	30	53	19	46	--	--	--	--	23	73
Sweden	--	--	--	--	2	9	--	--	--	--	34	277
Taiwan	--	--	26	37	7	13	--	--	6	93	1	1
United Kingdom	--	--	12	23	34	117	--	--	28	93	56	185
Venezuela	--	--	10	25	2	2	--	--	149	263	--	--
Other	1	3	241	402	71	163	--	--	111	201	32	136
Total	66	130	12,217	21,953	1,161	4,819	105	136	26,309	44,907	1,647	6,805

[1] Less than 1/2 unit.

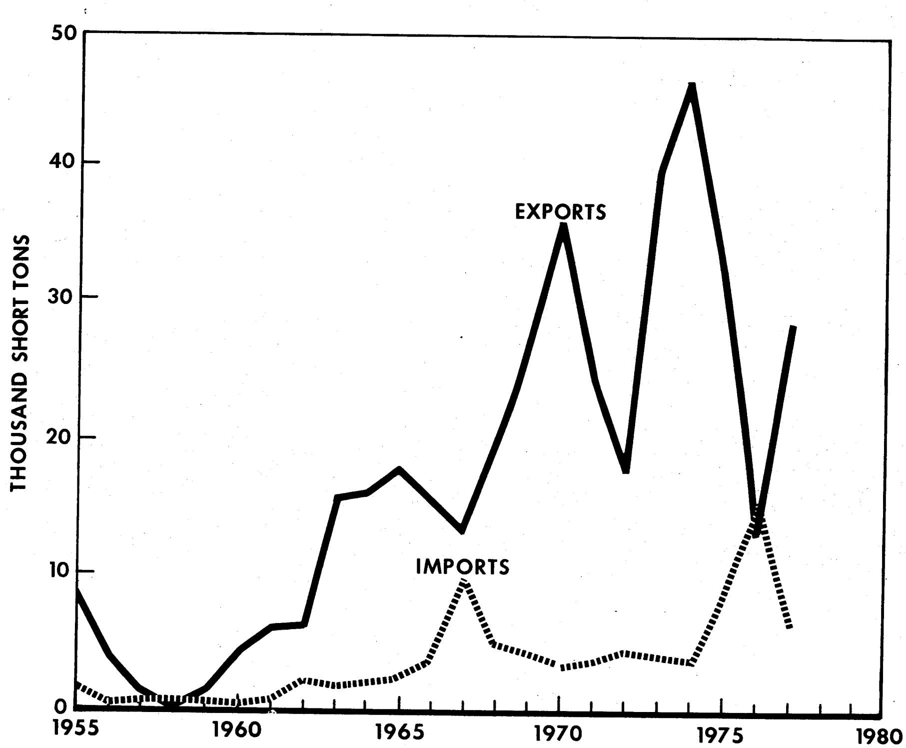


Figure 2.—U.S. imports and exports of magnesium.

WORLD REVIEW

World production of magnesium excluding that of the United States increased slightly from that of 1976. Major world producers of primary magnesium metal were the U.S.S.R. (47%) and Norway (28%). The remainder was supplied by Canada, China, France, Italy, and Japan.

Canada.—Chromasco Ltd. continued to produce magnesium metal using the silicothermic process near Haley, Ontario. The plant capacity remained at about 11,000 tons per annum.

Canada was a net exporter of magnesium metal in 1976. The country imported 1,242 tons and exported 3,556 tons of metal. Domestic consumption of the metal declined from 5,957 tons in in 1975 to 4,663 tons in 1976.

Norway.—In 1976 Norsk Hydro-Elektrisk A/S announced plans to construct a new magnesium production plant at Mongstad. Subsequently, the company decided not to implement the plans because of lower anticipated market expansion for magnesium and high Norwegian labor and other costs.

Japan.—Furukawa Magnesium and Ube Kyosan produced primary magnesium metal by the silicothermic process. These companies use dolomite and seawater, respectively, as initial raw materials.

Table 7.—Magnesium: World production,[1] by country

(Short tons)

Country	1975	1976	1977[p]
Canada	4,217	6,715	8,356
China, People's Republic of[e]	1,100	1,100	1,100
France	8,303	8,825	9,574
Italy	6,993	7,753	8,031
Japan[2]	9,412	12,335	10,379
Norway	42,259	42,778	42,070
U.S.S.R.[e]	66,000	69,000	71,000
United States	W	W	W
Total[3]	138,284	148,506	150,510

[e]Estimate. [p]Preliminary. W Withheld to avoid disclosing individual company confidential data.
[1]Primary only.
[2]Secondary production was as follows, in short tons: 1975—10,171; 1976—8,153; and 1977—8,392.
[3]Excludes United States production, which in previous years accounted for approximately 50% of the total.

TECHNOLOGY

A series of papers were published reviewing magnesium metal market conditions and providing technical papers on subjects such as hot chamber diecasting, new magnesium casting alloy, coatings and finishes for diecastings, desulfurization of iron, and production of magnesium from carnalite.[2]

Another report addressed the problems of conservation of of energy in the production and use of magnesium.[3]

An epoxy coating was developed and tested for use on magnesium alloy parts to inhibit corrosion.[4]

A study was prepared that evaluated the effects of different surface treatments and corrosion resistant coating systems on the fatigue properties of several different cast magnesium alloys that were or will be used for helicopter component housing.[5]

[1]Physical scientist, Division of Nonferrous Metals.
[2]International Magnesium Association. Proceedings, 34th Ann. Meeting, Columbus, Ohio, May 22-24, 1977, 57 pp.
[3]Flemings, M. C., R. S. Busk, W. A. Barnes, and J. P. Clark. Rept. from Internat. Conf. on Energy Conservation in Production and Utilization of Magnesium. Massachusetts Institute of Technology, May 25-27, 1977, 190 pp.
[4]Pulley, D. F. Development of an Alkaline-Inhibited Epoxy Primer for Magnesium Alloys. Naval Air Development Center, Air Vehicle Technol. Dept. (Warminster, Pa.) Rept. NADC-76297-30, Dec. 9, 1976, 19 pp. Available from NTIS, Springfield, Va.
[5]Bethke, J. J. Effect of Corrosion Resistant Coatings on the Fatigue Strength of Cast Magnesium Alloys. Naval Air Development Center, Air Vehicle Technol. Dept. (Warminster, Pa.) Rept. NADC-77140-30, Sept. 1, 1977, 86 pp. Available from NTIS, Springfield, Va.

Magnesium Compounds

By Benjamin Petkof[1]

In 1977, the United States retained its place as a major world producer of magnesium compounds. Domestic output was based chiefly on the production of magnesia from brines. The quantity of magnesium compounds shipped and used declined from that of 1976. Exports of magnesite and magnesia increased. Imports of processed magnesite declined from those of 1976.

Austria, Greece, the U.S.S.R., the People's Republic of China, and North Korea were major sources of magnesite.

Table 1.—Salient magnesium compound statistics

(Thousand short tons and thousand dollars)

	1973	1974	1975	1976	1977
United States:					
Caustic-calcined and specified magnesias:[1]					
Shipments by producers:					
Quantity	158	149	120	134	129
Value	26,929	27,916	17,207	28,277	29,574
Exports: Value[2]	4,196	5,088	4,538	5,422	6,336
Imports for consumption: Value[2]	734	692	502	808	566
Refractory magnesia:					
Sold and used by producers:					
Quantity	807	803	709	768	690
Value	69,904	77,044	103,839	106,522	94,799
Exports: Value	6,104	7,749	14,146	13,466	16,477
Imports: Value	13,469	16,463	20,588	13,976	12,332
Dead-burned dolomite:					
Sold and used by producers:					
Quantity	1,250	1,277	914	1,007	968
Value	23,441	32,078	31,193	37,079	37,992
World: Crude magnesite production: Quantity	10,162	11,097	r10,614	r9,847	9,753

r Revised.
[1]Excludes caustic-calcined magnesia used in production of refractory magnesia.
[2]Caustic-calcined magnesia only.

DOMESTIC PRODUCTION

Natural brine solutions continued to be the primary source of domestically produced magnesium compounds. Natural magnesite and olivine were produced only at a few operations in the United States.

Barcroft Co., The Dow Chemical Co., Harbison-Walker Refractories Co., Kaiser Aluminum & Chemical Corp., and Merck & Co., Inc., produced magnesium hydroxide from seawater and well brines. Magnesium hydroxide was processed primarily into magnesia for conversion into basic refractories. The following firms produced refractory magnesia in 1977: Basic, Inc.; Basic Magnesia, Inc.; Corhart Refractories Co.; A. P. Green Refractories Co.; Harbison-Walker Refractories Co.; Kaiser Aluminum & Chemical Corp.; and Martin Marietta Chemicals.

Caustic-calcined magnesia was produced by Basic, Inc.; Basic Magnesia, Inc.; The Dow Chemical Co.; Kaiser Aluminum & Chemical Corp.; Martin Marietta Chemicals; and Velsicol Chemical Corp. Merck & Co., Inc., and Morton Chemical Co. produced specified magnesias. The Dow Chemical Co., Mallinckrodt Chemical Works, and Philadelphia Quartz Co. produced magnesium sulfate. Magnesium carbonate was produced by Mallinckrodt Chemical Works, Merck & Co., Inc., Velsicol Chemical Corp., and Morton Chemical Co.

Magnesium chloride production was reported by the American Magnesium Co.; The Dow Chemical Co., Kaiser Aluminum & Chemical Corp., and Mallinckrodt Chemical Works. Magnesium chloride was used primarily as cell-feed material for the production of magnesium metal. Domestic magnesium compounds producers by raw material source, location, and capacity follow:

Raw material source and producing company	Location	Capacity (short tons of MgO equivalent)
Magnesite: Basic, Inc	Gabbs, Nev	150,000
Lake brines:		
Great Salt Lake Minerals & Chemicals Corp	Ogden, Utah	100,000
Kaiser Aluminum & Chemical Corp	Wendover, Utah	50,000
Well brines:		
The Dow Chemical Co	Ludington, Mich	250,000
Martin Marietta Chemicals	Manistee, Mich	280,000
Morton Chemical Co	Manistee, Mich	5,000
Velsicol Chemical Corp	St. Louis, Mich	25,000
Seawater:		
Barcroft Co	Lewes, Del	5,000
Basic Magnesia, Inc	Port St. Joe, Fla	100,000
Corhart Refractories Co	Pascagoula, Miss	40,000
The Dow Chemical Co	Freeport, Tex	100,000
Harbison-Walker Refractories Co	Cape May, N.J	100,000
Kaiser Aluminum & Chemical Corp	Moss Landing, Calif	150,000
Merck & Co., Inc	South San Francisco, Calif	10,000
Western Magnesium Corp	Chula Vista, Calif	5,000
Total		1,370,000

CONSUMPTION AND USES

Domestic demand for magnesium compounds was strong during 1977, but declines were noted in major consumption areas. The manufacture of refractory products was the major end use for magnesia. Refractory magnesia consumption declined 10% in quantity and 11% in value from that of 1976. Consumption of caustic-calcined and specified magnesias declined almost 4% in quantity but increased 5% in value; magnesium hydroxide use increased 53% in both quantity and value; magnesium sulfate increased 2% in quantity and 22% in value; and the market for magnesium carbonate decreased 27% in quantity and 32% in value.

While the total quantity of caustic calcined and specified magnesias used for various end uses declined 4% from that of 1976, the quantity used for chemical processing, manufacturing, and metallurgy increased about 1%. The quantities used for agricultural, nutritional, and pharmaceutical applications and in construction materials declined about 7% and 8%, respectively.

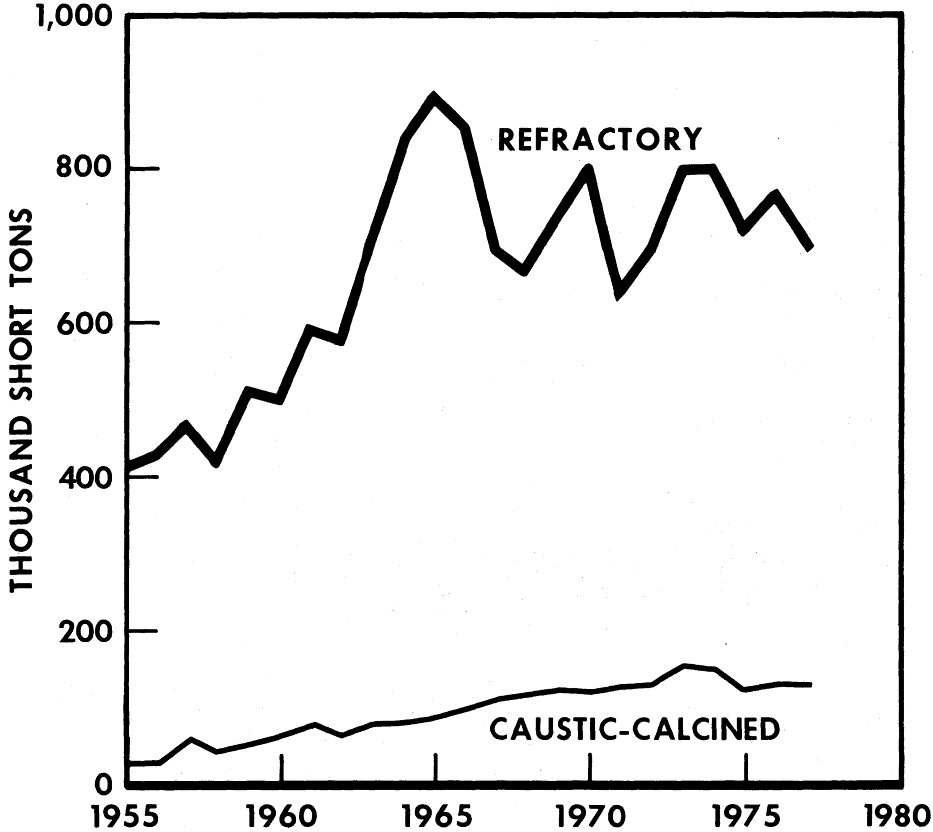


Figure 1.—Consumption and shipments of magnesia in the United States.

Table 2.—Magnesium compounds shipped and used in the United States

	1976		1977	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Caustic-calcined[1] and specified (USP and technical) magnesias	134,458	$28,277	128,846	$29,574
Refractory magnesia	767,607	106,522	689,847	94,799
Magnesium hydroxide (100% $Mg(OH)_2$)[1]	61,059	7,784	93,314	11,879
Magnesium sulfate (anhydrous and hydrous)	55,993	9,835	57,113	11,953
Precipitated magnesium carbonate[1]	5,535	1,496	4,046	1,020

[1]Excludes material produced as an intermediate step in the manufacture of other magnesium compounds.

Table 3.—Domestic shipments of caustic-calcined and specified magnesias, by use

(Short tons)

Use	1976	1977
Agriculture, nutrition, and pharmaceuticals:		
Animal feed	29,859	26,518
Fertilizer	7,695	10,379
Medicinals and pharmaceuticals	2,548	689
Sugar and candy	W	3,886
Winemaking	W	--
Total	44,393	41,472
Construction materials:		
Insulation and wallboard	(1)	(1)
Oxychloride and oxysulfate cement	11,797	10,889
Total	11,797	10,889
Chemical processing, manufacturing, and metallurgical:		
Chemical	10,051	7,935
Electrical heating rods	11,629	11,650
Flux	W	W
Petroleum additive	10,955	11,912
Pulp and paper	12,997	15,933
Rayon	10,095	9,785
Rubber	12,103	11,677
Uranium processing	W	W
Water treatment	5,688	3,089
Total	75,418	76,485
Unspecified uses	2,850	W
Grand total	134,458	128,846

W Withheld to avoid disclosing individual company confidential data; included with "Total."
[1]Included with "Oxychloride and oxysulfate cement."

PRICES

The Chemical Marketing Reporter quoted the following prices for magnesium compounds at yearend: Magnesia, natural, technical, heavy, 85% and 90% (bulk, carlot and truckload, f.o.b., Nevada), at $120 and $140 per short ton, respectively; magnesia, technical, neoprene-grade, light (bags, carlot and truckload, works), at $346 per ton; magnesium carbonate, technical (bags, carlot and truckload, works, freight-equalized), at $0.22 to $0.23 per pound, and NF-grade (bags, carlot, works, freight-equalized), at $0.30 to $0.31 per pound; magnesium hydroxide, NF, powder (drums, carlot and truck load, works, freight-equalized), at $0.35 to $0.36 per pound; magnesium chloride, hydrous, 99%, flake (bags, carlot, works), at $140 per ton; magnesium sulfate, technical (bags, mixed carlot, 10,000-pound minimum works), at $.091 per pound, and in bulk (same basis), $.085 per pound.

FOREIGN TRADE

Dead-burned magnesite and magnesia exports increased 7% in quantity and 22% in value from those of 1976. Most of the material was exported to Canada (72%), the Federal Republic of Germany (17%), and France (5%).

Magnesite exports including crude, caustic-calcined, lump or ground, increased 19% in quantity and 17% in value from those of 1976. Shipments to Canada and Venezuela accounted for 61% of the exports in this category.

Imports of lump or ground caustic-calcined magnesia decreased 29% in quantity and 30% in value from those of 1976. The bulk of the imports were from India (70%) and Australia (22%). Imports of dead-burned and grain magnesia and periclase containing a maximum of 4% lime decreased 16% in quantity and 12% in value from those of 1976. Almost the entire quantity imported originated in Ireland, Greece, and Japan. Imports in this category have declined since 1973. Imports of the same material but containing over 4% lime increased 18% in quantity and 22% in value. Total imports of crude and processed magnesite declined 15%, from 96,229 tons in 1976 to 81,412 tons in 1977.

Imports of specified magnesium compounds and compounds not specifically provided for were valued at $3,057,000, an increase of 35% over that of 1976.

Table 4.—U.S. exports of magnesite and magnesia, by country

Destination	Magnesite and magnesia, dead-burned				Magnesite, n.e.c., including crude caustic-calcined, lump or ground			
	1976		1977		1976		1977	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Argentina	3,319	$582	2,222	$449	60	$46	84	$68
Australia	--	--	17	15	731	624	467	401
Austria	754	171	--	--	6	4	5	4
Belgium-Luxembourg	--	--	--	--	46	29	42	22
Brazil	93	94	87	80	112	81	37	32
Canada	42,043	7,038	55,370	10,564	3,036	1,292	2,962	1,525
Chile	294	54	90	21	52	25	22	21
Colombia	29	14	8	8	54	43	79	58
Denmark	22	7	--	--	--	--	44	14
Finland	--	--	--	--	78	62	26	24
France	983	177	3,680	744	343	282	223	143
Germany, Federal Republic of	17,085	3,675	12,976	3,795	667	465	522	399
India	--	--	--	--	--	--	47	46
Iran	--	--	--	--	--	--	116	71
Israel	--	--	--	--	22	15	44	36
Italy	--	--	--	--	395	225	235	156
Japan	33	24	--	--	85	155	184	186
Korea, Republic of	--	--	6	4	9	8	56	45
Mexico	3,544	461	177	27	635	94	56	43
Netherlands	15	4	15	6	261	185	307	427
Netherlands-Antilles	4	2	--	--	--	--	--	--
New Zealand	16	15	59	63	133	127	177	175
Peru	--	--	--	--	23	21	7	6
Philippines	144	49	4	1	44	36	39	36
Poland	--	--	--	--	--	--	276	57
Singapore	--	--	--	--	--	--	8	6
South Africa, Republic of	183	180	113	121	172	86	168	91
Spain	3	3	--	--	273	48	175	88
Sweden	22	23	33	35	357	380	225	247
Switzerland	--	--	--	--	--	--	7	5
Taiwan	--	--	16	13	41	25	180	101
United Kingdom	478	401	1,522	481	496	380	707	515
Venezuela	--	--	4	7	1,586	517	4,409	1,196
Yugoslavia	--	--	--	--	23	21	23	21
Other	2,309	492	90	43	381	146	81	71
Total	71,373	13,466	76,489	16,477	10,121	5,422	12,040	6,336

Table 5.—U.S. imports for consumption of crude and processed magnesite, by country

Country	1976 Quantity (short tons)	1976 Value (thousands)	1977 Quantity (short tons)	1977 Value (thousands)
Lump or ground caustic-calcined magnesia:[1]				
Australia	1,501	$228	1,286	$189
Canada	7	2	--	--
Germany, Federal Republic of	--	--	2	(2)
India	5,427	406	4,073	294
Japan	175	20	103	41
Netherlands	203	27	103	17
Turkey	881	125	221	25
Total	8,194	808	5,788	566
Dead-burned and grain magnesia and periclase:				
Not containing lime or not over 4% lime:				
Austria	3,373	394	--	--
Canada	231	4	--	--
Czechoslovakia	--	--	44	7
Greece	33,094	5,638	18,327	3,009
Ireland	42,662	7,368	41,386	7,671
Japan	3,316	572	9,463	1,638
Netherlands	--	--	88	7
Total	82,676	13,976	69,308	12,332
Containing over 4% lime:				
Canada	410	47	253	28
Germany, Federal Republic of	1	2	--	--
Greece	--	--	5,918	622
Mexico	--	--	57	3
Netherlands	--	--	88	10
Spain	4,948	493	--	--
Total	5,359	542	6,316	663
Total dead-burned and grain magnesia and periclase	88,035	14,518	75,624	12,995

[1]In addition, crude magnesite was imported as follows: 1976—India, 5 short tons ($456), Japan, 10 short tons ($590), Mexico, 2 short tons ($519), and the United Kingdom, 3 short tons ($376); 1977— India, 13 short tons ($636), and the Republic of South Africa, 236 short tons ($10,596).
[2]Less than 1/2 unit.

Table 6.—U.S. imports for consumption of magnesium compounds

Year	Oxide or calcined magnesia Quantity (short tons)	Oxide or calcined magnesia Value (thousands)	Magnesium carbonate[1] (precipitated) Quantity (short tons)	Magnesium carbonate[1] (precipitated) Value (thousands)	Magnesium chloride (anhydrous) Quantity (short tons)	Magnesium chloride (anhydrous) Value (thousands)	Magnesium chloride (other) Quantity (short tons)	Magnesium chloride (other) Value (thousands)	Magnesium sulfate (epsom salts and kieserite) Quantity (short tons)	Magnesium sulfate (epsom salts and kieserite) Value (thousands)	Magnesium salts and compounds n.s.p.f.[2] Quantity (short tons)	Magnesium salts and compounds n.s.p.f.[2] Value (thousands)
1975	360	$148	63	$97	103	$42	50	$9	32,991	$1,070	2,999	$427
1976	299	332	80	108	217	158	428	108	23,139	1,109	2,874	451
1977	420	536	67	117	53	26	90	14	36,100	1,388	5,115	976

[1]In addition, magnesium carbonate not precipitated, was imported in 1975—6 short tons ($2,226); 1976—2 short tons ($915); 1977—33 short tons ($29,064).
[2]Not specifically provided for; includes magnesium silicofluoride or fluosilicate and calcined magnesium.

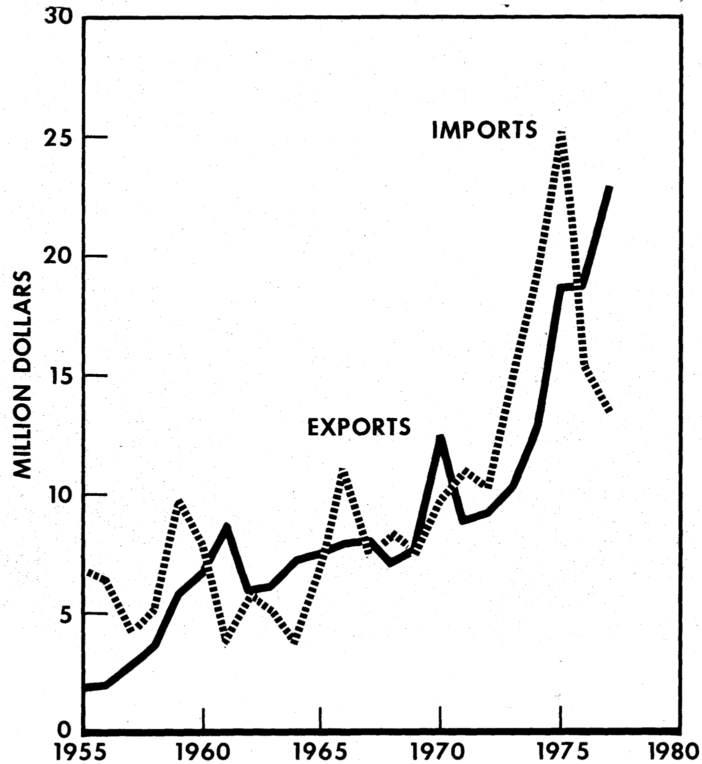


Figure 2.—Value of U.S. exports and imports of magnesia.

WORLD REVIEW

Greece.— The Financial Mining-Industrial & Shipping Corp. (FIMISCO) of the Scalistiri Group delayed its plans to construct a $50 million plant for the production of refractory-grade magnesia from seawater and dolomite. However, the engineering study for this project was completed in 1977. FIMISCO also canceled plans to develop magnesite mines on Lesbos Island.

FIMISCO began the production of Magflot, a briquetted, dead-burned magnesite produced from processed low-grade magnesite and wastes by proprietary technology, at the end of 1976 and continued production throughout 1977.

The Macedonian Magnesite Mining Industrial and Shipping Corp. (another Scalistiri Group Company) did not implement its authorization to construct a dead-burned magnesite plant similar to FIMISCO's operation. Construction of this plant was possible by the end of 1978.

The Scalistiri Group's total production of dead-burned magnesite and Magflot was 235,960 tons in 1977. The Scalistiri Group exported 150,000 tons of these refractory materials.

General Refractories' subsidiary, Magnomin General Mining Co., S.A., postponed its 1977 plans to install a new kiln at its Chalkidiki magnesite-processing facility. The firm began production of insulating board from low-grade, caustic-calcined magnesite, and wood for export to the Mediterranean and Middle East areas.

India.—On March 14, 1977, the Government temporarily relaxed its ban on calcined magnesite exports containing over 6.5% silica by approving the export of 9,072 tons during 1977. Dead-burned, raw and calcined magnesite containing over 9% silica remained exportable to all countries without any control.

United Kingdom.—Steetley Refractories

Ltd. opened a new section at its Hartlepool seawater magnesia plant at midyear. This section produced large grain, high density refractory magnesia using a new filtration method that eliminated calcination and pelletization processes. Annual production capacity of the new plant section was 40,000 tons.

Table 7.—Magnesite: World production by country[1]

(Short tons)

Country	1975	1976	1977[p]
North America:			
Mexico	43,567	25,558	[e]28,000
United States	W	W	W
South America:			
Brazil[2]	[r]191,477	215,917	[e]220,000
Colombia[e]	[r]865	[r e]900	[e]900
Europe:			
Austria	1,395,358	1,021,334	1,105,662
Czechoslovakia	729,729	718,706	[e]717,000
Greece	[r]1,601,368	1,415,730	1,146,903
Poland	29,597	28,219	[e]29,000
Spain	377,034	330,693	[e]330,000
U.S.S.R.[e]	1,980,000	1,980,000	2,040,000
Yugoslavia	534,952	431,003	380,297
Africa:			
Kenya	[r e]10	[r e]10	3,941
Rhodesia, Southern[e]	22,000	22,000	22,000
South Africa, Republic of	67,464	69,289	54,255
Sudan[e]	110	110	--
Tanzania[e]	(3)	(3)	--
Asia:			
China, People's Republic of[e]	1,100,000	1,100,000	1,100,000
India	[r]345,522	363,373	443,894
Iran[4]	17,600	5,500	[e]11,000
Korea, North[e]	[r]1,650,000	[r]1,650,000	[r]1,650,000
Pakistan	2,864	3,854	[e]4,000
Turkey	505,816	447,539	[e]450,000
Oceania:			
Australia	[r]17,866	16,001	[e]15,500
New Zealand	872	887	[e]880
Total	[r]10,614,071	9,846,623	9,753,232

[e]Estimate. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing individual company confidential data.

[1]Figures represent crude salable magnesite. In addition to the countries listed, Bulgaria and Canada produce magnesite, but output is not reported and available information is inadequate to make reliable estimates of output levels.

[2]Series revised to reflect output of marketable concentrates. Production of crude ore for 1970-77 was as follows in short tons: 1970—238,542; 1971—256,885; 1972—304,979; 1973—303,392; 1974—393,151; 1975—484,428; 1976—457,031; 1977—463,000 (estimate). Production of marketable concentrates for 1970-74 was as follows in short tons: 1970—114,000 (estimate); 1971—121,000 (estimate); 1972—144,515; 1973—142,884; 1974—190,114.

[3]Revised to zero.

[4]Year beginning March 21 of that stated.

TECHNOLOGY

Attrition grinding was investigated as a method to prepare foundry-sand-grade olivine from low-grade olivine sources such as such as dunite. The resulting concentrates met the Steel Founder's Society of America loss-of-ignition specifications. Studies indicated that the green and tensile strengths of the attrition-ground material were equivalent or superior to those of commercial materials. Metal casting molds from attrition-ground olivine produced better surface finishes that were attributed in part to increased grain sphericity.[2]

A report described the geology, reserves, and economic potential of an olivine deposit on the San Carlos Apache Reservation in Arizona.[3]

A paper described the history and processes used to recover magnesium compounds from seawater for processing into magnesium oxide for refractory use.[4]

[1]Physical scientist, Division of Nonferrous Metals.

[2]Lamont, W. E., G. V. Sullivan, E. G. Davis, and S. D. Sanders. Olivine Foundry Sand From North Carolina Dunite by Differential Grinding. Preprint No. 77 H 369. Soc. of Min. Eng., AIME, Salt Lake City, Utah, 22 pp.

[3]Vuich, J. S., and R. T. Moore. Olivine Resources on San Carlos Apache Reservation. Arizona BuMines Fieldnotes No. 2, July 1977, pp. 1-10.

[4]Gilpin, W. C., and N. Heasman. Recovery of Magnesium Compounds From Sea Water. Chem. and Ind., No. 14, July 16, 1977, pp. 567-572.

Manganese

Gilbert L. DeHuff[1]

There continued to be neither production nor shipments of manganese ore containing 35% or more manganese in the United States in 1977. Some manganiferous ores of lower grade were, however, produced and shipped from Minnesota, New Mexico, and South Carolina. Imports of ferromanganese continued at the record high level of 1976, and both domestic production and shipments from furnaces dropped off drastically. The price of the imported high-carbon alloy was well below the published producer price of $399.50 that prevailed for most of the year. Deliveries of ore continued to be made by the General Services Administration (GSA) from Government stockpile excesses. The new stockpile goals established in 1976 were suspended early in 1977 but were reaffirmed in October.

Legislation and Government Programs.—The new stockpile goals established by GSA on October 1, 1976, were suspended in February 1977, and a moratorium was imposed on requests for new acquisitions and disposals. On October 7, 1977, it was announced that the goals had been reaffirmed and that the moratorium was being lifted with the provision that the overall goals would be reviewed at least annually. As reported by GSA, sales of Government manganese stockpile excesses in calendar year 1977 consisted of 50,288 short tons of metallurgical ore of nonstockpile grade and 3,318 tons of stockpile-grade natural battery ore.

Decreases in Government stockpile physical inventories for manganese items were all in ore, as follows in short tons, gross weight: Stockpile-grade natural battery ore, 19,466 tons to 230,975 tons; chemical ore, 10,053 tons to 220,810 tons; metallurgical ore, nonstockpile grade, 31,726 tons to 1,287,304 tons; and metallurgical ore, stockpile grade, 759,279 tons to 4,210,249 tons. Inventory adjustments increased the reported inventories for synthetic dioxide 5 tons to 3,011 tons, and those for high-carbon ferromanganese 6 tons to 599,763 tons. Both inventories for metallurgical ore at the end of 1977 included material sold under long-term contract but not yet shipped.

Public Law 95-95, the Clean Air Act Amendments of 1977, signed by President Carter on August 7, limited the manganese concentration in gasoline to 0.0625 gram per gallon of fuel effective November 30, 1977. Effective September 8, the California Air Resources Board banned the addition of manganese to unleaded gasoline.

Table 1.—Salient manganese statistics in the United States

(Short tons)

	1973	1974	1975	1976	1977
Manganese ore (35% or more Mn):					
Production (shipments)	239	--	--	--	--
Imports, general	1,509,793	1,225,033	1,574,045	1,316,812	930,947
Consumption	2,140,058	1,880,176	1,818,983	1,600,873	1,358,811
Manganiferous ore (5% to 35% Mn):					
Production (shipments)	203,055	272,908	159,225	256,633	215,893
Ferromanganese:					
Production	683,075	544,361	575,809	482,662	334,134
Exports	8,574	7,011	32,300	6,789	6,051
Imports for consumption	390,591	421,222	397,212	537,409	534,423
Consumption	1,116,602	1,115,395	881,527	896,775	886,299

DOMESTIC PRODUCTION

There was neither domestic production, nor were there any shipments, of manganese ore, concentrate, or nodules, containing 35% or more manganese. Ferruginous manganese ores or concentrates containing 10% to 35% manganese were produced and shipped in New Mexico and in the Cuyuna Range of Minnesota. Manganiferous schist, clay, or other earthy material associated with the manganiferous member of the Battleground schist of the Kings Mountain area was mined in Cherokee County, S.C., by brick manufacturers or contractors for use in coloring brick. The material reported in table 2 ranged in manganese content from 5% to 15%, but averaged less than 10%.

Table 2.—Manganese and manganiferous ore shipped[1] in the United States, by State

(Short tons)

Type and State	1976		1977	
	Gross weight	Manganese content	Gross weight	Manganese content
Manganese ore (35% or more Mn, natural)	--	--	--	--
Manganiferous ore:				
Ferruginous manganese ore (10% to 35% Mn, natural:				
Minnesota	202,271	25,891	166,440	22,286
New Mexico	--	--	29,120	2,970
Total	202,271	25,891	195,560	25,256
Manganiferous iron ore (5% to 10% Mn, natural):				
New Mexico	45,362	4,445	--	--
South Carolina[2]	[e]9,000	[e]660	20,333	1,913
Total	54,362	5,105	20,333	1,913
Total manganiferous ore	256,633	30,996	215,893	27,169
Value of manganese and manganiferous ore	$2,260,209	XX	$2,248,825	XX

[e]Estimate. XX Not applicable.

[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]Miscellaneous ore.

CONSUMPTION, USES, AND STOCKS

In the production of raw steel (ingots, continuous- or pressure-cast blooms, billets, slabs, etc., and including steel castings), consumption of manganese as ferroalloys, metal, and direct-charged ore, as reported to the Bureau of Mines by consumers, was 12.2 pounds per short ton of raw steel produced. Of this total, 10.6 pounds was contained in ferromanganese; 1.3 pounds, silicomanganese; 0.02 pound, spiegeleisen; 0.2 pound, metal; and 0.03 pound, manganese ore (containing 35% or more manganese). The comparable 1976 total, on the same basis, was also 12.2 pounds with ferromanganese at 10.6, silicomanganese at 1.4, spiegeleisen at 0.01, metal at 0.2, and ore at 0.01. In addition to the aforementioned consumption of manganese in 1977, there was consumed per ton of raw steel produced approximately 1.3 pounds of manganese contained in manganese ore used in making pig iron or equivalent hot metal. The comparable figures for 1976 and 1975 were 1.0 and 1.3 pounds, respectively.

In late December, Union Carbide Corp. shut down the Tenn-Tex plant at Houston, Tex., in which it had been producing ferromanganese and silicomanganese since 1974 under a lease agreement that expires in the middle of 1980. High imports of these alloys at low prices, coupled with worldwide low demand, created an oversupply situation with little prospect for improving the plant's competitive position in the near future. The same problems, together with rising costs and freight rates, faced all producers of these alloys.

Electrolytic Manganese Metal.—All of the manganese metal produced domestically and virtually all of that imported was electrolytic metal. Virtually all of the metal consumed was electrolytic metal, although some low-carbon ferromanganese (such as the domestically produced "Massive Manganese" or the imported "Gimel Metal") and some manganese-aluminum additives may have been erroneously reported by consumers as manganese metal. The metal that was used to make manganese-aluminum additives is included in table 4 under the "Alloys (excludes alloy steels and superalloys)" category. These additives are not knowingly included in the table, it being desired to report consumption at the metal rather than the additive level of the usage cycle.

Production of electrolytic manganese metal increased to 24,390 short tons from 23,966 tons in 1976. Production was by the same three plants of the same three companies: Foote Mineral Co., New Johnsonville, Tenn.; Kerr-McGee Chemical Corp., Hamilton (Aberdeen), Miss.; and Union Carbide Corp., Marietta, Ohio.

Table 3.—Consumption and industry stocks of manganese ore[1] in the United States

(Short tons)

	Consumption		Stocks Dec. 31, 1977
	1976	1977	
By use:			
Manganese alloys and metal	1,263,531	926,635	1,169,305
Pig iron and steel	143,761	200,803	158,634
Dry cells, chemicals and miscellaneous	193,581	231,373	297,641
Total	1,600,873	1,358,811	1,625,580
By origin:			
Domestic	81,607	61,152	95,711
Foreign	1,519,266	1,297,659	1,529,869
Total	1,600,873	1,358,811	1,625,580

[1]Containing 35% or more manganese (natural).

Table 4.—Consumption, by end use, and industry stocks of manganese ferroalloys and metal in the United States in 1977

(Short tons, gross weight)

End use	Ferromanganese		Silico-manganese	Spiegel-eisen	Manganese metal[1]
	High carbon	Medium and low carbon			
Steel:					
Carbon	583,524	103,869	81,293	5,862	7,927
Stainless and heat-resisting	10,312	1,782	7,502	--	3,257
Full alloy	81,391	17,657	26,389	130	957
High-strength low-alloy	49,946	10,295	7,947	--	817
Electric	303	137	474	--	9
Tool	571	74	55	--	450
Unspecified	279	499	2,803	--	--
Total steel	726,326	134,313	126,463	5,992	13,417
Cast irons	18,693	1,637	16,514	838	137
Superalloys	205	21	W	--	204
Alloys (excludes alloy steels and superalloys)	2,523	1,421	2,412	4	12,246
Miscellaneous and unspecified	364	796	2,370	--	970
Total consumption	748,111	138,188	147,759	6,834	26,974
Stocks, Dec. 31:					
Consumer	147,779	16,039	14,484	W	2,965
Producer	101,054	31,592	36,161	W	6,023
Total stocks	248,833	47,631	50,645	134	8,988

W Withheld to avoid disclosing company proprietary data, included in "Miscellaneous and unspecified" where applicable.
[1]Virtually all electrolytic.

Table 5.—Ferromanganese and silicomanganese produced in the United States and manganese ore[1] consumed in their manufacture

Year	Production				Manganese ore[1] consumed (gross weight, short tons)			
	Ferromanganese			Silicomanganese (gross weight, short tons)	Foreign[2]	Domestic[2]	Per ton of ferromanganese made[3]	Per ton of ferromanganese and silicomanganese made[3 4]
	Gross weight (short tons)	Manganese content: Percent	Manganese content: Short tons					
1973	683,075	78.8	538,119	184,000	1,648,806	25,912	2.4	1.9
1974	544,361	78.0	424,405	196,000	1,348,425	55,822	2.5	1.8
1975	575,809	78.9	454,309	143,000	1,389,300	48,011	2.4	1.9
1976	482,662	79.0	381,328	129,000	1,208,336	53,632	2.5	2.0
1977	334,134	78.8	263,136	120,000	889,296	35,769	2.6	1.9

[1]Containing 35% or more manganese (natural).
[2]Includes ore used in producing silicomanganese and metal.
[3]Includes ore used in producing silicomanganese.
[4]Ratio of ore consumed to ferromanganese produced if silicomanganese is considered a special grade of ferromanganese.

Ferromanganese.—The only domestic production of ferromanganese in blast furnaces in 1977 was at the Johnstown, Pa., plant of Bethlehem Steel Corp. A disastrous flood on July 19 halted production and seriously damaged the furnace and its auxiliary equipment. There was no further production for the remainder of the year. Because of oversupply of the alloy and low prices relative to costs, there was little prospect for resumption of production in the near future. Electric furnaces were used to produce ferromanganese for shipment by five companies in six plants: Airco Alloys Div., Airco Inc., Calvert City, Ky.; Ohio Ferro-Alloys Corp., Philo, Ohio; Roane Electric Furnace Co. (Englehard Minerals & Chemicals Corp.), Rockwood, Tenn.; Tenn-Tex Alloy Corp. of Houston, Houston, Tex. (under lease to Union Carbide Corp.); and Union Carbide Corp., Marietta, Ohio, and Portland, Oreg. Fused-salt electrolysis continued to be used by Chemetals Div., Diamond Shamrock Corp., Kingwood, W.Va., to make low carbon ferromanganese sold under the trade name of Massive Manganese. Shipments of ferromanganese from U.S. furnaces totaled 338,000 tons, compared with 494,000 tons in 1976 and 556,000 tons in 1975.

The ferromanganese production reported in the various tables of this chapter is net production; that is, the quantity of ferromanganese produced for shipment outside the producing ferroalloy facility. It does not include the remelt material; that is, the fines, offgrade, or other ferromanganese output of the furnace that was fed back to the furnace or lost in the plant, and which is included in gross production data reported by the furnace operator. It does include ferromanganese made for use in the company's steel furnaces at the same or other location.

Table 6.—Manganese ore used in producing ferromanganese, silicomanganese, and manganese metal in the United States in 1977, by source of ore

Source	Gross weight (short tons)	Mn content, natural (percent)
Domestic[1]	35,769	44
Foreign:		
Africa	304,132	47
Australia	77,743	49
Brazil	367,692	47
Cuba[1]	25,287	48
India	38,106	46
Mexico	23,184	39
U.S.S.R.[1]	4,267	46
Unidentified	48,885	--
Total	925,065	47

[1]Most, if not all, from U.S. Government excess stockpile disposals.

Silicomanganese.—Domestic production of silicomanganese decreased to 120,000 short tons from the 129,000 tons produced in 1976. This is net production produced for shipment and does not include silicomanganese produced for use as an intermediate in the same plant for the production of medium- or low-carbon ferromanganese. Silicomanganese shipments from furnaces were 122,000 tons, compared with 132,000 tons in 1976 and 126,000 tons in 1975. Five companies used eight plants to produce silicomanganese for shipment in 1977: Airco Alloys Div., Airco Inc., Calvert City, Ky., and Theodore (Mobile), Ala.; Ohio Ferro-Alloys Corp., Philo, Ohio; Roane Electric

Furnace Co. (Englehard Minerals & Chemicals Corp.), Rockwood, Tenn.; Tenn-Tex Alloy Corp. of Houston, Houston, Tex. (under lease to Union Carbide Corp.); and Union Carbide Corp., Alloy, W.Va., Marietta, Ohio, and Portland, Oreg. End-use consumption of silicomanganese—that is, consumption outside the ferroalloy plants—was 16.7% that of ferromanganese compared with 17.2% in 1976.

Spiegeleisen.—There was no domestic production of spiegeleisen.

Pig Iron.—A total of 543,000 short tons of manganese-bearing ores containing 5% or more manganese (natural) was consumed in the production of pig iron (or its equivalent hot metal). Domestic sources supplied 335,000 tons, of which 274,000 tons was manganiferous iron ore containing 5% to 10% manganese, 57,000 tons was ferruginous manganese ore containing 10% to 35% manganese, and 4,000 tons was manganese ore containing 35% or more manganese that was apparently obtained from GSA through its program for disposal of stockpile excesses. Foreign sources supplied 208,000 tons, of which 16,000 tons was ferruginous manganese ore and 192,000 tons was manganese ore containing 35% or more manganese.

Battery and Miscellaneous Industries.—The ore reported in table 3 includes that consumed in making synthetic manganese dioxide by both electrolytic and chemical means, but it does not include consumption of the synthetic dioxide. Although some synthetic dioxide is used for chemical purposes, most of it is used in the manufacture of dry-cell batteries, particularly for the manganese-alkaline type, premium or heavy-duty Leclanché (manganese dioxide-ammonium chloride-zinc) cells, and as a blend with natural ore in ordinary Leclanché cells.

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.

Carus Chemical Co., the world's largest producer of potassium permanganate and the only producer in the United States, announced that it was expanding its facilities to be able to produce more than 30 million pounds per year after expansion is completed in late 1978. It was also reported to have begun the production of anhydrous manganese chloride on a pilot plant basis to investigate the feasibility of large-scale production. Manganese chloride is used to make the gasoline anti-knock additive, methylcyclopentadienyl manganese tricarbonyl (MMT).

Probably the first, at least in recent years, comprehensive account of the nonmetallurgical uses of manganese and the worldwide associated industry was published.[2]

PRICES

Manganese Ore.—All manganese ore prices are negotiated. In addition to the manganese content, they are dependent on the chemical analysis otherwise, the physical character, quantity offered, delivery terms, fluctuating ocean freight rates, insurance, inclusion or exclusion of duties if applicable, needs of the buyer, and the general availability of ores that will fill these particular needs. Trade journal quotations reflect the paper's evaluation of the market. A representative contract price for 1977 delivery of metallurgical ore containing 46% to 48% manganese was $1.48 per long ton unit, c.i.f. U.S. ports, favoring the high side of the content range. A comparable representative price for 1976 was $1.45. Contracts were not finalized until the year was well advanced, later than in 1976. As in the earlier year, spot purchases were not a factor in the 1977 market. Contracts for delivery in 1978 had not been negotiated by yearend 1977.

Manganese Alloys.—The published domestic producer price for standard high-carbon ferromanganese, having a minimum manganese content of 78%, was cut by $25.50 in March to $399.50 per long ton of alloy f.o.b. shipping point. This list price prevailed for the remainder of the year. However, because of low demand and heavy imports, it was reportedly being discounted to $350 or lower. Prices for imported alloy of the same manganese content (although not necessarily comparable in quality, delivery terms, or other respects) fell off during the year from a January range of $340 to $355 per long ton, f.o.b. Pittsburgh or Chicago warehouses, to $305 to $320 in December. Some offerings were reportedly as low as $290 or less.

Manganese Metal.—Also because of low demand and heavy imports, domestic producers of electrolytic manganese metal were reportedly selling the metal at discounts of 4 to 6 cents below the unchanged list price of 58 cents per pound, f.o.b. producer plant, shipments of 30,000 pounds or more, for the standard and comparable grades of chips packed in pallet boxes. The bulk list price continued at 57 cents throughout the year.

FOREIGN TRADE

Ferromanganese exports totaled 6,051 short tons valued at $3,391,108, compared with 6,789 tons valued at $3,461,560 in 1976. Of the 1977 total, Canada took 2,661 tons; the Netherlands, 1,655 tons; the Federal Republic of Germany, 827 tons; Sweden, 416 tons; Ghana, 216 tons; Venezuela, 108 tons; Guatemala, 66 tons; Colombia, 46 tons; the Republic of South Africa, 20 tons; Brazil, 12 tons; Bolivia, 11 tons; Belgium, 6 tons; Italy, 5 tons; and Malaysia, 2 tons. Exports classified as "manganese and manganese alloys, wrought or unwrought, and waste and scrap" totaled 2,953 tons with a value of $3,207,681 after deducting 1,176 tons of silicomanganese exported to Canada in January that was reported in this class instead of under "ferroalloys, n.e.c." Instructions for the category in which to report silicomanganese have not been clear for a number of years, however, and it has been reported under various categories. It is probable that reported tonnages of the "manganese and manganese alloys, wrought or unwrought, and waste and scrap" category have for some time included some silicomanganese. This classification includes electrolytic manganese metal and manganese-copper alloys, but it does not include ferromanganese and was not intended to include silicomanganese. The new 1978 export schedule of the Bureau of the Census, Schedule B, places silicomanganese in a class by itself so that it will be reported separately beginning with January 1978 data. Exports of ore and concentrate containing more than 10% manganese amounted to 138,250 tons valued at $9,221,263, compared with 127,971 tons valued at $7,509,928 in 1976. Of the 1977 total, large quantities having relatively low average values were distributed as follows: Canada, 37,000 tons; Mexico, 32,000 tons; Norway, 28,000 tons; and Spain, 18,000 tons. Some of these tonnages appear to have been metallurgical ore obtained from GSA sales of Government excess stocks. Most of the remainder is believed to have been imported manganese dioxide ore that may or may not have been subjected to grinding, blending, or otherwise classifying in the United States.

The average grade of imported manganese ore was 49% manganese in 1977, the same as in 1976. Gabon supplied 53% in 1977; Brazil, 25%; and Mexico, 9%. The Republic of South Africa, Morocco, Zaire, and Australia each provided about 3% of the total manganese ore imported. A small quantity of manganiferous ore (more than 10% but less than 35% manganese) was imported from Mexico.

Ferromanganese imports were at the same high level as that of 1976. The Republic of South Africa and France supplied 53% of the total in 1977 in almost equal quantities. Silicomanganese imports for consumption totaled 87,900 short tons containing 58,329 tons of manganese. Sources and gross weight tonnages were reported as follows: Norway, 21,865; Brazil, 17,650; the Republic of South Africa, 12,258; Mexico, 7,621; Japan, 7,394; Yugoslavia, 6,961; France, 5,338; Portugal, 4,382; Spain, 2,000; Canada, 1,856; Gabon 561, and the Federal Republic of Germany, 14. Imports for consumption classified as unwrought manganese metal, and metal waste and scrap, totaled 6,841 short tons, compared with 7,082 tons in 1976 and 4,378 tons in 1975. Of the 1977 total, 6,062 tons was from the Republic of South Africa, 497 tons from Canada, 259 tons from Japan, and 22 tons from the People's Republic of China. It is most probable that the metal from Canada originated in the Republic of South Africa. However, of the 497 tons from Canada only 11 tons had high enough value to be electrolytic manganese metal, the remainder ranging in value from 11 to 2 cents per pound. Imports of spiegeleisen in 1977 totaled 60 short tons, all from Mexico.

Table 7.—U.S. imports[1] of manganese ore (35% or more Mn), by country

Country	1976			1977		
	Gross weight (short tons)	Mn content (short tons)	Value (thousands)	Gross weight (short tons)	Mn content (short tons)	Value (thousands)
Australia	234,636	117,367	$12,048	25,551	13,834	$1,699
Brazil	333,479	161,108	18,033	231,742	111,639	11,943
Congo[2]	26,572	13,286	2,238	--	--	--
Gabon[3]	513,078	256,412	31,731	490,442	245,221	34,032
Mexico	39,831	18,485	1,994	87,752	34,882	2,957
Morocco	25,782	18,688	1,545	31,606	17,070	2,302
South Africa, Republic of	137,316	60,963	5,890	34,454	16,882	1,928
Zaire	6,118	2,936	148	29,400	14,700	1,494
Total	1,316,812	649,245	73,627	930,947	454,228	[4]56,357

[1]Quantities for general imports and imports for consumption were identical.
[2]Actually from Gabon.
[3]In addition in 1976, Gabon imports reported as Congo were 26,572 tons (gross weight).
[4]Data do not add to total shown because of independent rounding.

Table 8.—U.S. imports for consumption of ferromanganese, by country

Country	1976			1977		
	Gross weight (short tons)	Mn content (short tons)	Value (thousands)	Gross weight (short tons)	Mn content (short tons)	Value (thousands)
Belgium-Luxembourg	33,136	25,338	$9,834	416	308	$119
Brazil	7,578	5,802	1,855	37,977	29,161	9,551
Canada	10,566	8,294	3,902	28,523	22,155	7,316
Chile	95	74	31	--	--	--
France	119,762	92,556	38,314	140,392	108,638	40,690
Germany, Federal Republic of	20	17	16	23,623	18,362	6,123
India	12,115	9,140	2,965	5,559	4,236	1,422
Italy	439	351	230	--	--	--
Japan	114,111	88,680	40,786	45,370	36,364	17,976
Mexico	44	33	19	26,188	20,345	7,195
Norway	27,770	21,775	7,594	19,278	14,945	5,272
Portugal	10,957	8,340	2,485	35,467	27,231	9,225
South Africa, Republic of	174,183	135,599	46,636	141,375	110,801	40,596
Spain	19,413	15,942	8,188	15,947	12,579	6,480
Taiwan	5,677	4,288	1,403	5,288	3,968	1,530
United Kingdom	--	--	--	1	(1)	(1)
Yugoslavia	1,543	1,204	440	9,016	6,986	2,168
Total[2]	537,409	417,433	164,698	534,423	416,081	155,662

[1]Less than 1/2 unit.
[2]Data may not add to totals shown because of independent rounding.

Imports for consumption classified as "manganese compounds, other" totaled 5,059 short tons compared with 3,467 tons in 1976. The sources, gross weights, and average values per pound in 1977 follow: Japan, 3,827 tons (38 cents); Belgium, 814 tons (34 cents); the United Kingdom, 209 tons (4 cents); Ireland, 140 tons (40 cents); the Federal Republic of Germany, 62 tons (84 cents); Greece, 4 tons (44 cents); and Canada, 3 tons (12 cents). The imports from Japan, Belgium, Ireland, and Greece appear to have consisted largely, if not entirely, of synthetic manganese dioxide. Manganese sulfate imports totaled 52 tons, of which 30 tons was from Japan and 22 tons was from the Netherlands.

Tariffs.—The duty on manganese ore from most nations, 0.12 cent per pound of contained manganese, remained suspended; the statutory rate continued at 1 cent per pound of contained manganese. The statutory rate continued to apply to ore from the U.S.S.R. and the People's Republic of China. The respective rates of duty for metal and the principal manganese ferroalloys remained unchanged. Qualifying developing nations continued to receive the benefit of duty-free treatment under the Generalized System of Preferences (GSP) with respect to U.S. imports of ferromanganese and silicomanganese.

WORLD REVIEW

In June, the United States participated in an intergovernmental meeting of manganese producers and consumers convened for the purpose of considering problems in marketing. The meeting was held at Geneva, Switzerland, under the auspices of the United Nations Conference on Trade and Development (UNCTAD). Manganese was 1 of the 18 commodities identified in the Integrated Programme for Commodities as set forth in Resolution 93(IV) of the 4th UNCTAD Conference held at Nairobi, Kenya, in May 1976. The general objective of this resolution was to improve the terms of trade of developing countries and to eliminate the economic imbalance between developed and developing countries. As a first step, Resolution 93(IV) called for preparatory meetings on individual commodities. This was the first such manganese meeting held under the resolution. No conclusions were reached as to the identification of specific problems, although some reference was made to worldwide ferromanganese production overcapacity.

The various consortia interested in development of deepsea manganese nodule deposits continued active. United States Steel Corp., a member of the group managed by Deepsea Ventures, Inc., was definitely interested in recovery of manganese from the nodules, and there were indications that some of the other consortia might be giving more consideration to manganese recovery than had been the case previously. The joint venture to develop technology for mining and processing seafloor manganese nodules headed by Lockheed Corp.'s subsidiary, Lockheed Missiles & Space Co., Inc., Sunnyvale, Calif., however, was not interested in manganese, at least initially; emphasis was on the nickel content. This joint venture was formalized as Ocean Minerals Co. with headquarters in Mountain View, Calif. Other participating members were Amoco Minerals Co., Chicago, Ill., a subsidiary of Standard Oil Co. of Indiana; Billiton B.V., The Hague, the Netherlands, a part of the Royal Dutch-Shell Group; and BKW Ocean Minerals B.V., Papendrecht, the Netherlands, a subsidiary of Bos Kalis Westminster Group.

Argentina.—Manganese ore imports were 40,000 metric tons in 1976 compared with 53,000 tons in 1975.

Australia.—The newly completed expansion of the Bell Bay, Tasmania, plant of Tasmanian Electro Metallurgical Co. Pty. Ltd. (TEMCO) was officially opened by the Premier of Tasmania on February 25. This expansion increased capacity for production of ferromanganese and silicomanganese to 135,000 metric tons per year from an annual capacity of 45,000 tons of ferromanganese and 21,500 tons of silicomanganese.[3] Preliminary data indicated that metallurgical ore produced in Australia in 1977 had an average manganese content of 47.7% compared with 48.1% for 1976.

Brazil.—Despite the fact that litigation over ownership was still pending, mining was started in September 1976 at the Urucum mine in Mato Grosso by Urucum Mineração S.A., the new company in which the Government-owned Cia. Vale do Rio Doce S.A. (CVRD) has a one-third interest.[4] With an accumulation of stocks and a decline in export sales, Indústria e Comércio de Minerios, S.A. (ICOMI) stopped production of manganese pellets about the beginning of August 1977 at its plant in Amapá Territory; the plant remained closed for the balance of the year. Large manganese ore deposits, variously estimated at 25 to 60 million tons of ore and averaging 40% or more manganese, have been found at or near Carajas, Pará, site of the very large iron ore deposits that were discovered several years ago by United States Steel Corp. and in which CVRD continues to be interested. Development of the manganese deposits is a likely possibility after mining of the iron ores begins. An invitation for bids for construction of the first section of the necessary railroad was issued in late 1977 or early 1978.

Brazilian exports of ferromanganese, consisting almost entirely of high-carbon ferromanganese, were 34,000 metric tons in 1977, compared with 13,000 tons in 1976 and 9,000 tons in 1975. Silicomanganese exports for 1977, 1976, and 1975 were 23,000, 14,000, and 5,000 tons, respectively.[5] In 1976, production of ferromanganese totaled 98,000 tons; that of silicomanganese totaled 65,000 tons.

Table 9.—Manganese ore: World production by country

(Short tons)

Country[1]	Percent Mn[e]	1975	1976	1977[p]
North America: Mexico[2]	35+	472,295	499,579	536,408
South America:				
Argentina	25-30	34,588	58,517	58,722
Bolivia[2 3]	28-54	1,362	13,521	4,770
Brazil[4]	38-50	2,376,527	1,869,738	[e]990,000
Chile	36-40	22,064	26,058	19,844
Peru	26-38	1,801	2,254	--
Europe:				
Bulgaria	30-	38,600	44,100	[e]44,100
Greece	50	[r]9,143	9,075	8,631
Hungary	18-28	201,023	181,963	177,061
Italy	30-	--	4,917	10,267
U.S.S.R.[5]	35	9,324,000	9,520,000	[e]9,370,000
Yugoslavia	30+	18,657	20,944	22,000
Africa:				
Egypt	35+	[r]3,947	4,691	4,225
Gabon	50-53	[r]2,474,932	2,443,556	2,040,187
Ghana	30-50	450,560	343,780	294,618
Morocco	50-53	144,344	129,305	125,164
South Africa, Republic of	30+	6,359,262	6,009,835	5,564,411
Sudan	48	--	505	496
Zaire	30-57	340,090	200,824	45,216
Asia:				
China, People's Republic of[e]	30+	1,100,000	1,100,000	1,100,000
India[6]	10-54	[r]1,738,184	1,940,066	1,955,498
Indonesia	47-56	15,082	10,839	6,587
Iran[7]	33+	39,700	44,100	44,100
Japan	26-44	174,089	156,244	138,931
Korea, Republic of	40	3,483	1,524	732
Pakistan	35-	[r]79	71	[e]65
Philippines	44+	--	11,658	22,706
Thailand	46-50	27,463	55,364	84,836
Turkey	30-46	[r]38,606	37,239	[e]41,300
Oceania:				
Australia	37-53	1,713,992	2,374,560	1,528,614
New Hebrides	40-44	51,279	[8]38,664	[8]27,246
Total	NA	[r]27,175,152	27,153,491	24,266,735

[e]Estimate. [p]Preliminary. [r]Revised. NA Not available.

[1]In addition to the countries listed, Colombia, Cuba, and the Territory of South-West Africa (Namibia) may have produced manganese ore and/or manganiferous ore, but available information is inadequate to make reliable estimates of output levels. Low grade ore not included in this table has been reported as follows in short tons: Czechoslovakia (about 17% Mn) 1975—1,101, 1976—1,212, 1977—1,003; Malaysia (grade unspecified but apparently a manganiferous ferruginous ore) 1975—146,947, 1976—103,741, 1977—50,040; Romania (about 22% Mn) 1975—[e]155,000, 1976—[e]155,000, 1977—[e]155,000; the Republic of South Africa (15% to 30% Mn, in addition to material listed in table) 1975—123,131, 1976—56,178, 1977—266,390.

[2]Estimated on the basis of reported contained manganese.

[3]Exports.

[4]Figures are the sum of: 1) sales of direct shipping manganese ore, and 2) production of beneficiated ore, both as reported in the 1975 and 1976 editions of Anuario Mineral Brasileiro.

[5]Source: The National Economy of the U.S.S.R., Central Statistical Administration, Moscow. Grade represents the annual averages obtained from reported metal contents of the gross weights shown in the table.

[6]Much of India's production grades below 35% Mn; recent details on output by grade are not available, but in 1974, 71% of total exports of 1,140,453 short tons were below 35% Mn.

[7]Reported as if data are for calendar years, but may actually represent output for Iranian calendar years beginning March 21 of the year stated.

[8]Japanese imports.

Canal Zone.—A total of 513,000 metric tons of manganese ore and concentrate passed through the Panama Canal in 1976, almost equally divided as to direction. The 1975 total was 527,000 tons.

European Economic Community.—Imports from countries outside the EEC were reported to amount to approximately 45% of the Community market for high-carbon ferromanganese.[6]

Gabon.—Production of battery- and chemical-grade manganese ore in 1977 was 78,000 metric tons with an average manganese dioxide content of 83%. Although track-laying on the Transgabon Railroad began in mid-1977, construction was reported to be as much as 1-1/2 to 2 years behind schedule, suggesting that it might be sometime in 1983 before the Libreville-Franceville portion would be in operation.

Germany, Federal Republic of.—Production of ferromanganese in 1977 consisted of 175,000 metric tons made in blast furnaces plus 33,000 tons made in electric furnaces.

Hungary.—The Urkut manganese mines in Transdanubia were supplying 28,000 metric tons of "enriched" ore to Poland in 1977. They have made deliveries of ore to Czechoslovakia and the German Democratic Republic for several years.[7]

India.—Using a process developed by the National Metallurgical Laboratory employing manganese ore of medium grade and waste ferrous sulfate-sulfuric acid solution, a 1,000-metric-ton-per-day synthetic manganese dioxide plant reportedly began operating in the southern part of the country at Trivandrum.[8] Production of ferromanganese in 1977 was 167,000 metric tons; silicomanganese production was 2,500 tons.

Indonesia.—Reported 1977 manganese ore production had an average manganese dioxide content of 87.7%. The greater part of this production was from small mines operated by companies owned by the West Java and Central Java provincial governments, but, apparently, there was appreciable unreported production from other small mines. The Indonesian deposits are small and mining operations are highly labor intensive, not being adaptable to mechanized methods of mining except for the use of bulldozers. Underground operations are manual operations except for some use of explosives. The ore is subject to a royalty of 30 cents per ton and an export tax of 50 cents per ton. The bulk of production is believed to have been exported to Japan and Taiwan, with the rest used domestically to produce dry-cell batteries. The firm, P.D. Perusahaan Pertambangan Yogyakarta, reportedly signed a contract with a Japanese firm to assist in the development of a mine to produce 10,000 metric tons per year. However, foreign participation in manganese mining is not allowed on Java, Madura, or Bali.

Japan.—Production of ferromanganese in 1977 was 527,000 metric tons; silicomanganese, 334,000 tons; electrolytic manganese metal, 7,267 tons; and synthetic manganese dioxide, 28,549 tons. The manganese ore produced in 1977 had an average manganese content of 26.0%. There was no production of battery- or chemical-grade natural dioxide ore.

Imports of manganese ore in 1976 and 1975 were from the following sources, in metric tons (1975 figures in parentheses): Republic of South Africa, 1,266,000 (1,607,000); Australia, 804,000 (655,000); India, 564,000 (671,000); Mexico, 129,000 (130,000); the U.S.S.R., 101,000 (178,000); and other, 491,000 (499,000).

Malagasy Republic.—Production of rhodonite in 1976 was 3,300 kilograms; exports were 500 kilograms.

Mexico.—With installation of two 33-megavoltampere (MVA) furnaces Cía. Minera Autlán, S.A. de C.V., increased its annual capacity to more than 107-MVA or more than 100,000 metric tons per year of ferromanganese, plus some silicomanganese and ferrosilicon production. Ferroaleaciones de Mexico, S.A., added a second furnace of 7-MVA capacity to its existing 19-MVA capacity to increase its ability to produce high-carbon ferromanganese to more than 50,000 tons per year. Mexico's third producer of ferromanganese, Ferralver, S.A., brought its annual capacity to 15-MVA and 23,000 tons of high-carbon ferromanganese.[9]

Morocco.—All manganese ore produced in 1976 and 1977 was chemical grade. That produced in 1977 had an average manganese dioxide content of 80%.

New Hebrides.—Le Manganese de Vaté, owned 87-1/2% by Southland Mining Ltd., Sydney, Australia, continued to mine the Forari manganese deposit, operating two 10-hour shifts 7 days per week with 110 employees, virtually all Pacific Islanders. Two ore bodies were being mined in early 1978, 5 and 7 kilometers from the washing plant. Overburden was from zero to a few feet in thickness, and was stripped from the deposit by bulldozers and a 2-1/2 yard dragline after dense tropical vegetation had been cleared away. A 7-cubic-yard front-end loader was used to load the trucks, five of which were used in transporting the ore to the crushing and washing plant where coral and clay were washed out. About 500 tons per week of tailing with a 30% manganese content was being washed into the bay, and consideration was being given to retrieval of this sand for concentration to a 40% manganese product. An annual contract with a Japanese commodity broker calls for shipment of 36,000 to 44,000 metric tons of concentrate subject to changing supply and demand conditions. The price in early 1978 was US$35 per ton for concentrate with a 40% manganese content. The concentrate normally contains from 40% to 42% manganese and is a metallurgical grade. Shipments are loaded out once every 6 or 7 weeks in 8,000 to 11,000 deadweight-ton ships. Reserves were estimated sufficient for 3 more years' operation at the current production rate. A 6% royalty payable to the New Hebrides Condominium has been applicable to the mining of manganese ores since 1959.

Norway.—Power shortages and the worldwide recession in the steel industry were responsible for substantial drops in production of manganese ferroalloys. Ferromanganese production in 1977 was down to 250,000 metric tons from 354,000 tons in 1976, while silicomanganese dropped to 137,000 tons from 173,000 tons. Exports of ferromanganese were 244,000 tons in 1977 compared with 327,000 tons in 1976; those for silicomanganese were down to 117,000 tons from 153,000 tons.

Peru.—Gran Bretaña S.M.R.L., Peru's only producer of manganese ore, stopped production in 1976. The small tonnage of ore produced in that year had an average manganese content of 26.7%.

Portugal.—Manganiferous iron ore produced in 1977 totaled 30,250 metric tons averaging 40.5% iron and 7.7% manganese.

South Africa, Republic of.—Associated Manganese Mines of South Africa Ltd., made large capital expenditures in 1977 in developing two new manganese mines, Gloria and Perth, to replace the smaller Adams and Devon mines where reserves were almost depleted; in completing the expansion program that had been under way for 2 or 3 years at its ferroalloy subsidiary, Feralloys Ltd.; and to enlarge the company's iron ore production and handling capabilities.[10] Opening of the Sishen-Saldanha Bay railway in September 1976 and its use for movement of iron ores from northwestern Cape Province relieved congestion on the 800-kilometer, Kuruman-Port Elizabeth rail line, which has been the established route for export of the region's manganese ores. Railway freight rates increased 20% during the year. Producers of manganese ferroalloys were also adversely affected by a 25% increase in electrical power charges and by the soft market for their products occasioned by worldwide steel production cutbacks. In June 1977, Transalloys (Pty.) Ltd. successfully commissioned its new 48-MVA silicomanganese submerged arc furnace, but market conditions necessitated the shutdown of the company's two existing submerged arc furnaces.

Producing from four mines in northwestern Cape Province—the Wessels underground mine and the Hotazel, Mamatwan, and Lohathla open pit mines—South African Manganese Amcor Ltd. (SAMANCOR) accounted for approximately 65% of the country's manganese ore output in 1977. Sinking of a second incline shaft at the Wessels mine was completed during the year and the mine's crushing and sizing capacity was increased. These improvements increased productive capacity of the mine to 500,000 tons per year from the previous 250,000 to 300,000 tons. Early in 1977 the Government-owned South African Iron and Steel Industrial Corp. Ltd. (ISCOR) announced that it planned to sell its 45% interest in SAMANCOR. A high bid by Anglo-American Corp. for the purchase was blocked by the Government's Ministry of Economic Affairs; apparently, the government felt that with Anglo-American's new Middleplaats mine the resulting organization would have a monopolistic control of the country's mining of manganese ore. Shaft sinking at the Middleplaats mine began in February 1977 with full-scale production of 1 million tons per year expected in 1979.

Typical analyses for different grades of manganese ore shipped by the country's mines are tabulated below, in percent:

	Minimum 48% Mn	Minimum 44% Mn	Minimum 38% Mn
Mn	49.26	45.96	40.33
Fe	10.82	13.33	14.91
SiO_2	2.84	2.41	2.24
$BaSO_4$	1.28	1.09	1.61
P	0.046	0.039	0.044
Al_2O_3	4.53	4.98	8.10

Spain.—Production of ferromanganese in 1977 totaled 148,000 metric tons; that for silicomanganese was 67,000 tons.

Sudan.—A small quantity of manganese ore was produced in 1977, averaging 48% manganese.

Turkey.—The manganese produced in 1976 and 1977 was estimated to have an average manganese content of 46%.

U.S.S.R.—An authoritative discussion of the geology of the manganese deposits of the Soviet Union, which was published in Russian in 1974, was published in English in 1977 with numerous U.S.S.R. references.[11]

Zambia.—A manganese mine near Mansa in Luapula Province was being reopened by the State-owned Industrial Development Corp. (70% participation) and Oy Airam of Finland (30%). The ore will be used to make dry-cell batteries in a new plant owned by Mansa Battery. Reserves were estimated at 30,000 tons for a life of 10 years.

TECHNOLOGY

With the assistance of the Manganese Centre, Paris, France, a variety of informative papers on the metallurgy of manganese were published in English and French under one cover (with abstracts of each paper in four languages—French, English, German, and Spanish): Manganese—Its resources and metallurgy, P. L. Dancoisne; Cast austenitic manganese steels, P. Detrez; Calloy—A new wear resistant alloy steel, A. Theckston and P. J. Mutton; Manganese and the engineering properties of steels, C. D. Desforges; Manganese and the properties of weldable structural steels, G. Murry; Development of a high manganese steel with good toughness, R. L. Miller; Plate properties of a low carbon 4% Mn steel, A. Brownrigg and G. G. Brown; The role of manganese additions in austenitic stainless steels, J. Hochmann; Manganese in aluminium alloys, L. F. Mondolfo and P. L. Dancoisne; Manganese in copper alloys, G. Greetham; Magnetic manganese materials, P. Hagenmuller and J. Claverie; Corrosion preventatives based on manganese and its compounds, K. Farrow, A. M. Pye, and G. Sanderson; Research and the development of manganese, P. L. Dancoisne. Several interesting photographs of manganese mines, plants, and applications, unrelated to the articles, were included in this special issue of the magazine.[12]

The Engine and Transmission Products Group, Federal-Mogul Corp., Ann Arbor, Mich., developed a new aluminum bearing alloy for heavy-duty engine bearing applications. The alloy, consisting of 1-1/2% manganese, 3% cadmium, 1% copper, 1% nickel, and an aluminum base, has high fatigue and stress resistance. It was being produced at the company's St. Johns, Mich., plant. It is cast and rolled into thin strips which are then bonded onto steel strips to form a bimetallic bearing material.[13]

Matushita Electric Industrial Ltd., Osaka, Japan, developed a new, permanent anisotropic magnet made of manganese, aluminum, and carbon. The new magnet has high mechanical strength and good machinability with a higher magnetic energy than the conventional alnico magnets that are made with nickel and cobalt. It was believed to be particularly suitable for use in measuring and control equipment, and for microswitches.

Dr. Yukio Tanaka, St. Mary's Hospital, Montreal, Canada, reported at the national meeting of the American Chemical Society that preliminary studies of epileptic children and their mothers suggested that manganese deficiency was the cause of epilepsy in certain cases and that a dietary supplement of this trace element could be helpful.

The growing use of methylcyclopentadienyl manganese tricarbonyl (MMT) as an antiknock additive to gasoline was under attack by the automobile manufacturers, who claimed that it built up deposits in the combustion chamber and increased hydrocarbon emissions. Plugging of the catalytic converters that have come into use, an earlier complaint of the automakers, appears not to be a matter of concern at the lower concentrations of MMT, except possibly under severe operating conditions such as trailer towing. Proponents of the additive, the oil companies and the only producer, Ethyl Corp., have maintained that insufficient testing has been done at the proper low concentrations. Coordinating Research Council (CRC), a research organization sponsored by the oil and automobile industries, was engaged in early 1978 in conducting California road tests with the objective of arriving at the answer, which may be a matter of deciding what is an acceptable concentration. Costs of producing gasoline and conservation of oil are at stake, and explain the oil industry's interest. This is another instance of balancing clean air objectives against energy costs. Ethyl Corp. estimated that, by yearend 1977, approximately 60% of U.S. refining capacity was using MMT to improve the octane rating of unleaded gasoline.[14]

---

[1]Supervisory physical scientist, Division of Ferrous Metals.

[2]Weiss, Stanley A. Manganese—The Other Uses. Metal Bulletin Books Ltd., London, 1977, 360 pp.

[3]Steel Times (London). $40m Expansion at Bell Bay Ferro-Alloy Plant. V. 205, No. 5, May 1977, p. 449.

[4]Yolen, S. Urucum Mine Reopens. Am. Metal Market, v. 84, No. 20, Jan. 28, 1977, p. 14.

[5]Yolen, S. Brazil's Exports, Production Soar. Am. Metal Market, v. 86, No. 101, May 24, 1978, p. 10A.

[6]Metal Bulletin (London). No. 6215, Aug. 9, 1977, p. 21.

[7]Mining Journal (London). V. 289, No. 7420, Nov. 4, 1977, p. 381.

[8]______. V. 289, No. 7420, Nov. 4, 1977, p. 379.

[9]Metal Bulletin (London). No. 6227, Sept. 23, 1977, p. 25.

[10]Skillings' Mining Review. V. 67, No. 17, Apr. 29, 1978, p. 19.

[11]Varentsov, I. M., and V. P. Rakhmanov. Deposits of Manganese. Ch. in Ore Deposits of the U.S.S.R., ed. by Academician V. I. Smirnov. Pitman Publishing, London, v. 1, 1977, pp. 114-178.

[12]Materiaux & Techniques (Paris). Manganese. Special Issue, December 1977, 134 pp.

[13]American Metal Market. High-Strength Bearing Alloy Developed by Federal-Mogul. V. 85, No. 142, July 25, 1977, p. 21.

[14]Anderson, Earl V. Phasing Lead Out of Gasoline: Hard Knocks for Lead Alkyls Producers. Chem. & Eng. News, v. 56, No. 6, Feb. 6, 1978, pp. 12-16.

Wrigley, A. Manganese Fuel Additives Boost Smog: Faix. Am. Metal Market, v. 86, No. 42, Mar. 2, 1978, p. 3.

Mercury

By Harold J. Drake[1]

U.S. mine production of mercury in 1977 totaled 28,244 flasks valued at $3.8 million. Production was reported from five mines, three in California and two in Nevada. The increase in production was accounted for primarily by the McDermitt mine in Nevada.

Secondary production more than doubled with 13% of the total accounted for by sales by the General Services Administration (GSA).

Consumption totaled 61,259 flasks. The decline was led by sharply reduced demand for use in the preparation of chlorine and caustic soda, which was accompanied by decreased demand for use in dental preparations, agriculture, and general labratory use. Increases were reported for electrical apparatus, pharmaceuticals, industrial and control instruments, catalysts, mildew-proofing paint, and other uses.

Producer, consumer, and dealer stocks continued to rise, and by yearend reached a level 8% above that at yearend 1976. Producer stocks rose 19%; consumer and dealer stocks rose about 3%.

The price per flask[2] of mercury remained at a low level throughout 1977. The average monthly price declined through the first half of 1977, and although rising thereafter, finished the year below the price at the beginning of the year. The monthly average flask price in New York was $135.71.

Exports and reexports rose 68%; imports for consumption decreased 35%, which accounted for 47% of the U.S. market for mercury. Algeria, Mexico, Yugoslavia, Spain, and Canada were the principal sources of imported mercury.

World production in 1977 totaled 198,879 flasks. Producers in Italy, Spain, and the U.S.S.R. reportedly continued to restrict sales of mercury in 1977; Italian, Yugoslavian, and Mexican producers continued to sharply curtail or completely shut down mercury-mining operations. Canadian mining operations, suspended in 1975 because of low prices, did not reopen in 1977. The international association of mercury producers that was formed in 1975 reportedly met during 1977. The group advocated price stabilization by curtailing production, withholding supplies from the market, restricting sales to dealers, and closely controlling sales agents.

Legislation and Government Pro-

Table 1.—Salient mercury statistics

	1973	1974	1975	1976	1977
United States:					
Producing mines	24	12	13	7	5
Production ---- flasks	2,227	2,189	7,366	23,133	28,244
Value ---- thousands	$637	$617	$1,165	$2,806	$3,833
Exports ---- flasks	342	466	339	501	852
Reexports ---- do	--	--	155	12	101
Imports:					
For consumption ---- do	46,026	52,180	43,865	44,415	28,750
General ---- do	46,076	52,102	44,472	43,964	28,750
Stocks, Dec. 31 ---- do	17,946	19,877	25,549	31,734	34,178
Consumption ---- do	54,283	59,479	50,838	64,870	61,259
Price: New York, average per flask	$286.23	$281.69	$158.12	$121.25	$135.71
World:					
Production ---- flasks	268,265	257,477	r252,329	r239,994	198,879
Price: London, average per flask	$273.54	$267.94	$130.11	$91.97	$140.70

rRevised.

grams.—GSA offered for sale 500 flasks of mercury monthly during 1977 but sold only 1,000 flasks. The mercury was obtained by GSA from other Government agencies. At yearend, the strategic stockpile contained 191,304 flasks, which was 137,300 flasks over the 54,004-flask goal. The U.S. Congress took no action on authorizing the release of the surplus mercury. The Federal Food and Drug Administration began developing new regulations covering mercury-vapor lamps. The lamps will have to be equipped with a self-extinguisher, which will automatically shutoff the lamp in the event of malfunction or breakage.

DOMESTIC PRODUCTION

Production of primary mercury totaled 28,244 flasks valued at $3.8 million in 1977, compared with 23,133 flasks valued at $2.8 million in 1976. Only four mercury mines reported production: Oat Hill, New Almaden, and Knoxville in California, and McDermitt in Nevada. Byproduct mercury was produced at a gold mine in Nevada. The increased output of primary mercury was accounted for by the McDermitt mine in Nevada. Startup problems at the mine's ore-processing facilities were resolved, and full-scale production was achieved throughout 1977.

The average grade of all ore processed in 1977, including ore processed at concentrators, increased to 9.9 pounds of mercury per ton. The increase in the grade of ore was accounted for by the McDermitt mine.

Production of secondary mercury, exclusive of GSA sales, amounted to 5,566 flasks, a level not quite double that of 1976. Most of the increase in secondary production was attributed to the higher price of mercury, which made it economical to process scrap into usable mercury. Major sources of secondary mercury were industrial and control instruments, batteries, sludges, and dental amalgams.

Table 2.—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
1973	26,257	[2]2,101	6.1
1974	28,858	[2]1,680	4.4
1975	76,772	6,905	6.8
1976	185,103	23,042	9.5
1977	216,577	28,244	9.9

[1]Excludes mercury produced from old surface ores, dumps, and placers, and as a byproduct.
[2]Includes mercury contained in concentrate for export.

Table 3.—Production of secondary mercury in the United States

(Flasks)

Year	Industrial production	GSA releases	Total
1973	7,746	2,583	10,329
1974	5,940	2,353	8,293
1975	7,538	500	8,038
1976	2,843	520	3,363
1977	5,566	1,000	6,566

CONSUMPTION AND USES

Consumption declined 6% from the 1976 level to 61,259 flasks. Of the major uses, electrical apparatus rose 6% to 29,180 flasks, and mildew-proofing paint, 7% to 8,365 flasks. Use in the production of chlorine and caustic soda fell 11% to 2,589 flasks. Other major changes were dental preparations, down 38%, and catalysts, up 22%. Use in agriculture fell 4% to 584 flasks, and general laboratory use fell 32% to 406 flasks.

Of the 61,259 flasks consumed in 1977, 79% consisted of primary mercury, 19% of redistilled mercury, and the remainder, secondary mercury. Primary mercury was used throughout the range of applications; redistilled was used primarily in electrical apparatus, industrial and control instruments, and dental preparations. Secondary mercury was used mainly in industrial and control instruments, electrical apparatus, catalysts, and dental preparations.

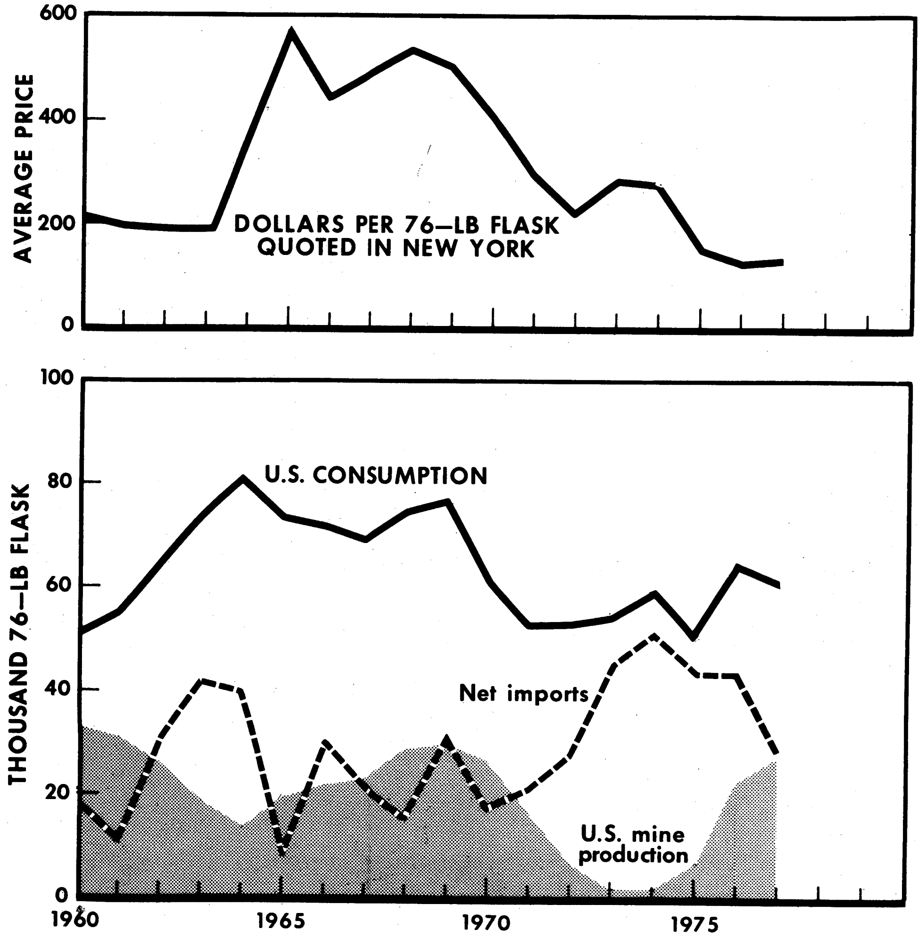


Figure 1.—Trends in production, consumption, and price of mercury.

Table 4.—Mercury consumed in the United States, by use

(Flasks)

Use	1973	1974	1975	1976	1977
Agriculture[1]	1,830	980	600	607	584
Amalgamation	--	--	7	11	W
Catalysts	673	1,298	838	1,264	1,545
Dental preparations	2,679	3,024	2,340	1,990	1,230
Electrical apparatus	18,000	19,678	16,971	27,498	29,180
Electrolytic preparation of chlorine and caustic soda	13,070	16,897	15,222	16,054	10,744
General laboratory use	658	476	335	595	406
Industrial and control instruments	7,155	6,202	4,598	5,067	5,221
Paint:					
Antifouling	32	6	--	--	--
Mildew-proofing	7,571	6,807	6,928	7,845	8,365
Pharmaceuticals	606	597	445	60	W
Other[2]	1,913	2,452	1,750	2,909	2,589
Total known uses	54,187	58,417	50,034	63,900	59,864
Total unknown uses	96	1,062	804	970	1,395
Grand total	54,283	59,479	50,838	64,870	61,259

W Withheld to avoid disclosing company confidential data; included in "Other."

[1]Includes fungicides and bactericides for industrial purposes.

[2]Includes mercury used for installation and expansion of chlorine and caustic soda plants.

Table 5.—Mercury consumed in the United States in 1977

(Flasks)

	Primary	Redistilled	Secondary	Total
Agriculture[1]	584	--	--	584
Catalysts	939	450	156	1,545
Dental preparations	533	586	111	1,230
Electrical apparatus	22,306	6,628	246	29,180
Electrolytic preparation of chlorine and caustic soda	10,744	--	--	10,744
General laboratory use	223	136	47	406
Industrial and control instruments	2,322	2,574	325	5,221
Paint: Mildew-proofing	8,365	--	--	8,365
Pharmaceuticals	W	W	W	W
Other[2]	1,912	675	2	2,589
Total known uses	47,928	11,049	887	59,864
Total unknown uses	501	495	399	1,395
Grand total	48,429	11,544	1,286	61,259

W Withheld to avoid disclosing individual company confidential data; included in "Other."
[1]Includes fungicides and bactericides for industrial purposes.
[2]Includes amalgamation.

STOCKS

Stocks of mercury at yearend 1977 totaled 34,178 flasks, compared with 31,734 flasks at yearend 1976. Producer stocks were up sharply from 9,494 flasks at yearend 1976 to 11,275 flasks at yearend 1977. The increase in producer stocks was accompanied by an increase of 663 flasks to 22,903 flasks held by consumers and dealers.

Table 6.—Stocks of mercury, December 31

(Flasks)

Year	Producer	Consumer and dealer	Total
1973	3,927	14,019	17,946
1974	4,100	15,777	19,877
1975	4,858	20,691	25,549
1976	9,494	22,240	31,734
1977	11,275	22,903	34,178

PRICES

Prices of primary mercury rose in the early part of 1977 but fell back during the middle months before resuming the rise in August. At yearend 1977, the New York price of mercury was $131 to $135 per flask, almost exactly what it had been at the beginning of the year. The average monthly New York price per flask was $135.71 in 1977, compared with $121.25 per flask in 1976. The London price showed similar fluctuations during 1977. At the beginning of 1977 the London price per flask was $104 to $110, compared with $127 to $132 per flask at yearend 1977. The average monthly London price per flask was $140.70 in 1977, compared with $91.97 per flask in 1976. The higher prices in 1977 were attributed to the reported discontinuance of international sales of mercury by Italy, Spain, and the U.S.S.R., and to a reduction in output by producers in Mexico, Yugoslavia, and other countries.

Table 7.—Average monthly prices of mercury at New York and London

(Per flask)

	1976		1977	
	New York[1]	London[2]	New York[1]	London[2]
January	$117.00	$81.38	$140.24	$145.79
February	124.72	94.51	159.84	165.64
March	128.22	99.06	169.04	184.44
April	127.91	99.63	154.14	159.32
May	113.50	82.00	132.29	138.28
June	109.05	82.50	116.77	122.79
July	108.18	83.25	110.26	118.58
August	108.18	83.25	115.00	122.82
September	122.43	87.75	132.52	130.63
October	132.25	100.23	138.60	136.34
November	131.42	101.67	131.53	126.43
December	132.13	108.38	128.29	137.32
Average	121.25	91.97	135.71	140.70

[1]Metals Week, New York.
[2]Metal Bulletin, London; reported in terms of U.S. dollars.

FOREIGN TRADE

Exports of mercury totaled 852 flasks valued at $287,000 compared with 501 flasks valued at $306,000 in 1976. Reexports totaled 101 flasks valued at $36,000 in 1977.

Table 8.—U.S. exports and reexports of mercury

Year	Exports		Reexports	
	Flasks	Value (thousands)	Flasks	Value (thousands)
1975	339	$152	155	$68
1976	501	306	12	6
1977	852	287	101	36

Imports for consumption decreased 35% in quantity and 25% in value to 28,750 flasks valued at $3.3 million. The average unit value for the year was $113.50 per flask, compared with $97.38 per flask in 1976. The share of the U.S. market for mercury supplied by foreign countries amounted to 47%.

Italy sharply reduced its exports to the United States from 13,172 flasks valued at $1.2 million in 1976 to 671 flasks valued at $71,000 in 1977. Imports from Algeria, the largest supplier, declined 14% to 8,806 flasks valued at $1.1 million, but imports from Spain, the second largest source, rose 82% to 8,790 flasks valued at $894,000. Imports from Yugoslavia fell 55% to 3,050 flasks valued at $343,000. Imports from Canada, which in past years accounted for the largest share of imports, fell drastically to 1,708 flasks valued at $211,000 as a result of the cessation of mercury-mining operations in Canada. The People's Republic of China, which became a significant exporter of mercury to the United States in 1976, sharply reduced its shipments from 4,353 flasks valued at $360,000 in 1976, to 575 flasks valued at $50,000 in 1977. Shipments from Mexico, another major source of imported mercury in past years, rose sharply from 1,719 flasks valued at $137,000 in 1976 to 4,668 flasks valued at $486,000 in 1977.

Imports from principal supplying nations in the Western Hemisphere (Canada, Mexico, and Peru) totaled 6,376 flasks in 1977, compared with 4,872 flasks in 1976. Conversely, imports from the other principal suppliers, Algeria, Italy, Spain, and Yugoslavia declined from 34,983 flasks in 1976 to 21,317 flasks in 1977.

The U.S. rate of duty on mercury metal imports during 1977 was 12.5 cents per pound ($9.50 per flask), with the duty on waste and scrap suspended until June 30, 1978. This rate applied to imports from market economy countries. The statutory rate of 25 cents per pound ($19 per flask) applied to central economy countries.

Table 9.—U.S. imports for consumption[1] of mercury, by country

Country	1975		1976		1977	
	Flasks	Value (thousands)	Flasks	Value (thousands)	Flasks	Value (thousands)
Algeria	9,296	$1,561	10,248	$1,110	8,806	$1,148
Australia	--	--	--	--	469	33
Canada	12,891	1,840	2,853	249	1,708	211
China, People's Republic of	200	37	4,353	360	575	50
Finland	35	6	--	--	6	1
France	400	81	--	--	--	--
Germany, Federal Republic of	400	49	--	--	(2)	1
Hong Kong	--	--	200	18	--	--
Italy	7,340	1,595	13,172	1,244	671	71
Mexico	2,213	442	1,719	137	4,668	486
Netherlands	601	68	--	--	--	--
Peru	1,025	207	300	64	--	--
Spain	4,575	963	4,824	461	8,790	894
Sweden	5	8	7	24	7	25
Turkey	58	14	--	--	--	--
U.S.S.R	490	101	--	--	--	--
Yugoslavia	4,336	627	6,739	658	3,050	343
Total	43,865	7,599	44,415	4,325	28,750	3,263

[1]General imports: 1975—44,472 flasks ($7,223,497), Italy 7,525 flasks ($1,151,729), the U.S.S.R. 600 flasks ($122,533), Yugoslavia 4,498 flasks ($645,967), and the People's Republic of China 350 flasks ($64,885); 1976—43,964 flasks ($4,290,514), Italy 13,222 flasks ($1,251,930), and the People's Republic of China 4,253 flasks ($353,559). In 1977, general imports and imports for consumption were the same.

[2]Less than 1/2 unit.

WORLD REVIEW

World production of primary mercury declined 17% to 198,879 flasks in 1977. Decreasing demand during 1977 and large inventories throughout the world acted to reduce production and to moderate the upward movement of prices during the year.

Canada.—Canadian mining operations, suspended because of low prices in 1975, did not reopen in 1977. Exports of inventory mercury continued in 1977.

China, People's Republic of.—Production of mercury was estimated to total 20,000 flasks in 1977. Because of low prices, sales in international markets were reduced in 1977.

Dominican Republic.—Production of mercury commenced at the Pueblo Viejo mine, the world's largest open pit gold mine.[3] Following discovery of mercury in the gold-silver ore in 1976, Rosario Dominicana S.A. erected a 12-tube retort to recover mercury from the doré precipitate from the cyanide plant. Mercury production in the 6 months following startup of the retort averaged 48 flasks per month.

Italy.—Mine production of mercury was suspended in 1977, as Societá Mercurifera Monte Amiata S.p.A., a 30,000-flask-per-year producer, continued to reorganize its mining activities. In addition, sales of mercury reportedly were reduced because of low prices.

Spain.—Production of mercury totaled 37,700 flasks compared with 40,134 flasks in 1976. Minas de Almadén, the largest producer, reportedly discontinued sales of mercury during 1977 because of low prices.

U.S.S.R.—Production of mercury was estimated to total 58,000 flasks. Because of low prices, Soviet suppliers reportedly continued to be inactive in the international market in 1977.

Yugoslavia.—Production of mercury in 1977 was very small compared with the 12,503 flasks produced in 1976. Yugoslavia's Idria mine, its principal producer, was closed early in 1977 due to low prices and declining grade of ore.

Table 10.—Mercury: World production, by country

(Flasks)

Country	1975	1976	1977[p]
Algeria	28,000	31,000	[e]26,000
Australia	6	4	[e]5
Canada	12,000	--	--
Chile	97	13	--
China, People's Republic of[e]	26,000	26,000	20,000
Czechoslovakia	5,900	5,800	[e]5,800
Finland	309	383	[e]400
Germany, Federal Republic of	3,191	3,191	[e]3,200
Ireland	423	--	--
Italy	31,677	22,278	--
Mexico	14,214	15,026	[e]15,230
Peru	1,530	--	--
Philippines	244	--	--
Spain	44,010	40,134	[e]37,700
Turkey	5,421	4,529	[e]4,300
U.S.S.R.[e]	55,000	56,000	58,000
United States	7,366	23,133	28,244
Yugoslavia	16,941	12,503	(1)
Total	[r]252,329	239,994	198,879

[e]Estimate. [p]Preliminary. [r]Revised.
[1]Reportedly, production of Yugoslavia's only mercury mine was suspended in "early 1977;" available sources list no production for the year, but a small quantity may have been produced prior to closure.

TECHNOLOGY

An electrolytic cell using a mercury cathode to recover metals from aqueous solutions was designed and evaluated.[4] The method allows continuous metal recovery, as amalgams or as metal powders for those metals not soluble in mercury, and reuse of the mercury. A method for recovering mercury from metallurgical precipitates and byproducts was developed.[5]

The mercury district in Southwest Arkansas was discussed in detail, and a completed description of all mines and prospects was given.[6]

---

[1]Physical scientist, Division of Nonferrous Metals.
[2]Flask as used throughout this chapter refers to the 76-pound flask.
[3]Addison, R. Rosario Dominicana's New Retort. World Mining, v. 31, No. 4, April 1978, pp. 56-60.
[4]Morris, T. M. Electrowinning Metals on Mercury Cathodes. Eng. and Min. J., v. 178, No. 4, April 1977, pp. 86-89.
[5]Poijarvi, J. T. I., and J. K. Rastas. (assigned to Outokumpu Oy). Method for Separating Recovery of Selenium and Mercury Raw Materials Containing Them. Brit. Pat. 1,449,704, Sept. 15, 1976.
[6]Clardy, B. F., and W. V. Bush. Mercury District of Southwest Ark. Ark. Geol. Comm. IC 23, 1976, p. 57.

Mica

By Stanley K. Haines[1]

Sheet mica production was limited to a small quantity of hand-picked low-quality muscovite from North Carolina. Domestic scrap and flake mica production increased 25% and sales of ground mica increased 23% in 1977.

Fabrication of block and film mica declined for the fourth consecutive year to 448,000 pounds, a 16% decrease. Consumption of mica splittings dropped 18% to the lowest level since 1939. Exports of all forms of mica increased 13% in quantity but decreased 6% in value. Imports of all forms of mica declined, led by a decline of 44% in imports of waste and scrap mica.

Legislation and Government Programs.—Sales of excess sheet mica by the General Service Administration (GSA) amounted to 630,000 pounds. The sale of 62,181 pounds of muscovite film depleted the current quantity authorized for disposal. Muscovite and phlogopite block sales remained frozen.

Table 1.—Salient mica statistics

	1973	1974	1975	1976	1977
United States:					
Production (sold or used by producing companies):					
Sheet mica ---- thousand pounds	30	20	5	5	1
Value ---- thousands	$15	$10	$3	$3	(1)
Scrap and flake mica ---- thousand short tons	153	137	135	r141	176
Value ---- thousands	$6,082	$5,475	$5,219	r$5,765	$6,480
Ground mica ---- thousand short tons	137	117	115	r133	163
Value ---- thousands	$9,464	$10,171	$9,381	r$10,305	$12,196
Consumption:					
Block and film ---- thousand pounds	1,265	974	623	534	448
Value ---- thousands	$2,106	$2,015	$1,608	$1,413	$990
Splittings ---- thousand pounds	5,178	6,186	4,746	5,025	4,144
Value ---- thousands	$1,715	$2,801	$2,634	$3,226	$2,718
Exports ---- thousand short tons	8	9	6	8	10
Imports ---- do	6	7	8	5	4
World production ---- thousand pounds	525,709	515,916	r491,872	r494,596	587,437

rRevised.
1Less than 1/2 unit.

Table 2.—Defense Materials Inventory for sheet mica as of December 31, 1977

(Pounds)

Category	Stockpile goal	Total inventory	Total excess	Balance of disposal authorization	Sold in 1977
Muscovite block, Stained or better	6,188,000	5,108,133	--	--	--
Muscovite film, 1st and 2d qualities	90,000	1,267,779	1,177,779	--	62,181
Muscovite splittings	12,631,000	22,111,961	9,480,961	3,052,086	430,380
Phlogopite block	206,064	127,773	--	--	--
Phlogopite splittings	932,000	2,911,301	1,979,301	1,611,301	136,652

Table 3.—Mica sold or used by producers in the United States

Year and State	Sheet mica						Scrap and flake mica[1]	
	Uncut punch and circle mica		Uncut mica larger than punch and circle		Total sheet mica			
	Pounds	Value	Pounds	Value	Pounds	Value	Short tons	Value
1973	--	--	30,000	$15,000	30,000	$15,000	153,327	$6,081,893
1974	--	--	20,000	[e]10,000	[e]20,000	[e]10,000	136,966	5,474,636
1975	--	--	[e]5,000	[e]2,500	[e]5,000	[e]2,500	134,582	5,219,461
1976	--	--	[e]5,000	[e]2,500	[e]5,000	[e]2,500	[r]140,712	[r]5,764,809
1977:								
North Carolina	--	--	[e]1,000	[e]([2])	[e]1,000	[e]([2])	91,379	4,207,049
South Carolina	--	--	--	--	--	--	42,747	588,993
Other States[3]	--	--	--	--	--	--	41,753	1,684,147
Total	--	--	[e]1,000	[e]([2])	[e]1,000	[e]([2])	175,879	6,480,189

[e]Estimate. [r]Revised.
[1]Includes finely divided mica recovered from mica and sericite schist, and mica that is a byproduct of feldspar and kaolin beneficiation.
[2]Less than 1/2 unit.
[3]Includes Alabama, Arizona, Connecticut, Georgia, New Mexico, Pennsylvania, and South Dakota.

Table 4.—Ground mica sold or used by producers in the United States, by method of grinding[1]

Year	Dry-ground		Wet-ground		Total[2]	
	Short tons	Value (thousands)	Short tons	Value (thousands)	Short tons	Value (thousands)
1973	120,762	$6,469	15,739	$2,995	136,501	$9,464
1974	101,455	6,335	15,908	3,836	117,363	10,171
1975	104,157	6,551	11,244	2,829	115,401	9,381
1976	[r]119,755	[r]7,198	13,197	3,107	[r]132,952	[r]10,305
1977	148,786	8,524	14,601	3,673	163,387	12,196

[r]Revised.
[1]Domestic and some imported scrap.
[2]Data may not add to totals shown because of independent rounding.

DOMESTIC PRODUCTION

Sheet Mica.—An estimated 1,000 pounds of low-quality and low-grade sheet muscovite was produced and sold locally in the Spruce Pine, N.C., area. The mica, which was hand-picked from occasional pockets uncovered during feldspar mining operations, was not mined as the primary product.

Scrap and Flake Mica.—North Carolina continued to lead the Nation with a total production of 91,400 tons of scrap and flake mica. This was 52% of the total U.S. production of 176,000 tons valued at $6.48 million. The 25% increase in total domestic production was attributed to the economic recovery of the construction industry. The remaining production came from Alabama, Arizona, Connecticut, Georgia, New Mexico, Pennsylvania, South Carolina, and South Dakota. Over 41% of the production was sericite (fine-grained muscovite mica). The remaining quantity was obtained by flotation of kaolin, feldspar, and mica ores.

INDUSMIN, a subsidiary of Falconbridge Nickel Mines, Ltd. purchased all shares of Lawson United Feldspar and Mineral Co., Inc., of Spruce Pine, N.C. Lawson United was a producer of scrap mica by flotation of pegmatite ore.

Leading producers of scrap and flake mica were Harris Mining Co., Spruce Pine, N.C.; Boren Clay Products, Gaffney, S.C.; Kings Mountain Mica Co., Inc., Kings Mountain, N.C.; Mineral Industrial Commodities of America, Inc., Santa Fe, N. Mex.; and Piedmont Minerals Co., Inc., Greensboro, N.C.

Ground Mica.—Sales of ground mica increased 23% in quantity and 18% in value over the revised 1976 totals. Dry-ground mica was 91% of the total and wet-ground mica constituted the remaining 9%. Both wet- and dry-ground mica increased in quantity and value. Twenty-one companies operated 22 plants for ground scrap and flake mica (including sericite). Eighteen of these plants produced dry-ground mica, 3 produced wet-ground mica, and 1 produced both wet- and dry-ground mica.

Leading producers were Boren Clay Products, Gaffney, S.C.; Harris Mining Co., Spruce Pine, N.C.; Deneen Mica Co., Inc., Micaville, N.C.; Mineral Industrial Commodities of America, Inc., Santa Fe, N. Mex.; and United States Gypsum Co., Chicago, Ill.

CONSUMPTION AND USES

Sheet Mica.—Consumption of block and film mica decreased for the fourth consecutive year. Fabrication of block and film mica (muscovite and phlogopite) declined 16% to 448,000 pounds. Of this total, 92% was muscovite block, 6% was phlogopite (magnesium mica) block, and 2% was muscovite film.

Vacuum tubes required 58% of the total muscovite block fabricated. The remaining fabricated block was used in gage glass and diaphragms (3%), and in capacitors and other uses (39%). Stained-quality muscovite block was in greatest demand and accounted for 58% of consumption; Lower than Stained, 40%; and Good Stained or better, 2%. Consumption of No. 6 grade was 42% of total fabrication of muscovite block, followed by smaller than No. 6, 18%; No. 5, 15%; No. 5 1/2, 13%; and No. 4 and larger, 12%.

Muscovite film fabrications decreased over 9% to 9,316 pounds in 1977. First-quality film was 54% of the total consumed, followed by second quality, 29%, and other quality, 17%. The film was consumed primarily in producing mica capacitors.

Muscovite block and film was consumed by nine companies in seven States. There were two consuming plants each in North Carolina and New Jersey, and one in Massachusetts, New York, Ohio, Pennsylvania, and Virginia.

Phlogopite block fabrication declined 40% from 43,865 pounds in 1976 to 26,143 pounds in 1977. The decrease was caused in part by the cost and difficulty of obtaining supplies of the raw mica. Phlogopite was consumed by seven companies in five States.

Consumption of mica splittings reached a 39-year low in 1977 by decreasing 18% in quantity. Phlogopite splittings consumption increased 35%, but this was not nearly enough to offset the 19% decline for muscovite splittings. Inventory adjustments of finished products made necessary by a declining market for the built-up mica caused the decline. Muscovite splittings, mainly from India, represented 96% of the total consumption. The remaining 4% was phlogopite splittings from Madagascar. Splittings were fabricated into various built-up mica products by 10 companies operating 11 plants in 8 States.

Built-up Mica.—This mica-base product was made by mechanical or hand setting of overlapping splittings and alternate layers of binders and splittings. The primary use was as electrical insulating material. Molding plate, segment plate, heater plate, and tape all registered declines in production. Segment plate retained the lead in production (31%), followed by molding plate (27%) and tape (17%).

Reconstituted Mica (Mica Paper).—Six companies consumed 4.99 million pounds of scrap mica to produce 3.46 million pounds of mica paper in 1977. The manufacturing companies were General Electric Co., Schenectady, N.Y.; U.S. Samica Corp., Rutland, Vt.; Kirkwood Acim Paper Co., Hempstead, N.Y.; Essex Group, United Technologies Corp., New Market, N.H.; Corona Films Inc., West Townsend, Mass; and Proctor Silex, Mount Airy, N.C. Proctor Silex began producing mica paper for captive use. The paper was built up into plates that were cut and used in various household appliances, such as toasters.

Ground Mica.—Sales of ground mica increased 23% over the 1976 level of 133,000 tons to 163,400 tons in 1977. The increase was due to the recovery of the construction industry and the output of several sericite operations in South Carolina. The principal end uses were joint cement (35%), brick (20%), paint (15%), and rubber (3%). Ground mica for use in brick was mainly sericite from North and South Carolina. The sericite lightened the color of the brick.

Table 5.—Fabrication of muscovite ruby and nonruby block and film mica and phlogopite block mica, in the United States in 1977, by quality and end-product use

(Pounds)

Variety, form, and quality	Electronic uses: Capacitors	Electronic uses: Tubes	Electronic uses: Other	Electronic uses: Total	Nonelectronic uses: Gage glass and diaphragms	Nonelectronic uses: Other	Nonelectronic uses: Total	Grand total
Muscovite:								
Block:								
Good Stained or better	500	369	3,194	4,063	3,162	1,878	5,040	9,103
Stained	155	173,946	36,111	210,212	1,966	28,378	30,344	240,556
Lower than Stained[1]	--	63,784	53,156	116,940	8,080	37,447	45,527	162,467
Total	655	238,099	92,461	331,215	13,208	67,703	80,911	412,126
Film:								
1st quality	2,372	2,650	--	5,022	--	--	--	5,022
2nd quality	2,744	--	--	2,744	--	--	--	2,744
Other quality	1,550	--	--	1,550	--	--	--	1,550
Total	6,666	2,650	--	9,316	--	--	--	9,316
Block and film:								
Good Stained or better[2]	2,872	3,019	3,194	9,085	3,162	1,878	5,040	14,125
Stained[3]	2,899	173,946	36,111	212,956	1,966	28,378	30,344	243,300
Lower than Stained	1,550	63,784	53,156	118,490	8,080	37,447	45,527	164,017
Total	7,321	240,749	92,461	340,531	13,208	67,703	80,911	421,442
Phlogopite: Block (all qualities)	--	--	1,328	1,328	--	24,815	24,815	26,143

[1]Includes punch mica.
[2]Includes 1st- and 2nd-quality film.
[3]Includes other-quality film.

Table 6.—Fabrication of muscovite ruby and nonruby block and film mica in the United States in 1977, by quality and grade

(Pounds)

Form, variety, and quality	No. 4 and larger	No. 5	No. 5 1/2	No. 6	Other[1]	Total
Block:						
Ruby:						
Good Stained or better	4,099	1,781	267	844	--	6,991
Stained	10,111	41,701	25,089	130,414	588	207,903
Lower than Stained	4,330	13,944	25,550	38,960	29,074	111,858
Total	18,540	57,426	50,906	170,218	29,662	326,752
Nonruby:						
Good Stained or better	1,952	60	--	100	--	2,112
Stained	24,740	3,864	1,444	2,605	--	32,653
Lower than Stained	3,274	10	--	2,825	44,500	50,609
Total	29,966	3,934	1,444	5,530	44,500	85,374
Film:						
Ruby:						
1st quality	640	807	425	2,250	--	4,122
2nd quality	344	900	900	300	--	2,444
Other quality	--	--	--	--	1,550	1,550
Total	984	1,707	1,325	2,550	1,550	8,116
Nonruby:						
1st quality	--	--	350	550	--	900
2nd quality	--	--	300	--	--	300
Other quality	--	--	--	--	--	--
Total	--	--	650	550	--	1,200

[1]Figures for block mica include all smaller than No. 6 grade and punch mica.

Table 7.—Consumption and stocks of mica splittings in the United States, by source

(Thousand pounds and thousand dollars)

	India		Malagasy		Total[1]	
	Quantity	Value	Quantity	Value	Quantity	Value
Consumption:						
1973	5,063	1,606	115	109	5,178	1,715
1974	6,026	2,673	160	128	6,186	2,801
1975	4,625	2,529	120	104	4,746	2,634
1976	4,903	3,084	122	142	5,025	3,226
1977	3,979	2,525	165	193	4,144	2,718
Stocks on Dec. 31:						
1973	1,246	NA	55	NA	1,301	NA
1974	3,170	NA	87	NA	3,257	NA
1975	3,465	NA	44	NA	3,510	NA
1976	3,166	NA	124	NA	3,290	NA
1977	3,130	NA	68	NA	3,198	NA

NA Not available.
[1]Data may not add to totals shown because of independent rounding.

Table 8.—Built-up mica[1] sold or used in the United States, by product

(Thousand pounds and thousand dollars)

Product	1976		1977	
	Quantity	Value	Quantity	Value
Molding plate	1,381	3,033	1,227	2,751
Segment plate	1,620	4,063	1,408	3,787
Heater plate	179	256	172	249
Flexible (cold)	588	1,612	617	1,804
Tape	819	3,344	775	3,414
Other	329	1,165	346	1,246
Total[2]	4,915	13,474	4,545	13,251

[1]Consists of alternate layers of binder and irregularly arranged and partly overlapped splittings.
[2]Data may not add to totals shown because of independent rounding.

Table 9.—Ground mica sold or used by producers in the United States, by use

Use	1976		1977	
	Short tons	Value (thousands)	Short tons	Value (thousands)
Roofing	5,011	$219	3,216	$200
Brick	W	W	32,851	59
Rubber	4,680	1,010	5,142	1,202
Paint	21,224	2,362	25,202	2,703
Joint cement	52,799	3,851	56,504	4,481
Other uses[1]	r49,238	r2,862	40,472	3,552
Total[2]	r132,952	r10,305	163,387	12,196

rRevised.
W Withheld to avoid disclosing individual company confidential data; included with "Other uses."
[1]Includes mica used for agricultural products, molded electric insulation, annealing, plastics, welding rods, well drilling, textile and decorative coating, wallpaper, and uses indicated by symbol W.
[2]Data may not add to totals shown because of independent rounding.

STOCKS

Yearend stocks of sheet mica were 3.6 million pounds. Of this total, 89% was splittings, 11% was block, and a small quantity was film. (This information was obtained by direct canvass of consumers of sheet mica).

PRICES

The average value of muscovite sheet in 1977, based on consumption data, follows: Block, $2.16 per pound; film, $4.14 per pound; and splittings, $0.63 per pound. The average values of phlogopite sheet mica were $2.42 per pound for block, and $1.17 per pound for splittings.

The average value of scrap and flake mica produced in 1977 was $36.12 per ton. The decline in average value was the result of the larger percentage of sericite that was included in the 1977 total. The average value for North Carolina scrap and flake, which is predominantly flotation product, was $46.03 per ton. In South Carolina, the average value was only $13.78 because the material was all sericite, which is considerably cheaper to mine.

Table 10.—Price of dry- or wet-ground mica in the United States in 1977,[1] per short ton

Dry-ground:	
Joint cement, 100 mesh	$80 -$100
Plastic, 100 mesh	80 - 100
Roofing, 20 to 80 mesh	50 - 70
Wet-ground:[2]	
Paint or lacquer, 325 mesh	220 - 240
Rubber	220 - 240
Wall paper	240 - 360

[1]In bags at works, carlots, unless otherwise noted.
[2]Freight allowed east of the Mississippi River.

Source: Chemical Marketing Reporter. V. 213, No. 26, Dec. 26, 1977.

FOREIGN TRADE

Exports of all forms of unmanufactured mica increased 26% to 18.2 million pounds in 1977. Canada was again the leading country of destination with 11.3 million pounds, valued at $674,000, or about 6 cents per pound. This was a 70% increase in quantity and a 35% increase in value. Venezuela was the second leading country with 1.2 million pounds valued at $176,000, or 15 cents per pound. The overall average value was 20 cents per pound in 1977, compared with 24 cents per pound in 1976 and 29 cents per pound in 1975. The average value indicated that most of the material exported was ground mica.

Twenty percent of the exports were moved through the Buffalo, N.Y., customs district, 18% went through the Ogdensburg, N.Y., district, and 9% went through the Seattle, Wash., district.

Imports of all classes of mica declined 18% from 9.2 million pounds in 1976 to 7.8 million pounds. Imports of waste and scrap dropped 44% to 2.3 million pounds. Splittings imports rose to 2.1 million pounds, a gain of 25%. India was the leading source country, providing 56% of the total imports; Brazil was second with 23%.

New York City was the leading district of entry for mica (62%), followed by the Boston and Buffalo districts (9% each).

Table 11.—U.S. exports of mica and manufactures of mica in 1977, by country

Destination	Mica, including block, film, splittings, waste, scrap and ground mica		Manufactured	
	Quantity (pounds)	Value (thousands)	Quantity (pounds)	Value (thousands)
Argentina	21,387	$70	41,687	$187
Australia	16,081	15	27,805	86
Bahamas	--	--	12,820	15
Bahrain	167	2	1,416	2
Barbados	40,000	3	--	--
Belgium-Luxembourg	4,258	5	--	--
Brazil	155,924	46	44,040	219
Canada	11,293,695	674	410,478	1,464
Chile	22,519	4	1,425	8
Colombia	206,038	42	663	6
Czechoslovakia	--	--	7,657	8
Denmark	--	--	892	2
Dominican Republic	56,000	7	--	--
Ecuador	39,561	7	--	--
Egypt	127,788	21	--	--
El Salvador	222,000	13	--	--
France	661,452	155	3,003	21
Germany, Federal Republic of	680,596	106	--	--
Ghana	40,784	4	9,104	14

Table 11.—U.S. exports of mica and manufactures of mica in 1977, by country —Continued

Destination	Mica, including block, film, splittings, waste, scrap and ground mica		Manufactured	
	Quantity (pounds)	Value (thousands)	Quantity (pounds)	Value (thousands)
Greece	13,400	$2	--	--
Guatemala	277,269	31	1,468	$3
Haiti	3,642	3	1,709	2
Honduras	43,000	4	--	--
Hungary	106,260	351	--	--
Iran	--	--	70,628	61
Ireland	15,400	3	--	--
Italy	792,828	159	40,411	199
Jamaica	8,694	2	17,528	18
Japan	195,714	442	283	2
Korea, Republic of	79,023	37	60	2
Malaysia	29,400	5	--	--
Mexico	374,299	465	73,175	303
Morocco	16,281	3	--	--
Netherlands	42,000	3	1,197	14
Netherland Antilles	392	2	3,162	6
New Zealand	39,904	8	--	--
Norway	95,008	7	2,294	13
Pakistan	26,400	5	5,234	13
Panama	20,000	1	14,801	21
Peru	137,528	15	29,754	93
Philippines	37,800	9	401	6
Portugal	--	--	2,904	23
Saudi Arabia	128,513	7	231	1
South Africa, Republic of	--	--	45,019	84
Spain	10,449	20	115,274	264
Sweden	--	--	1,025	5
Switzerland	15,969	6	4,369	12
Taiwan	41,545	10	1,150	9
Tanzania	24,719	4	--	--
Thailand	26,400	1	--	--
Trinidad and Tobago	273,420	40	513	3
United Arab Emirates	399,207	89	67	2
United Kingdom	154,314	466	6,320	35
Venezuela	1,153,584	176	7,943	13
Zaire	13,200	3	--	--
Other	18,571	4	5,067	28
Total	18,202,383	3,557	1,012,977	3,267

Table 12.—U.S. exports and imports of mica

(Thousand pounds and thousand dollars)

Year	Exports (all classes)		Imports for consumption: Uncut sheet and punch		Imports for consumption: Scrap		Imports for consumption: Manufactured	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1975	12,110	7,104	904	696	10,672	356	5,075	2,935
1976	16,930	7,253	1,655	941	4,213	205	3,328	3,193
1977	19,215	6,824	2,179	988	2,348	112	3,267	3,373

Table 13.—U.S. imports for consumption of mica, by kind and country

Year and country	Waste and scrap: Phlogopite: Quantity (pounds)	Waste and scrap: Phlogopite: Value (thousands)	Waste and scrap: Other: Quantity (pounds)	Waste and scrap: Other: Value (thousands)	Block mica: Quantity (pounds)	Block mica: Value (thousands)	Other: Muscovite: Quantity (pounds)	Other: Muscovite: Value (thousands)	Other: Other, n.e.c.: Quantity (pounds)	Other: Other, n.e.c.: Value (thousands)
1975	--	--	10,672,125	$356	247,681	$507	1,084	$13	655,727	$176
1976	2,836	$3	4,209,738	202	347,828	675	3,440	32	1,303,425	234
1977:										
Brazil	--	--	485,012	25	264,561	327	811	8	1,041,002	155
Canada	2,600	1	246,900	7	--	--	--	--	448,500	15
Germany, Federal Republic of	--	--	--	--	--	--	--	--	639	2
India	--	--	1,613,767	79	188,476	313	7,400	18	213,558	125
Japan	--	--	--	--	--	--	--	--	124	(1)
Madagascar	--	--	--	--	4,300	7	220	1	2,866	7
Sweden	--	--	--	--	6,506	(1)	--	--	--	--
Tanzania	--	--	--	--	--	--	293	2	--	--
United Kingdom	--	--	--	--	36	6	95	2	--	--
Total	2,600	1	2,345,679	111	463,879	653	8,819	31	1,706,689	304

Year and country	Splittings: Quantity (pounds)	Splittings: Value (thousands)	Not cut or stamped not over 0.006 inch in thickness: Quantity (pounds)	Not cut or stamped not over 0.006 inch in thickness: Value (thousands)	Cut or stamped: Not over 0.006 inch in thickness: Quantity (pounds)	Cut or stamped: Not over 0.006 inch in thickness: Value (thousands)	Cut or stamped: Over 0.006 inch in thickness: Quantity (pounds)	Cut or stamped: Over 0.006 inch in thickness: Value (thousands)
1975	3,790,511	$911	3,751	$8	30,344	$350	59,096	$127
1976	1,710,973	561	100	1	74,413	789	107,799	233
1977:								
Canada	--	--	3,782	4	--	--	3,249	20
France	--	--	175	2	2,436	6	--	--
Haiti	--	--	--	--	983	11	80	2
India	2,075,091	604	3,500	3	76,285	1,082	73,005	283
Korea, Republic of	--	--	--	--	18	1	--	--
Madagascar	56,325	46	--	--	--	--	--	--
Malaysia	220	1	--	--	--	--	--	--
Mexico	341	1	--	--	--	--	181	1
Singapore	--	--	--	--	15	(1)	--	--
Spain	--	--	--	--	175	2	355	2
Taiwan	3,756	9	--	--	26	1	--	--
United Kingdom	5,000	22	--	--	1,587	67	85	3
Total	2,140,733	683	7,457	9	81,525	1,170	76,955	311

Year and country	Mica plates and built-up mica: Quantity (pounds)	Mica plates and built-up mica: Value (thousands)	Ground or pulverized: Quantity (pounds)	Ground or pulverized: Value (thousands)	Articles not especially provided for of mica: Quantity (pounds)	Articles not especially provided for of mica: Value (thousands)
1975	973,638	$1,255	201,996	$22	15,310	$262
1976	848,758	1,276	546,854	48	39,344	285
1977:						
Belgium-Luxembourg	495,655	770	--	--	--	--
Canada	8,982	30	254,007	21	2,322	19
France	11,118	14	37,478	8	--	--
Germany, Federal Republic of	5,708	15	--	--	--	--
India	120,855	204	--	--	2,503	31
Japan	2,367	8	--	--	--	--
Mexico	--	--	--	--	135	8
Netherlands	--	--	--	--	55	10
Singapore	--	--	--	--	122	3
Switzerland	279	2	--	--	--	--
United Kingdom	395	2	--	--	18,233	55
Total	645,359	1,045	291,485	29	23,370	126

[1]Less than 1/2 unit.

WORLD REVIEW

World production of all forms of mica decreased 19% to 587.4 million pounds in 1977. India led the world in production of sheet mica. The United States remained the world leader for production of scrap and flake mica.

India.—The Government's Mica Trading Co., Ltd., agreed to supply about $9 million worth of mica to the U.S.S.R. in 1977.[2]

U.S.S.R.—Estimated output of mica in 1976 was 47,400 short tons. This was expected to increase to 51,800 tons by 1980. Mamsko Chuysk County of Irkutsk Oblast supplied 75% of the country's production of mica. Nine underground mines operated in 1976.[3]

[1]Physical scientist, Division of Nonmetallic Minerals.
[2]Engineering and Mining Journal. V. 178, No. 4, April 1977, p. 159.
[3]Mining Annual Review. U.S.S.R. June 1977, p. 549.

Table 14.—Mica: World production, by country

(Thousand pounds)

Country[1]	1975	1976	1977[p]
Argentina:			
Sheet	948	725	6,371 (Sheet and waste, scrap, etc.)
Waste, scrap, etc.	6,393	5,051	
Brazil[2]	2,425	6,171	[e]6,200
Colombia[e]	90	90	100
Egypt	15	[r] [e]110	[e]190
France[e]	8,800	8,800	8,800
India:			
Exports:			
Block[3]	1,241	[e]1,800	2,423
Splittings[4]	7,628	[e]8,800	7,873
Scrap[5]	26,389	[e]33,000	33,076
Domestic consumption, all classes[e]	44,000	22,000	33,000
Total[e]	79,258	65,600	76,372
Korea, Republic of (sericite)	[e]6,600	11,715	22,339
Madagascar (phlogopite):			
Block	218	15	176 (Block, splittings, and scrap)
Splittings	981	137	
Scrap	--	26	
Mexico	1,367	2,873	1,700
Mozambique (including scrap)	1,984	[e]2,000	[e]2,000
Nepal	9	[e]10	[e]10
Norway (including scrap)	[r]7,886	6,797	[e]6,200
Peru[e]	10	20	20
South Africa, Republic of:			
Sheet	(6)	(6)	(6)
Scrap	5,536	5,247	6,927
Spain	1,162	[e]1,100	--
Sri Lanka (scrap)	5,432	302	[e]220
Sudan	[e]550	1,213	[e]880
Tanzania, sheet	13	15	[e]18
U.S.S.R. (all grades)[e]	92,000	95,000	97,000
United States:			
Sheet	5	5	1
Scrap and flake	270,000	281,424	352,758
Yugoslavia	190	150	[e]155
Total	[r]491,872	494,596	587,437

[e]Estimate. [p]Preliminary. [r]Revised.
[1]In addition to the countries listed, the People's Republic of China, Romania, Southern Rhodesia, the Territory of South-West Africa and Sweden are known to produce mica, but available information is inadequate to make reliable estimates of output levels.
[2]Exports.
[3]Includes micanite and other built up mica.
[4]Includes condenser film, washer and disks.
[5]Includes sheet, strips, and powder.
[6]Less than 1/2 unit.

Molybdenum

By John T. Kummer[1]

For the fifth consecutive year, worldwide consumption of molybdenum in 1977 exceeded mine production, with the result that inventories were further reduced. World mine output increased 7% over that of 1976 to a record high of about 206 million pounds of molybdenum; still, world output was possibly 10 million to 15 million pounds less than world demand. The United States accounted for nearly 60% of the world output and exported over 67 million pounds, mostly as concentrate and oxide, to alleviate the supply deficit for the rest of the industrialized world. Reported U.S. consumption of primary products increased 8% to 54.6 million pounds, while apparent demand increased 2.3% to 61.4 million pounds. Total domestic industry stocks fell to 28.8 million pounds, the lowest level since yearend 1967. As a consequence of the current strong demand and anticipated demand increases in the future, exploration and study of new molybdenum sources were intensified, especially in the United States and Canada. One price increase of 12% to 16% on molybdenum products was instituted by major producers during the year.

Legislation and Government Programs.—During 1977, the General Services Administration (GSA) shipped 22,231 pounds of molybdenum in ferromolybdenum from Government stockpile excesses. This quantity represented the last of the molybdenum material in the stockpile. Present goals set by GSA do not include molybdenum materials.

The Government stockpile of molybdenum in concentrate, oxide, and ferromolybdenum was accumulated during the 1950's, reaching a maximum in 1959 of 84.6 million pounds of molybdenum. Subsequent changes in stockpile objectives resulted in the sale of these materials beginning in 1963 and the eventual depletion of all forms in 1977.

Table 1.—Salient molybdenum statistics

(Thousand pounds of contained molybdenum and thousand dollars)

	1973	1974	1975	1976	1977
United States:					
Concentrate:					
Production	115,859	112,011	105,980	113,233	122,408
Shipments	135,097	118,163	105,170	114,527	124,974
Value	$217,721	$234,658	$259,328	$333,494	$450,421
Consumption	82,477	91,706	90,046	84,966	91,041
Imports for consumption	458	155	2,567	2,093	1,976
Stocks, Dec. 31: Mine and plant	21,998	18,659	10,680	9,390	9,161
Primary products:					
Production	85,046	88,509	87,501	83,970	90,520
Shipments	108,687	114,799	89,789	99,144	100,626
Consumption	57,049	63,476	51,743	50,448	54,557
Stocks, Dec. 31: Producers	22,387	16,078	22,863	13,210	10,141
World: Production	180,088	185,568	176,713	r191,736	205,921

rRevised.

DOMESTIC PRODUCTION

A record high of 122.4 million pounds of molybdenum was produced from domestic mines in 1977. Of this total, output from primary molybdenum mines contributed 82.9 million pounds (67.7%), and output from byproduct and coproduct sources accounted for the remaining 39.5 million pounds (32.3%). Almost all byproduct and coproduct molybdenum was produced from mining of copper porphyry ores; a small amount was recovered from tungsten and uranium mining operations.

Molybdenum output from primary ores increased about 10% compared with that of 1976. The increase was due entirely to the expansion of production at the Henderson mine of AMAX Inc. in Colorado. During 1977, the first full year of operation, nearly 24 million pounds of molybdenum in concentrate was produced at Henderson. Output is scheduled to increase during the next 2 to 3 years to eventually reach the capacity production rate of 50 million pounds per year in 1980. Molybdenum output at AMAX's other Colorado property, the Climax mine, totaled about 51 million pounds, a decrease of nearly 10 million pounds compared with that of 1976. Production was adversely affected by the lower grade of ore processed at the Climax mine. Approximately 30% of the Climax production was obtained by surface mining methods.

Output at the third primary molybdenum deposit in the United States, the Questa mine, operated by Molycorp Inc. in New Mexico, decreased from a record high of 11.5 million pounds in 1976 to 8.1 million pounds in 1977. The decline in output was the result of storm damage to mine facilities in June and a rock slide within the open pit workings in July. Reportedly, some stockpiled ore was milled during the second half of the year to offset the drop in ore extracted from the mine itself. Moreover, operations at the mine ceased after December 1 when labor problems closed down the mine. With a reduced supply of molybdenum concentrate for its conversion facility in Pennsylvania, Molycorp was forced to limit deliveries of molybdic oxide and ferromolybdenum to customers during the second half of the year.

Byproduct molybdenum was produced at 14 mines, 12 of which were operations at porphyry copper deposits located in Arizona, Nevada, New Mexico, and Utah. At one property in Arizona, the Sierrita mine of Duval Corp. (Pennzoil Co.), copper and molybdenum were recovered as coproducts. Copper-mining activity was generally depressed during the year and, as a result, output of byproduct molybdenum was reduced at several mines compared with that of 1976. However, because of strong molybdenum demand and prices, molybdenum recovery was emphasized at other byprod-

Table 2.—Production, shipments, and stocks of molybdenum products in the United States

(Thousand pounds of contained molybdenum)

	Molybdic oxides[1]		Metal powder		Ammonium molybdate	
	1976	1977	1976	1977	1976	1977
Received from other producers	6,541	6,634	16	40	923	792
Gross production during year	90,884	98,003	4,461	4,976	2,457	4,074
Used to make other products listed here	25,141	29,332	622	834	1,506	1,474
Net production	65,743	68,671	3,839	4,142	951	2,600
Shipments	77,300	78,308	4,045	4,299	2,378	3,244
Producer stocks, Dec. 31	10,003	6,914	448	327	752	640
	Sodium molybdate		Other[2]		Total	
Received from other producers	48	24	43	73	7,571	7,563
Gross production during year	1,133	1,275	12,406	13,912	111,341	122,240
Used to make other products listed here	1	1	101	80	27,371	31,721
Net production	1,132	1,275	12,305	13,832	83,970	90,520
Shipments	1,279	1,266	14,142	13,509	99,144	100,626
Producer stocks, Dec. 31	71	97	1,936	2,163	13,210	10,141

[1]Includes technical and purified molybdic oxide and briquets.
[2]Includes ferromolybdenum, calcium molybdate, phosphomolybdic acid, molybdenum disulfide, molybdic acid, molybdenum metal, pellets, molybdenum pentachloride, and molybdenum hexacarbonyl.

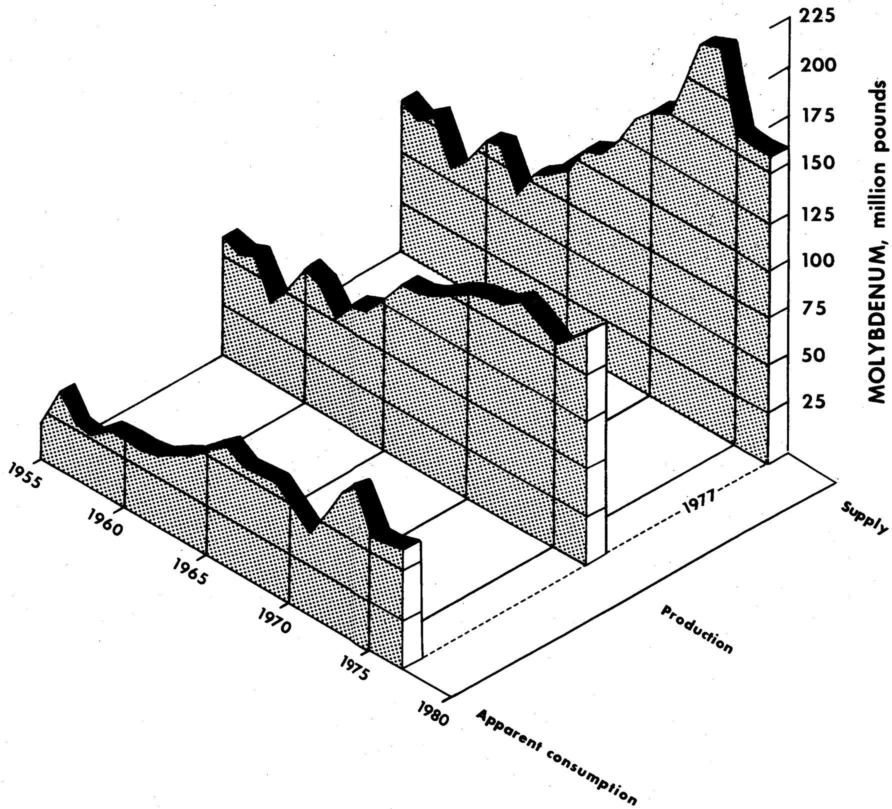


Figure 1.—Apparent consumption, production, and supply of molybdenum in the United States.

uct mines, which resulted in an increase in molybdenum output. Overall, molybdenum produced from byproduct and coproduct sources increased 4% compared with that of 1976.

The two major byproduct and coproduct producers were the Sierrita mine and the Utah mine of Kennecott Copper Corp. Both Duval and Kennecott operate other surface copper mines that produced byproduct molybdenum. AMAX, Molycorp, Duval, and Kennecott accounted for over 92% of domestic production in 1977. Other producers of byproduct molybdenum included Anamax Mining Co., Magma Copper Co., and Cyprus Mines Corp., all of which operated copper mines in Arizona. Molybdenum concentrate production was resumed at Kennecott's Nevada Mines division near McGill after having been temporarily suspended in 1976. Molybdenum output from this facility was small.

The persisting problems of oversupply, low prices, and unusually large inventories within the copper industry exerted a disconcerting influence on anticipated supplies of byproduct molybdenum throughout the year. Because of the poor copper market, Duval halted mining at its three copper-molybdenum properties in Arizona from August 8 to September 18. Production of molybdenum concentrate and oxide was not entirely suspended, however, because Duval's mill and roaster facilities worked off stockpiled ore and concentrate. Shipments of oxide to customers from inventories helped maintain near-normal deliveries. After the 6-week suspension, Duval shut down the Esperanza mine on September 26 for an indefinite period, but resumed mining operations at its Sierrita and Mineral Park properties. Molybdenum output was emphasized at the two concentrating plants. The Esperanza mine was closed for the remainder of the year.

Similarly, Cyprus Mines Corp. suspended operations in September at its Cyprus Pima mine near Tucson, Ariz. The company was to periodically review the copper market to determine when reopening of the mine would be warranted. The mine, which produced 1 million to 2 million pounds per year of byproduct molybdenum in recent years, remained closed into 1978. Kennecott Copper Corp. and Magma Copper Co., a subsidiary of Newmont Mining Corp. announced employee reductions and/or mining curtailments in an effort to reduce operating costs. Output of byproduct molybdenum from these copper mines was little affected, however.

A second factor that merited considerable attention during the year was the renegotiation of labor contracts and the possible effect of strike actions on molybdenum output. Both primary-molybdenum producers (AMAX and Molycorp) and the copper industry were involved in negotiating new, 3-year labor pacts. Fortunately, in a year characterized by strong demand, labor stoppages did not significantly disrupt mine activity. Although employees at the Climax mine did not ratify their contract until about 10 days after a July 15 deadline, normal operations at the mine were not interrupted. Except for Kennecott, copper producers with significant byproduct molybdenum output reached agreements with worker unions without loss of production. Mines operated by Kennecott were inactive for about 3 weeks in July while negotiations were underway. At Molycorp's Questa mine, a work stoppage occurred on December 1. The mine remained closed for the balance of the year.

A major change in company ownership occurred in July when shareholders of Molycorp Inc. approved the acquisition of the company by Union Oil Co. of California. The transaction involved an exchange of common stock shares valued at about $240 million and provided for Molycorp to operate as a wholly-owned subsidiary of Union Oil. At the close of the year, Molycorp announced that its partnership with Kennecott Copper Co. had been dissolved. The two firms had been in partnership since 1975 to conduct exploratory drilling and feasibility studies on Molycorp's Questa property. The joint-venture was successful in delineating additional molybdenite mineralization estimated at 100 million tons of ore grading 0.33% molybdenite. At yearend, Molycorp was studying mining plans to develop the new underground reserves. According to a company spokesman, a decision will be made in 1978 on whether to proceed with development, with production possible by 1983. Reserves that are supporting the current surface mining operation at Questa may be exhausted before 1983, in which case output from the Questa property could cease for an indefinite period in the early 1980's.

The discovery of a major molybdenum deposit, located near Mount Emmons, about 4 miles from Crested Butte, Colo., was announced by AMAX in August. Exploratory drilling over a 1,800- by 2,200-foot elliptical pattern encountered mineralization at an average depth of 1,200 feet. The ore body was initially estimated at 90 million tons averaging 0.4% molybdenite. In September, the size estimate was revised upward to 130 million tons. The company was engaged in further exploration and was studying the feasibility of establishing a mine and concentrating facility at the site. These studies were expected to take at least 1 year.

U.S. Borax & Chemical Corp., a subsidiary of Rio Tinto-Zinc Corp., Ltd., completed about 30,000 feet of additional drilling during the year at its Quartz Hill molybdenum property in southeastern Alaska. The deposit, first discovered in 1974, is located about 45 miles east of Ketchikan. The results of drilling completed indicated that the ore body may be in excess of 250 million tons with molybdenite grades ranging from 0.18% to 0.25%. Of this mineralization, about 50 million tons grading 0.25% molybdenite outcrop at the surface. The ore body has not yet been fully outlined and additional tonnage could exist. According to company officials, complete evaluation of the deposit was dependent on the construction of an access road from tidewater to the property. The U.S. Forest Service issued a special-use permit for the road in November, but an appeal was filed, primarily by environmental groups, for withdrawal of the permit.

Discovery of a molybdenum prospect, in Beaver County, Utah, was announced early in 1978 by Phelps Dodge Corp. Four holes drilled by the company intersected porphyry-type molybdenum mineralization with minor tungsten values at depths of 3,000 to 5,000 feet below the surface. Molybdenite grades of 0.29% to 0.38% were encountered. The company stated that an extensive drilling program would be required to fully determine the size and grade of the mineralized zone.

Cyprus Bagdad Copper Co. (Cyprus Mines Corp.) completed a 4-year project to expand its open pit mine, construct a 40,000-ton-per-day concentrator, and build ancillary facilities at the Bagdad copper mine in Arizona. Total cost of the project was reportedly $226 million. At full production rates, to be achieved during 1978, output of byproduct molybdenum from the new facility was expected to exceed 2 million pounds per year.

New conversion capacity was brought onstream with the startup of the first roaster at AMAX's plant near Fort Madison, Iowa. A second roaster was scheduled for completion in 1979. AMAX also completed construction of sulfuric acid plants at its Fort Madison and Langeloth, Pa., conversion facilities. Recovery of the sulfur emitted during roasting of molybdenite concentrates was necessary to meet pollution control standards.

CONSUMPTION AND USES

The quantity of molybdenum in concentrate roasted to produce technical-grade molybdic oxide increased to 91.0 million pounds, about 7.1% greater than in 1976. Some concentrate was purified to lubrication-grade molybdenum disulfide, which has experienced growing demand in recent years. A small quantity of concentrate was consumed in direct addition to iron and steel furnaces. Molybdic oxide is the chief form of molybdenum utilized by industry and is also converted to other materials such as ferromolybdenum, ammonium and sodium molybdate, or metal powder.

Domestic end-use consumption of molybdenum materials increased 8.1% over that of 1976, totaling 54.6 million pounds of molybdenum. Apparent domestic molybdenum consumption increased to 61.4 million pounds, 2.3% higher than that of 1976. Both figures underscore the strong demand for molybdenum during the year.

The overall increase in end-use consumption was due predominantly to increased demand for molybdenum-containing steels. Reported molybdenum use in all forms of steel increased by 3.8 million pounds, or about 11% over that of 1976. Most of that gain was recorded in full alloy and stainless and heat-resisting steels, the two major categories of steel in which molybdenum is utilized. The steel industry accounted for about 69% of the domestic molybdenum consumed in 1977.

Molybdenum consumption decreased in cast irons and superalloys. Use of molybdenum metal to manufacture mill products (wire, rod, and sheet) increased nearly 10% compared with that of 1976. All metallurgical applications accounted for 90% of the molybdenum consumption in 1977. Chemical uses, mainly in pigments, catalysts, and lubricants, comprised slightly over 8% of the total molybdenum consumed in 1977.

Table 3.—U.S. consumption of molybdenum in 1977, by end use and form

(Thousand pounds of contained molybdenum)

End use	Molybdic oxides	Ferromolybdenum[1]	Ammonium and sodium molybdate	Other molybdenum materials[2]	Total
Steel:					
Carbon	2,237	214	--	50	2,501
Stainless and heat resisting	6,279	1,274	--	251	7,804
Full alloy	20,395	1,507	--	385	22,287
High-strength low-alloy	1,914	245	--	17	2,176
Electric	197	14	--	--	211
Tool	1,965	735	--	31	2,731
Cast irons	805	3,045	--	174	4,024
Superalloys	1,057	359	--	1,186	2,602
Alloys (excludes steels and superalloys):					
Welding and alloy hard-facing rods and materials	--	413	--	49	462
Other alloys[3]	141	470	--	135	746
Mill products made from metal powder	--	--	--	3,590	3,590
Chemical and ceramic uses:					
Pigments	533	--	444	7	984
Catalysts	2,033	--	332	--	2,365
Other	35	28	48	1,082	1,193

See footnotes at end of table.

Table 3.—U.S. consumption of molybdenum in 1977, by end use and form —Continued

(Thousand pounds of contained molybdenum)

End use	Molybdic oxides	Ferro-molyb-denum[1]	Ammo-nium and sodium molyb-date	Other molyb-denum mater-ials[2]	Total
Miscellaneous and unspecified	193	131	49	508	881
Total	37,784	8,435	873	7,465	54,557

[1]Includes calcium molybdate.
[2]Includes purified molybdenum disulfide, molybdenite concentrate added directly to steel, molybdenum metal powder, molybdenum metal, pellets, and other molybdenum materials.
[3]Includes magnetic and nonferrous alloys.

STOCKS

Total industry stocks of molybdenum within the United States decreased for the fifth consecutive year in response to the increased domestic demand and export market. During the year, total molybdenum inventories decreased 3.7 million pounds, or about 11% from those at yearend 1976. For most of the year, stocks of molybdenum in concentrate at mines and plants were greater than at yearend 1976, rising to a maximum of 16.5 million pounds at the close of August. However, concentrate stocks dropped sharply during the last third of the year to close at 9.2 million pounds of molybdenum. Producers' stocks of molybdenum materials ranged from 9 to 11 million pounds (contained molybdenum) throughout the year, their lowest levels since yearend 1967. When compared with average monthly shipments, producers' stocks amounted to about 1 month's supply of molybdenum. The low levels of producers' stocks compounded the concerns of domestic consumers over molybdenum availability. Consumers' stocks of molybdenum materials also decreased during the year, by about 400,000 pounds compared with yearend 1976. Consumer stock levels exhibited no definite month-to-month trend, but varied between 8.9 and 9.8 million pounds of molybdenum throughout the year. This quantity represented about a 2 month supply when compared with average monthly consumption.

Table 4.—Industry stocks of molybdenum materials, December 31

(Thousand pounds of contained molybdenum)

Material	1973	1974	1975	1976	1977
Concentrate: Mine and plant	21,998	18,659	10,680	9,390	9,161
Producers:					
Molybdic oxides[1]	17,312	10,601	17,130	10,003	6,914
Metal powder	586	559	473	448	327
Ammonium molybdate	542	635	1,347	752	640
Sodium molybdate	280	143	170	71	97
Other[2]	3,667	4,140	3,743	1,936	2,163
Total	22,387	16,078	22,863	13,210	10,141
Consumers:					
Molybdic oxides[1]	4,482	8,181	4,036	6,958	5,761
Ferromolybdenum[3]	2,209	2,380	1,416	1,501	1,940
Ammonium and sodium molybdate	193	209	127	183	338
Other[4]	1,242	1,345	1,242	1,235	1,421
Total	8,126	12,115	6,821	9,877	9,460
Grand total	52,511	46,852	40,364	32,477	28,762

[1]Includes technical and purified molybdic oxide and briquets.
[2]Includes ferromolybdenum, calcium molybdate, phosphomolybdic acid, molybdenum disulfide, molybdic acid, molybdenum metal, pellets, molybdenum pentachloride, and molybdenum hexacarbonyl.
[3]Includes calcium molybdate.
[4]Includes purified molybdenum disulfide, molybdenite concentrate added directly to steel, molybdenum metal powder, molybdenum metal, pellets, and other molybdenum materials.

PRICES

Producer prices of molybdenum concentrate, molybdic oxide, and other molybdenum materials were raised once during 1977. The price increases became effective in early August and ranged from 12% to 16% on individual products. The price of Climax concentrate per pound of contained molybdenum was raised from $3.45 to $4.01, giving a weighted average price of $3.68 for the year. Strong demand and increased costs of operation, development, and exploration were cited as factors contributing to the price increase. Because of strong worldwide demand, dealer prices were at considerable premium over producer quotes throughout the year. At yearend, the published price of products per pound of contained molybdenum were as follows:

Climax concentrate	$4.01
Byproduct concentrate	$3.85-4.01
Climax oxide/cans	4.31
Dealer oxide	5.60-6.00
K-2 oxide/cans	4.24
Ferromolybdenum/Climax lump	4.99
Ferromolybdenum/dealer export	5.65-6.40

FOREIGN TRADE

Exports.—Exports of molybdenum in concentrate and oxide totaled 65.7 million pounds, a 5% increase compared with those of 1976. These exports represented about 54% of the domestic mine output during the year. The Netherlands, Japan, Belgium-Luxembourg, and the Federal Republic of Germany received nearly 85% of the concentrate and oxide exported in 1977. Total value of exports was $245.8 million, or 34% greater than in 1976. It was estimated that these exports furnished approximately 42% of foreign consumption of molybdenum.

Exports of other molybdenum materials, in gross weight, were ferromolybdenum, 1.6 million pounds; unwrought metal and alloys and scrap, 332,000 pounds; molybdenum alloy wire, 475,000 pounds; molybdenum alloy powder, 151,000 pounds; and wrought metal alloys, 164,000 pounds. The total value of these exports was nearly $15 million.

Imports.—A small quantity of molybdenum in a variety of forms , is imported into the United States each year. The total value of these imports was $9.9 million in 1977. As in the previous 2 years, molybdenum concentrate was the most significant form of molybdenum imported in terms of both quantity and value. During 1977, the molybdenum content of concentrate imported totaled 1,976,466 pounds and was valued at $4.9 million. Canada supplied nearly 95% of the imports; the remainder came from Chile and the Philippines.

Ferromolybdenum containing 128,276 pounds of molybdenum and valued at $612,292 was imported chiefly from Canada, Sweden, the Republic of Korea, and Austria. Wrought molybdenum metal, with a gross weight of 82,072 pounds and a value of $1.3 million, was supplied mainly from Austria. Sweden and Austria supplied 62,188 pounds of molybdenum as unwrought metal valued at $221,250. Molybdenum waste and scrap, with a gross weight of 2.1 million pounds and valued at $1.5 million, was imported from 10 countries; in terms of quantity, the United Kingdom supplied 89% of the imports. Imported material in which the chief component was molybdenum contained 252,045 pounds of molybdenum valued at $625,371. Canada and the United Kingdom were the principal countries of origin.

Imports of molybdenum orange totaled 491,273 pounds gross weight valued at $487,002, and were supplied by three countries; Canada provided 92% of the total. Unspecified compounds and mixtures containing 35,468 pounds of molybdenum valued at $265,461 were imported from seven countries. The Netherlands supplied about one-third of these materials.

Table 5.—Molybdenum reported by producers as shipments for export from the United States

(Thousand pounds of contained molybdenum)

Product	1976	1977
Molybdenite concentrate	30,935	29,666
Molybdic oxide	29,644	31,529
All other primary products	2,152	1,803

Table 6.—U.S. exports of molybdenum ore and concentrates (including roasted concentrates), by country

(Thousand pounds of contained molybdenum and thousand dollars)

Country	1976		1977	
	Quantity	Value	Quantity	Value
Argentina	165	615	179	810
Australia	39	154	217	799
Austria	87	259	600	2,456
Belgium-Luxembourg	6,871	21,210	7,077	25,560
Brazil	241	761	303	1,272
Canada	373	856	524	1,703
France	396	1,169	583	2,039
Germany:				
Democratic Republic of	11	69	--	--
Federal Republic of	8,049	21,245	5,598	18,309
India	461	1,465	529	1,944
Italy	43	110	617	2,724
Japan	11,748	35,401	10,425	41,391
Korea, Republic of	48	72	--	--
Mexico	881	2,076	635	1,888
Netherlands	27,987	85,102	32,578	123,421
New Zealand	3	14	5	34
Philippines	1	2	4	17
South Africa, Republic of	75	198	188	620
Spain	102	196	(1)	1
Sweden	2,748	7,173	2,282	7,458
Switzerland	442	1,223	--	--
Taiwan	--	--	38	259
United Kingdom	1,096	2,702	895	3,289
U.S.S.R	--	--	2,388	9,777
Venezuela	599	1,437	--	--
Other	8	27	1	6
Total	62,474	183,536	65,666	245,777

[1]Less than 1/2 unit.

Table 7.—U.S. exports of molybdenum products

(Thousand pounds, gross weight, and thousand dollars)

Product and country	1976		1977	
	Quantity	Value	Quantity	Value
Ferromolybdenum:[1]				
Argentina	213	616	275	948
Australia	177	393	351	1,053
Belgium-Luxembourg	121	482	--	--
Brazil	14	36	--	--
Canada	284	674	164	498
Colombia	17	41	13	36
India	369	999	135	412
Japan	871	1,921	287	817
Korea, Republic of	--	--	30	115
Mexico	--	--	35	122
Netherlands	519	1,438	--	--
Peru	--	--	4	16
Philippines	7	16	--	--
South Africa, Republic of	261	723	88	252
Spain	255	858	--	--
Sweden	289	720	183	530
Switzerland	110	340	13	39
Taiwan	7	16	12	21
United Kingdom	80	169	--	--
Other	2	5	5	4
Total	3,596	9,447	1,595	4,863
Metal and alloys in crude form and scrap:				
France	1	2	1	4
Germany, Federal Republic of	116	144	--	--
Japan	35	144	1	5
Mexico	10	10	233	516
Taiwan	--	--	4	15
United Kingdom	59	78	87	274
Other	2	12	6	37
Total	223	390	332	851

See footnotes at end of table.

Table 7.—U.S. exports of molybdenum products —Continued

(Thousand pounds, gross weight, and thousand dollars)

Product and country	1976		1977	
	Quantity	Value	Quantity	Value
Wire:				
Argentina	5	67	9	127
Australia	11	84	14	142
Belgium-Luxembourg	14	110	15	177
Brazil	27	440	23	376
Canada	58	502	71	624
France	34	333	50	601
Germany, Federal Republic of	89	820	133	1,563
India	2	17	3	29
Italy	13	133	40	486
Japan	50	434	63	745
Mexico	9	175	8	309
Philippines	(2)	7	1	24
Singapore	3	256	1	216
Spain	14	113	23	301
United Kingdom	10	125	17	209
Other	4	56	4	118
Total	343	3,672	475	6,047
Powder:				
Australia	1	7	(2)	5
Canada	2	15	5	48
Germany, Federal Republic of	4	16	21	148
Italy	--	--	7	31
Japan	5	13	5	13
Mexico	6	37	81	315
Netherlands	--	--	25	147
Sweden	5	30	(2)	2
Taiwan	--	--	2	16
United Kingdom	(2)	2	1	11
Other	2	16	4	23
Total	25	136	151	759
Semifabricated forms, n.e.c.:				
Australia	7	28	4	55
Austria	--	--	3	30
Brazil	2	22	5	40
Canada	6	75	33	323
France	10	173	29	488
Germany, Federal Republic of	29	420	28	434
India	--	--	3	28
Italy	2	27	1	53
Japan	18	329	24	453
Korea, Republic of	2	35	6	12
Mexico	2	26	3	29
Netherlands	4	92	1	55
South Africa, Republic of	5	48	--	--
Sweden	(2)	8	(2)	8
Taiwan	76	8	(2)	10
United Kingdom	14	179	15	330
Other	7	r114	9	93
Total	184	1,584	164	2,441

r Revised.
[1]Ferromolybdenum contains about 60% to 65% molybdenum.
[2]Less than 1/2 unit.

Table 8.—U.S. import duties

Item	Article	Rate of duty, Jan. 1, 1978[1]
601.33	Molybdenum ore	12 cents per pound on molybdenum content.
603.40	Material in chief value molybdenum	10 cents per pound on molybdenum content plus 3% ad valorem.
607.40	Ferromolybdenum	Do.
	Molybdenum:	
628.70	Waste and scrap	10.5% ad valorem.[2]
628.72	Unwrought	10 cents per pound on molybdenum content plus 3% ad valorem.
628.74	Wrought	12.5% ad valorem.
	Molybdenum chemicals:	
417.28	Ammonium molybdate	10 cents per pound on molybdenum content plus 3% ad valorem.
418.26	Calcium molybdate	Do.
419.60	Molybdenum compounds	Do.
420.22	Potassium molybdate	Do.
421.10	Sodium molybdate	Do.
423.88	Mixtures of inorganic compounds, chief value molybdenum	Do.
473.18	Molybdenum orange	5% ad valorem.

[1]Not applicable to countries that have centrally controlled economies.
[2]Duty on waste and scrap temporarily suspended.

WORLD REVIEW

World mine production of molybdenum totaled 205.9 million pounds, or 7.4% higher than that of 1976. The United States, Canada, and Chile were the principal producing nations among market economy countries and together accounted for about 89% of the total world output. Estimated production of molybdenum in the U.S.S.R. comprised about 10% of the total world output.

Canada.—AMAX Inc., through its subsidiary, Climax Molybdenum Corp. of British Columbia, Ltd., continued to investigate the economic feasibility of reopening an open pit mine and mill at the Lime Creek property located in the Alice Arms area of British Columbia. The mine and mill facility, which had been operated by British Columbia Molybdenum Ltd., last produced concentrate in 1972 and was acquired by Climax in 1973. The company stated that proven and probable reserves were calculated at 105 million tons averaging 0.192% molybdenite. If reopened, expanded capacity of the mill could be 12,000 tons per day, and about 10 million pounds per year of molybdenum in concentrate could be produced for about 25 years.

Exploratory drilling by Noranda Mines Ltd. confirmed additional ore potential at the company's Boss Mountain molybdenum mine near Hendrix Lake, British Columbia. The company reported that remaining proved ore would be depleted by mid-1978, but that production from the newly found ore might then be possible. At yearend, proved ore at the mine totaled 340,000 tons grading 0.20% molybdenum, and probable ore was estimated at 2,840,000 tons grading 0.21% molybdenum.

Highmont Mining Corp., Ltd., examined the possibility of bringing into production its copper-molybdenum deposit in the Highland Valley area of British Columbia. Ore reserves at the property were reported to be 145 million tons grading 0.27% copper and 0.047% molybdenite. Highmont also acquired the adjoining Gnawed Mountain property from New Minex Resources Ltd. This deposit contains reserves of 48 million tons grading 0.27% copper and 0.04% molybdenum.

Chile.—Molybdenos y Metales S.A. (Molymet) installed a new molybdenite roaster, thereby increasing the company's roasting capacity to 14 million pounds of molybdenum per year. The firm is a major producer of molybdic oxide and ferromolybdenum.

Iran.—Startup of the concentrating plant at the Sar Cheshmeh copper-molybdenum project was expected in early 1978. The facility will have the capacity to treat 40,000 tons per day of ore. A molybdenum recovery circuit was expected to be operating late in 1978. Estimated output of the facility was expected to be 11 tons per day of concentrate containing 54% molybdenum, or about 4 million pounds of molybdenum per year.

Mexico.—Development of the large La Caridad copper-molybdenum deposit in Sonora neared completion during the year. Initial production of concentrate was expected in 1978. During the year, waste stripping and stockpiling of ore proceeded. In addition, a pilot plant was operated to determine a molybdenum recovery flowsheet for a mill which was under construction. Recovery of molybdenite may begin sooner than originally planned because of current strong demand and high price for molybdenum.

Peru.—Approximately 15.2 million tons of ore was processed in 1977 at the Cuajone copper-molybdenum mine during its first full year of operation. Production of copper concentrate at the mine, which was operated by Southern Peru Copper Corp., began in 1976 and the concentrator was operating at near capacity during 1977. A molybdenum recovery circuit with an expected output of about 3,500 tons of molybdenite per year, is planned for the concentrator plant.

Table 9.—Molybdenum: World mine production by country

(Thousand pounds contained molybdenum)

Country[1]	1975	1976	1977[p]
Australia[e]	25	25	25
Canada (shipments)	28,719	32,229	36,225
Chile	20,042	24,028	[e]24,250
Japan	309	[e]330	[e]330
Korea, Republic of	166	264	222
Mexico	37	35	[e]40
Peru	1,435	992	1,021
U.S.S.R.[e]	20,000	20,600	21,400
United States	105,980	113,233	122,408
Total	176,713	191,736	205,921

[e]Estimate. [p]Preliminary.

[1]In addition to the countries listed, Bulgaria, the People's Republic of China, North Korea, Nigeria, the Philippines, and Romania are believed to produce molybdenum, but output is not reported quantitatively, and available general information is inadequate to make reliable estimates of output levels.

TECHNOLOGY

Bureau of Mines metallurgists have for several years worked to develop an electrooxidation process to recover molybdenum and rhenium from offgrade molybdenite concentrate. An electrooxidation cell has been successfully operated and, during the year, this technology was transferred to industrial representatives. Industry personnel studied the engineering feasibility of the electrooxidation process; data were provided by the Bureau as required.

The Bureau of Mines also engaged in a program to develop investment shell molds suitable for precision casting of molybdenum and molybdenum-base alloys. Molybdenum metal and alloy castings might be substituted for castings of other metals that are used in high-temperature applications but for which the United States is import dependent. After evaluation of various refractory oxides and oxide-forming binders, investment molds produced from zirconium oxide (ZrO_2) with zirconium acetate as a binder were found to exhibit the best thermal and dimensional properties. Additional studies are continuing in order to reduce the reactivity of the ZrO_2 investment molds, to achieve proper elimination of mold gases, and to improve the quality of the molybdenum castings.

A review of the corrosion-resistant properties of iron-chromium-molybdenum (Fe-Cr-Mo) ferritic stainless steels was published.[2] These steels are replacing austenitic stainless steels in the production of some industrial equipment that must resist chloride stress corrosion cracking. Moreover, the newer ferritic stainless steels can now be produced with low contents of carbon and nitrogen, thus improving weldability and resistance to intergranular corrosion compared with established ferritic stainless steels. The study summarized the behavior of the better known types of these new ferritic steels, such as 18 Cr-2 Mo, 26 Cr-1 Mo, and 29 Cr-4 Mo, in various corrosive environments. Variations in chromium and molybdenum content and additions of other alloying elements, such as nickel, titanium, and columbium were discussed in relation to their effect on the general and specific corrosive properties of ferritic stainless steels.

The effect of variations in molybdenum content on the corrosion resistance of stainless steel types AISI 316 and AISI 317 in simulated scrubber environments was investigated.[3] These steels, containing 2% to 4% molybdenum, are exposed to severe corrosive attack when utilized in scrubbers to remove sulfur dioxide from exhaust gases of powerplants and smelters. In general, the study found that type 317 steels with at least 3.4% molybdenum exhibited lower corrosion rates than 316 steels with less than 3% molybdenum. The advantage of the higher molybdenum contents was shown to exist at temperatures of 80°C and 90°C in solutions of pH2-5.3 and chloride ion contents of 3,000 parts per million (ppm) and 30,000 ppm.

Other industrial research efforts reported during the year concerned the development, properties, and applications of metallurgical materials that contain molybdenum as an important alloying element. The influence of varying degrees of cold work on the embrittlement of 18 Cr-2 Mo ferritic stainless steels was studied.[4] Surface hardening treatments of boriding, siliciding, and nitriding were found to improve the wear resistance of molybdenum metal and its major alloy, TZM, at temperatures of 260°C and 430°C.[5] The fracture toughness of AISI M2 and M7 high-speed steels, which nominally contain 5% and 8.75% molybdenum, respectively, was found to depend principally on austenitizing temperature and hardness level.[6] Lower austenitizing temperatures yielded higher fracture toughness in the two high-speed steels. Recent developments in the production of molybdenum-base superalloys and current applications for TZM alloy were reviewed, especially with regard to performance at high temperatures.[7]

U.S. patents granted during 1977 were concerned primarily with new methods to recover molybdenum from ores, leach solutions, and copper smelting slag. Several patents were also granted for procedures to upgrade molybdenum concentrate and technical-grade oxide to high purity oxide and other molybdenum products.

---

[1]Physical scientist, Division of Ferrous Metals.

[2]Steigerwald, R. F., A. P. Bond, H. J. Dundas, and E. A. Lizlovs. The New Fe-Cr-Mo Ferritic Stainless Steels. Corrosion, v. 33, No. 8, August 1977, pp. 279-295.

[3]Lizlovs, E. A. Corrosion Resistance of Types 316 and 317 Stainless Steels in Simulated S0₂ Scrubber Environment. J. Electrochem. Soc., v. 124, No. 12, December 1977, pp. 1887-1888.

[4]Grobner, P. J., and R. F. Steigerwald. Effect of Cold Work on the 885F (475) Embrittlement of 18 Cr-2mo Ferritic Stainless Steels. J. Metals, v. 29, No. 7, July 1977, pp. 17-23.

[5]Kalns, E. Effects of Surface Hardening Treatments on Wear Resistance of Mo and TZM Sheet. J. Metals, v. 29, No. 4, April 1977, pp. 7-11.

[6]Johnson, A. R. Fracture Toughness of AISI M2 and AISI M7 High-Speed Steels. Metallurgical Transactions A, v. 8A, June 1977, pp. 891-897.

[7]Burman, R. W. Molybdenum-A Super Superalloy. J. Metals, v. 29, No. 12, December 1977, pp. 12-17.

Nickel

By John D. Corrick[1]

The nickel situation during 1977 was marked by depressed demand, which led to unstable prices, increased stocks held by producers, and production cutbacks. Consumers were able to reduce their stocks to very low levels because of the oversupply situation. Major nickel producers announced plans during the latter part of 1977 to reduce production in an attempt to lower operating costs and nickel inventories.

Domestic nickel consumption stagnated at a level about 5% below that of 1976. Consumer-held stocks reached their lowest level in nearly 6 years as consumers took advantage of the oversupply situation that plagued major nickel producers. By reducing inventories, nickel consumers were able to free considerable capital for other uses. The share of ferronickel and nickel oxide of the total U.S. market in 1977 increased at the expense of pure unwrought nickel. The pattern of nickel consumption remained essentially unchanged in 1977 from the previous years.

The lower-than-anticipated demand for nickel in 1977 resulted in the price of cathode nickel being decreased on July 25 from $2.41 per pound to $2.20 per pound. Additional price reductions occurred until December, when most major nickel producers announced support of a $2.08-per-pound price for cathode nickel that would extend through the first quarter of 1978.

World trade in nickel was somewhat hampered by the lack of demand. Imports of nickel into the United States in 1977 decreased 11% when compared with those of 1976. Leading suppliers of nickel to the United States, in descending order, were Canada, Norway, New Caledonia, the Dominican Republic, Botswana, and the Philippines. Japanese importers attempted to reduce the quantities of nickel ore and ferronickel previously ordered from various producer nations for delivery in 1977.

Table 1.—Salient nickel statistics

(Short tons, contained nickel)

	1973	1974	1975	1976	1977
United States:					
Mine production[1]	18,272	16,618	16,987	16,469	14,347
Plant production:					
Domestic ores	13,895	14,093	14,343	13,869	12,897
Imported materials	--	226	7,978	20,070	24,757
Secondary	32,629	20,930	17,880	13,273	12,349
Exports (gross weight)	22,070	30,442	30,121	r47,166	39,412
Imports for consumption	190,418	220,655	160,507	188,147	167,111
Consumption	197,723	208,409	146,495	162,927	155,260
Stocks, Dec. 31: Consumer	28,759	45,291	35,485	r31,690	18,638
Price cents per pound	153	153-201	201-220	220	241-208
World: Mine production	782,588	849,257	r890,532	r904,680	851,647

rRevised.
[1]Mine shipments.

DOMESTIC PRODUCTION

The one domestic nickel mine, operated by Hanna Mining Co. at Riddle, Oreg., produced 14,347 tons of nickel from laterite ore, as measured by mine shipments. Nickel recovered at the Hanna smelter and byproduct nickel salts and metals produced at copper and other metal refineries amounted to 12,897 tons; part of the byproduct output originated from scrap. AMAX Inc.'s Port Nickel refinery, located at Braithwaite, La., increased nickel production from 20,070 tons in 1976 to 25,000 tons in 1977, which is about 75% of capacity. The AMAX facility is a pure nickel refinery processing nickel-copper matte and producing refined nickel along with copper, cobalt, and ammonium sulfate as byproducts. Both companies announced plans in 1977 for establishing operating levels that would coincide with market demands in the coming year. At midyear, AMAX announced an agreement to purchase the total production of the Western Australia Agnew project, up to an annual maximum of 16,500 tons of nickel contained in concentrate. Western Mining Corp. in Kalgoorlie, Western Australia, would toll-smelt the concentrate to matte for the joint venture; the matte would be shipped to the Port Nickel, La. plant for refining to pure nickel. Matte was being supplied in 1977 to the AMAX refinery from Rustenburg Platinum Mines Ltd. in the Republic of South Africa, Société Métallurgique Le Nickel (SLN) in New Caledonia, and Bamangwato Concessions Ltd. in Botswana.

AMAX Exploration Inc. announced that its test shaft near Babbitt. Minn., was bottomed at 1,728 feet on June 10. Underground exploration of the deposit will consist of four drifts totaling 3,600 feet. The exploration was being done to determine the continuity of mineralization indicated by diamond drilling from the surface. The company also wanted to determine the mining and environmental parameters, and excavate bulk samples for concentrating tests at facilities in the United States and Canada, as well as conduct smelting tests on the concentrate at plants employing the Outokumpu-type flash furnaces. Inspiration Development Co. conducted exploration studies at the Eight Dollar Mountain deposit in Josephine County in southwestern Oregon. The work involved seismic surveying, mapping, back-hoe sampling, and trommel processing of large bulk samples to test upgrading techniques. The Federal Bureau of Mines conducted reconnaissance sampling and bulk sampling of this and other southwestern Oregon laterites. Reportedly, INCO Ltd. continued to make progress on the construction of its plant at Ellwood City, Pa. for converting waste particulates into remelt alloys. Falconbridge Nickel Mines Ltd. (FALCO) formed a new marketing subsidiary in the United States known as Falconbridge U.S. Inc., located in Pittsburgh, Pa. Warehousing facilities have been strategically located in several U.S. centers to improve product distribution.

Table 2.—Primary nickel produced in the United States

(Short tons, contained nickel)

	1973	1974	1975	1976	1977
Domestic ores	13,895	14,093	14,343	13,869	12,897
Imported materials	--	226	7,978	20,070	24,757

CONSUMPTION AND USES

The demand for nickel stagnated in 1977, showing a slight decrease from that registered in 1976. Consumer-held stocks reached their lowest level in nearly 6 years, totaling 18.6 million pounds at yearend 1977. The low level of stocks could be attributed to consumer's confidence that they could obtain nickel from producers in nearly any quantity needed and on short notice, because producers' stocks were at record high levels.

Ferronickel and nickel oxide increased their share of the total U.S. nickel market in 1977 at the expense of pure unwrought nickel. Pure unwrought nickel accounted for 62% of the total nickel consumed in 1977, compared with 64% in 1976 and 68% in 1975. Most of the pure nickel was consumed in the production of nickel wrought products and nickel alloys and electroplating. Ferronickel accounted for 20% of the total nickel consumed in 1977, compared with 19% in 1976 and 17% in 1975. Principal consumption of ferronickel was in stainless and alloy steels.

Domestic nickel consumption in 1977 decreased 4.7% compared with that consumed in 1976. The pattern of nickel consumption in 1977 was as follows: stainless and heat-resisting steels, 34%; other nickel and nickel alloys, 21%; electroplating, 14%; alloy steels, 11%; and superalloys, 7%.

Table 3.—Nickel recovered from nonferrous scrap processed in the United States, by kind of scrap and form of recovery

(Short tons, contained nickel)

Kind of scrap	1976	1977	Form of recovery	1976	1977
New scrap:			As metal	701	492
Nickel-base	1,691	1,532	In nickel-base alloys	2,470	3,811
Copper-base	4,189	3,159	In copper-base alloys	6,565	5,854
Aluminum-base	1,499	1,554	In aluminum-base alloys	1,478	1,459
			In ferrous and high-temperature alloys [1]	1,138	68
Total	7,379	6,245	In chemical compounds	921	765
Old scrap:			Total	13,273	12,349
Nickel-base	5,372	5,628			
Copper-base	415	445			
Aluminum-base	107	31			
Total	5,894	6,104			
Grand total	13,273	12,349			

[1]Includes only nonferrous scrap added to ferrous high-temperature alloys.

Table 4.—Stocks and consumption of new and old nickel scrap in the United States in 1977

(Gross weight, short tons)

Class of consumer and type of scrap	Stocks, beginning of year	Receipts	Consumption: New	Consumption: Old	Consumption: Total	Stocks, end of year
Smelters and refiners:						
Nickel and nickel alloys	599	6,093	2,088	4,470	6,558	134
Nickel-copper metal	311	912	246	643	889	334
Nickel-silver[1]	683	2,897	231	2,621	2,852	728
Cupronickel[1]	64	257	--	212	212	109
Nickel residues	W	W	W	W	W	W
Total	910	7,005	2,334	5,113	7,447	468
Foundries and other manufacturers:						
Nickel and nickel alloys	293	1,753	1,027	709	1,736	310
Nickel-copper metal	33	225	--	219	219	39
Nickel-silver[1]	2,965	16,371	18,296	36	18,332	1,004
Cupronickel[1]	1,599	9,801	9,661	80	9,741	1,659
Nickel residues	103	250	59	176	235	118
Total	429	2,228	1,086	1,104	2,190	467
Grand total:						
Nickel and nickel alloys	892	7,846	3,115	5,179	8,294	444
Nickel-copper metal	344	1,137	246	862	1,108	373
Nickel-silver[1]	3,648	19,268	18,527	2,657	21,184	1,732
Cupronickel[1]	1,663	10,058	9,661	292	9,953	1,768
Nickel residues	103	250	59	176	235	118
Total	1,339	9,233	3,420	6,217	9,637	935

W Withheld to avoid disclosing company proprietary data; included in "Nickel and nickel alloys."
[1] Excluded from totals because it is copper-base scrap, although containing considerable nickel.

Table 5.—Nickel (exclusive of scrap) consumed in the United States, by form

(Short tons, contained nickel)

Form	1973	1974	1975	1976	1977
Metal	121,821	123,996	99,693	104,374	96,058
Ferronickel	36,371	45,661	25,325	31,210	31,784
Oxide powder and oxide sinter	33,257	33,617	16,630	22,198	22,446
Salts[1]	3,668	2,026	1,751	2,437	2,395
Other	2,606	3,109	3,096	2,708	2,577
Total	197,723	208,409	146,495	162,927	155,260

[1]Metallic nickel salts consumed by plating industry are estimated.

Table 6.—U.S. consumption of nickel (exclusive of scrap) in 1977, by use and form

(Short tons, contained nickel)

Use	Commercially pure unwrought nickel	Ferronickel	Nickel oxide	Nickel sulfate and other nickel salts	Other forms	Total
Steel:						
Stainless and heat-resisting	15,108	24,553	13,371	--	154	53,186
Alloys (excludes stainless)	5,133	5,227	7,181	--	289	17,830
Superalloys	10,609	427	97	--	229	11,362
Nickel-copper and copper-nickel alloys	6,745	42	56	--	125	6,968
Permanent magnet alloys	551	155	22	--	--	728
Other nickel and nickel alloys	29,845	1,138	402	21	481	31,887
Cast irons	1,846	175	718	--	988	3,727
Electroplating[1]	19,806	--	18	1,932	--	21,756
Chemicals and chemical uses	1,783	--	439	214	56	2,492
Other uses[2]	4,632	67	142	228	255	5,324
Total reported by companies canvassed and estimated	96,058	31,784	22,446	2,395	2,577	155,260

[1]Based on monthly estimated sales to platers.
[2]Includes batteries, ceramics, and other alloys containing nickel.

Table 7.—Nickel (exclusive of scrap) in consumer stocks in the United States, by form

(Short tons, contained nickel)

Form	1975	1976	1977[p]
Metal	19,702	18,333	9,846
Ferronickel	11,210	6,905	3,895
Oxide powder and oxide sinter	3,378	5,268	3,985
Salts	564	496	417
Other	631	688	495
Total	35,485	31,690	18,638

[p]Preliminary.

Table 8.—Consumption, stocks, receipts, shipments, and/or sales of secondary nickel in 1977, by use

(Short tons, contained nickel)

Use	Receipts	Consumption	Shipments or sales	Stocks, end of year
Steel (stainless and heat-resisting and alloy)	36,357	34,378	1,594	3,554
Nonferrous alloys (super, nickel-copper and copper-nickel, permanent magnet, and other nickel)	3,184	3,262	--	474
Foundry (cast irons)	399	385	--	26
Chemicals (catalysts, ceramics, plating salts, and other chemical uses)	15	17	--	2
Total reported by companies canvassed and estimated	39,955	38,042	1,594	4,056

PRICES

Two major changes occurred in nickel pricing during 1977; INCO discontinued its practice of quoting nickel prices and producers began selling nickel on a delivered-price basis. The latter change brought nickel pricing into line with the practice of most other metals.

The price of cathode nickel decreased on July 25 from $2.41 per pound to $2.20 per pound due to lower than anticipated demand for nickel in 1977. The subsequent refusal by major nickel producers to quote prices caused considerable concern within the industry. This situation was somewhat alleviated in December when the major nickel producers announced support of a $2.08-per-pound price for cathode nickel. AMAX Nickel Inc. announced that briquettes in 250-kilogram (550-pound) drums would be priced at $2.06 per pound. FALCO quoted a price of $2 per pound for nickel contained in ferronickel produced by its Dominican Republic smelter. INCO officials stated that the realized price per pound of primary nickel sold in 1977 was $2.17, compared with $2.15 per pound in 1976, and $2 per pound in 1975.

The price of domestically produced ferronickel was reduced from $2.34 per pound of contained nickel to $2.025 per pound of contained nickel in December. Reportedly, little nickel was sold for $2.34 per pound. Le Nickel Inc.'s September prices were as follows: FN-4, $2.10 per pound of contained nickel; FN-1, $2.17 per pound of contained nickel; FN-C, $2.12 per pound of contained nickel; and FN-3, $2.14 per pound of contained nickel. These prices were lowered in December to the following: FN-1, $2.09 per pound of contained nickel; FN-3, $2.065 per pound of contained nickel; FN-C, $2.045 per pound of contained nickel; and FN-4, $2.025 per pound of contained nickel.

FOREIGN TRADE

The gross weight of U.S. exports of nickel, nickel alloys, and nickel catalysts was 16% less in 1977 than that exported in 1976. Exports of unwrought nickel in 1977 increased 4% over that exported in 1976.

Canada remained the principal supplier of nickel to the United States in 1977, and accounted for 47% of the total imports. The next most important sources, in decreasing order of magnitude, were Norway, New Caledonia, Botswana, the Philippines, and the Dominican Republic. These six countries accounted for 86% of the nickel imported into the United States in 1977. Imports of ferronickel increased from 9% of total imports in 1976 to 12.7% in 1977, while unwrought nickel decreased from 59% in 1976 to 57% in 1977. The total of all forms imported for consumption in 1977 was 12% less than that imported in 1976.

Table 9.—U.S. exports of nickel and nickel alloy products, by class

Class	1975		1976		1977	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Unwrought	6,676	$25,281	r14,573	r$66,826	15,188	$68,212
Bars, rods, angles, shapes, sections	3,400	22,132	2,519	15,634	2,122	16,915
Plates, sheets, strip	5,808	44,402	4,397	37,631	3,997	32,217
Anodes	275	940	r311	1,598	254	1,410
Wire	679	4,769	769	5,253	764	6,006
Powder and flakes	429	4,575	488	6,150	1,176	10,440
Foil	26	54	17	89	64	182
Catalysts	3,536	13,713	4,442	16,282	4,064	15,674
Tubes, pipes, blanks, fittings therefor, hollow bars	2,333	15,791	3,702	24,497	3,386	26,185
Waste and scrap	6,959	9,645	15,948	19,635	8,397	13,339
Total	30,121	141,302	r47,166	r193,595	39,412	190,580

rRevised.

Table 10.—U.S. imports for consumption of nickel products, by class

Class	1975 Quantity (short tons)	1975 Value (thousands)	1976 Quantity (short tons)	1976 Value (thousands)	1977 Quantity (short tons)	1977 Value (thousands)
Ore	1,135	$47	6,706	r$272	111	$2
Unwrought	107,084	406,894	111,255	r459,398	103,269	451,582
Oxide and oxide sinter	5,063	15,172	5,932	21,948	4,914	17,477
Slurry[1]	23,991	63,522	33,280	98,178	24,762	78,039
Bars, plates, sheets, anodes	517	3,272	776	4,372	947	6,048
Rods and wire	960	5,804	1,774	9,896	7,236	13,511
Shapes, sections, angles	10	81	5	16	11	55
Pipes, tubes, fittings	265	1,961	668	6,064	1,147	13,666
Powder	9,749	39,328	10,046	44,687	13,614	67,098
Flakes	23	85	135	580	146	610
Waste and scrap	2,353	5,864	2,359	4,827	3,175	6,546
Ferronickel	65,046	67,813	55,721	72,161	80,436	95,275
Total (gross weight)	216,196	609,843	228,657	r722,399	239,768	749,909
Nickel content (estimated)[2]	160,507	XX	188,147	XX	167,111	XX

rRevised. XX Not applicable.
[1]Nickel-containing material in 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]Estimated from gross weight of primary nickel products.

Table 11.—U.S. imports for consumption of new nickel products,[1] by country

(Short tons)

Country	Metal (gross weight)		Powder and flakes (gross weight)		Oxide and oxide sinter (gross weight)		Slurry and other[2]			
							1976		1977	
	1976	1977	1976	1977	1976	1977	Gross weight	Nickel content	Gross weight	Nickel content
Australia	3,684	3,310	1,218	1,756	--	395	735	670	3	3
Canada	77,819	61,728	6,280	8,226	5,843	4,438	26,233	19,637	16,455	12,190
Dominican Republic	133	8	--	--	--	--	--	--	--	--
Finland	844	1,918	--	--	--	--	46	40	79	79
France	9	--	34	--	59	59	--	--	--	--
Germany, Federal Republic of	(3)	(3)	7	3	2	--	79	16	--	--
Japan	848	756	--	--	--	7	360	276	--	--
Netherlands	43	39	(3)	--	(3)	(3)	--	--	2	1
New Caledonia	--	--	--	--	--	--	5,727	4,383	8,146	6,284
Norway	13,913	17,412	264	101	--	--	--	--	--	--
Philippines	6,972	9,857	1,209	2,314	--	--	--	--	--	--
Rhodesia, Southern	3,103	4,340	--	--	--	--	--	--	--	--
South Africa, Republic of	2,661	1,713	308	382	--	--	--	--	--	--
Switzerland	19	--	1	--	--	--	--	--	--	
U.S.S.R	1,055	1,515	--	--	--	--	--	--	--	--
United Kingdom	82	254	860	977	8	(3)	100	25	77	23
Other	70	419	(3)	1	20	15	--	--	--	--
Total	111,255	103,269	10,181	13,760	5,932	4,914	33,280	25,047	24,762	18,580

[1]Ore imports in 1976 were, 6,687 tons from New Caledonia and 19 tons from Canada. Ore imports in 1977 were, 111 tons, all from New Caledonia.
[2]Nickel-containing material in slurry, or in any form derived from ore by chemical, physical, or any other means, and requiring further processing to recover nickel or other metals.
[3]Less than 1/2 unit.

WORLD REVIEW

Australia.—Western Mining Corp., Ltd. (WMC) sold 41,631 tons of nickel in 1977, compared with 47,837 tons in 1976. The decrease was due to a reduction in production that was instituted at the beginning of September. Operations were suspended at the Great Boulder mine, and reductions were made at the Fisher and Kambalda mines. The firm's work force was reduced by 600 workers out of a total of 4,200. Officials of WMC stated that the cutback was necessitated by a decrease in the price of nickel which resulted from surplus stocks. WMC announced plans to close its Kalgoorlie smelter in Western Australia and build a new $37.5 million smelter. Two-thirds of the financing would come from Mount Isa Mines Ltd., and Western Selcast Pty., Ltd. The Kalgoorlie smelter will then be placed on standby. The new flash furnace initially is scheduled to smelt up to 500,000 tons of concentrate per year. Nearly 110,000 tons per year of Agnew ore would be treated in the new furnace. The addition of oxygen to furnace air is to make possible an increase in capacity to more than 800,000 tons per year at a later date. The future of Poseidon Ltd., which was placed in receivership in 1976, remained uncertain throughout 1977. The major creditor, Australian Industrial Development Corporation (AIDC), offered WMC $3.5 million to develop a program at the Windarra mine. This offer was in addition to usual financial spending by Poseidon, owner of 50% of the Windarra mine, which amounted to nearly $1 million per month. Shell of Australia Ltd. apparently successfully bid for the 50% share of the Windarra project previously held by Poseidon. Shell's share of the output was committed to Canada's Sherritt Gordon Mines Ltd. until 1979 at world free-market prices. Full ratification of Shell's takeover was undecided at yearend, and was awaiting the outcome of the Australian supreme court ruling concerning the sale of Poseidon assets. Development work underway during 1977 was expected to cost between $5 million and $7 million. The work was directed toward removing several million tons of overburden and continued deep drilling to define ore reserves.

Further restructuring of the finances of the Greenvale laterite operation in Queensland was announced early in 1977. New agreements on the terms of loan and interest repayments were reached with the project financiers and the Queensland Government. The new arrangements allowed for flexibility in debt servicing and thereby enabled retention of sufficient working capital. Reportedly, all cash from the project in excess of $11 million needed for working capital will be applied to debt commitments. The partners will be required to pay a minimum of 30% of the scheduled debt payments during the next 3 years, ending in 1979. Reportedly, output improved modestly in the third quarter and the cash value of production exceeded, by a slight margin, the cash operating costs and the minimum of cash interest payments due under the restructuring plan. Late in 1977, the owners canceled plans for an $18 million expansion. The expansion was to include the purchase of two new roasters and one cooler.

Development work continued on the Agnew nickel deposit jointly held by Mount Isa Mines Ltd. and Western Selcast Pty., Ltd. Initial work was directed at constructing an incline shaft into the area to be mined, and on the collar of a shaft to be sunk for exploring deeper ore bodies. The project received a boost when AMAX signed long-term contracts, valued at $500 million, to take the total production from Agnew for the next 10 years. A limit of 16,500 tons per year was specified in the contract. The ore will be mined and concentrated at the Agnew mine site and the concentrate will be shipped to WMC's smelter at Kalgoorlie. The matte will be shipped to AMAX's Port Nickel refinery located in Louisiana for refining into pure nickel. Initial mine production was scheduled for 1978.

Early in 1977, AMAX announced that it was reevaluating the economics of mining at Forrestania, based on ore bodies at Flying Fox, Digger Rocks, and Cosmic Bay. Reportedly, one drill hole at Flying Fox assayed 9% nickel over a length of 16 feet. A feasibility study was being made. Officials at Endeavor Oil Co. NL stated that AMAX had begun a diamond drilling program at the Digger Rocks prospect. Endeavour holds a 30% interest in Digger Rocks. The program was to be comprised of six new drill holes to obtain ore samples and substantiate correlations used in calculations of ore reserves and thus supplement the Forrestania feasibility study.

Production of ore from the Spargoville mine in Western Australia increased during 1977; the mine is operated by Selcast Exploration Ltd. Ore reserves were reported to be 500,000 tons grading 2.61% nickel. Anglo American Corp. was exploring the Sally Malay nickel deposit near Turkey Creek in northeastern Western Australia. The company expected that sufficient information would be amassed by yearend 1977 for a decision to be made on whether a full-scale feasibility study should be made. Sally Malay is in a remote area and would probably require heavy capital expenditure for development of the needed infrastructure.

Botswana.—Specialists were called in from the Republic of South Africa and Finland to assist in repairing furnaces at the Selebi-Pickwe nickel-copper operations in March 1977. Company officials of Bamangwato Concessions Ltd. announced at midyear that the mine had reached its design capacity of 5,850 tons per day. The smelter's capacity of 3,500 tons per month

Table 12.—Nickel: World mine production[1] by country

(Short tons)

Country	1975	1976	1977[p]
Albania[e]	[r]7,100	[r]7,700	8,000
Australia (content of concentrate)	[r]83,583	91,652	94,578
Botswana	18,314	13,866	13,331
Brazil (content of ore)	3,516	5,812	6,100
Burma (content of speiss)	21	26	19
Canada[2]	266,957	265,464	259,442
Cuba (content of oxide sulfide)[e]	40,300	[r]40,600	40,800
Dominican Republic	29,652	26,896	26,676
Finland:			
Content of concentrate	[r]5,840	7,008	6,393
Content of nickel sulfate	228	209	[e]210
German Democratic Republic[e]	2,800	2,800	2,800
Greece (recoverable content of ore)[3]	31,014	30,380	[e]21,000
Indonesia (content of ore)[3]	21,193	21,928	[e]15,400
Mexico (content of ore)	55	62	[e]65
Morocco (content of nickel ore and cobalt ore)	550	220	[e]220
New Caledonia (recoverable)[4]	[r]146,938	131,065	120,218
Norway (content of concentrate)	335	[r] [e]440	[e]440
Philippines	10,472	20,723	[e]16,500
Poland (content of ore)[e]	2,800	[r]3,100	3,100
Rhodesia, Southern (content of concentrate)[e]	11,000	[r]17,600	17,600
South Africa, Republic of	22,877	24,660	25,400
U.S.S.R. (content of ore)[e]	[r]168,000	[r]176,000	159,000
United States (content of ore shipped)	16,987	16,469	14,347
Total	[r]890,532	904,680	851,647

[e]Estimate. [p]Preliminary. [r]Revised.
[1]Insofar as possible, this table represents mine production of nickel; where data relates to some more highly processed form, the figures given have been used in lieu of unreported actual mine output to provide some indication of the magnitude of mine output, and are so noted parenthetically following the country name, or by footnote.
[2]Refined nickel and nickel content of oxides and salts produced, plus recoverable nickel in exported matte and speiss.
[3]Includes a small amount of cobalt not reported separately.
[4]Nickel-cobalt content of metallurgical plant products, plus recoverable nickel-cobalt in exported ores.

Table 13.—Nickel: World smelter production,[1] by country

(Short tons)

Country[2]	1975	1976	1977[p]
Australia	[r]40,014	50,700	[e]50,700
Botswana	7,099	13,000	13,100
Brazil[3]	2,513	2,369	[e]2,600
Canada[4]	196,211	196,321	167,130
Cuba[e 3]	20,000	[r]20,000	20,000
Czechoslovakia[e]	[r]3,900	[r]3,900	3,900
Dominican Republic[3]	33,100	26,896	[e]26,900
Finland	7,214	8,404	10,362
France	11,968	13,573	[e]10,400
German Democratic Republic[e]	2,900	[r]3,100	3,100
Germany, Federal Republic of	134	143	[e]130
Greece	[r]16,383	18,131	[e]13,000
Japan	85,980	104,199	98,264
Mexico	55	62	[e]70
New Caledonia[5]	78,339	68,264	[e]57,500
Norway	40,847	36,028	42,218
Philippines	10,322	15,763	[e]23,700
Poland[e]	2,800	[r]3,100	3,100
Rhodesia, Southern[e]	10,000	11,000	11,000
South Africa, Republic of	[r]15,400	18,700	18,700
United Kingdom	[r]41,108	36,514	[e]25,100
U.S.S.R.[e]	[r]190,000	[r]200,000	207,000
United States[6]	14,343	13,869	12,897
Total	[r]830,630	864,036	820,871

[e]Estimate. [p]Preliminary. [r]Revised.
[1]Refined nickel plus nickel content of ferronickel produced from ore and/or concentrates unless otherwise specified.
[2]In addition to the countries listed, North Korea is believed to produce metallic nickel and/or ferronickel, but information is inadequate for formulation of reliable estimates of output levels.
[3]Nickel content of ferronickel only (no refined nickel is produced).
[4]Includes nickel content of nickel oxide and nickel fonte in addition to metallic nickel and ferronickel.
[5]Nickel-cobalt content of ferronickel and nickel matte produced for export.
[6]Byproduct of metal refinery plus recovery from domestic ore.

of high-grade matte containing 1,275 tons of nickel and 1,452 tons of copper was also attained. Metal recovery in the matte steadily improved from 50% in 1975 to 60% in 1976, and finally to 70% in 1977. Production of copper-nickel matte was reported as 33,849 tons in 1977, compared with 35,757 in 1976. Sale of nickel was 14,725 tons in 1977, compared with 13,270 tons in 1976. A switch from oil to coal was accomplished in certain parts of the production process. Reportedly, the Botswana Government agreed to accept a royalty of 3% of the value of the metal contained in the matte. The matte production was valued at $35.5 million in 1977.

Burundi.—The United Nations awarded a $150,000 contract to the Mineral Sciences Division of UOP Inc. to make a detailed metallurgical study of nickel-bearing ores of Burundi. The contract called for UOP to make recommendations as to the most suitable method for economically treating the nickeliferous laterite ores located near Musongati. Reportedly, UOP will test samples from discrete zones of the ore deposits on a laboratory-scale basis, conduct small extraction tests, and provide an economic analysis of alternate methods of processing the ore. If feasible, ore processing could include the recovery of copper, cobalt, and the platinum-group metals.

Canada.—Mine production of nickel in Canada in 1977 amounted to 259.4 million pounds, compared with 265.5 million pounds in 1976. Canada remained the leading producer of nickel in the world and accounted for 30% of the total world mine production. The principal producers of nickel in Canada remained INCO, FALCO, and Sherritt Gordon Mines Ltd. Much concern was evident in Canada during 1977 as the major nickel producers announced production cutbacks and layoffs due to excessive inventory buildups.

INCO mined a total of 19.6 million tons of ore in 1977, compared with 19.8 million tons mined in 1976. INCO's nickel production in 1977 amounted to 417 million pounds, compared with 462 million pounds in 1976. Nickel deliveries by INCO were reported to be 312.3 million pounds, or 24% below the 1976 level of 409.8 million pounds. Reportedly, from yearend 1974 to yearend 1977, INCO produced 264 million pounds more finished nickel than it sold. At yearend, INCO inventories of finished nickel available for sale were 341 million pounds, or 241 million pounds more than a normal inventory of 100 million pounds. In July, INCO announced that it was reducing its nickel production by not replacing employees lost through attrition at Canadian operations. On October 20, 1977, the company announced a further cutback in production of 15% for 1978. The Victoria mine will be completely shutdown because of depleted ore; the other affected mines will be maintained on a standby basis. Development work on the Levack East mine was deferred in the third quarter of 1977. The mine was originally scheduled to begin production in 1983. In Manitoba, mine production from Birchtree was suspended in December, and development work at Pipe No. 2 shaft was suspended in July. The lower mine production will be reflected in reduced activity at most surface plants, including mills, smelters, and refineries. INCO reported its 1977 nickel production capacity as being 460 million pounds per year. The older section of the tankhouse at Port Colborne, built in 1918, was shutdown permanently, and electrolytic nickel production was discontinued. A new centralized shop facility, including a machine shop, was being constructed to replace the one that burned in 1977. Canadian reserves held by INCO as of December 31, 1977, were reported as 407 million tons of ore containing 6.9 million tons of nickel, compared with 412 million tons of ore containing 6.8 million tons of nickel held at yearend 1976. INCO spent $22 million on exploration work during 1977, compared with $23 million in 1976. More than 65% was spent in Canada in the vicinity of INCO's producing mines. The company performed deep drilling from the surface to test unexplored geological targets to a depth of 10,000 feet in the Sudbury district.

FALCO and Sherritt Gordon remained Canada's second- and third-ranked nickel producers, respectively, in 1977. FALCO announced it would close its Manibridge nickel-copper mine in Manitoba. The reason given for the closure was exhaustion of economic ore. The mine accounted for 5% of FALCO's nickel production. The mill was to be mothballed pending further evaluation of a nearby deposit owned by Bowden Lake Nickel Mines Ltd., which in turn is owned 60% by FALCO. The company announced that lateral development work was started on its new Fraser mine in the Sudbury district, and that the mine was scheduled to start production in 1979. A second new mine, Craig, was to reach production by 1983. Company officials also announced that ore reserves at the Longvack South mine had been depleted. About $75 million was to be spent on various improvement programs during 1977; as follows: $43 million was slated for the Sudbury smelter environmental-improvement project scheduled for completion in April 1978; $19.6 million for development and preproduction expenses; $4.4 million for plant and equipment; $4.1 million for other environmental projects; and $3.6 million for projects at the new Fraser and Craig mines. In August, FALCO announced the complete shutdown of its Sudbury operations from September 11 to October 9th. The shutdown affected nearly 4,000 employees. Operations were also closed for 4 days during the November 11 Remembrance Day holiday and between Christmas and New Year's Day. The shutdowns were made to curtail production and thereby alleviate excess nickel stock buildups. FALCO inventories of nickel at yearend 1977 were reported as 73 million pounds, compared with 13 million pounds at yearend 1976. Normal inventories were given as 8 million pounds. Further production cutbacks were announced for 1978 and could reduce capacity to slightly over 50%. Ore reserves in 1977 were reported at 80,670,000 tons grading 1.46% nickel (1,178,000 tons of nickel), compared with 83,405,000 tons grading 1.46% nickel (1,218,000 tons of nickel) in 1976.

The Sherritt Gordon refinery became totally dependent on imported materials in 1977 when its only nickel-copper mine, located at Lynn Lake, was shutdown. Salvage of old equipment from the Lynn Lake mine was completed by midyear, and the mine was then allowed to flood. The salvaged equipment was being reconditioned at the Lynn Lake workshop to be utilized at the Fox and Ruttan mines, which produced copper and zinc. The refinery's nickel production capacity was reported as 40 million pounds per year.

Exploration work continued on Teck Corp.'s Montcalm copper-nickel deposit, located 35 miles northwest of Timmins, Ontario. The deposit, consisting of two sulfide zones separated by an 80-foot-thick granite dike, was discovered in 1976. Ore reserves were reported at 4 million tons grading 1.44% nickel and 0.68% copper. Engineering work was being done prior to the start of a feasibility study. Uranerz Exploration and Mining Co. announced plans to develop its Key Lake property, which contains uranium and about 50 million pounds of nickel. The plans called for production by 1983. Nickel would be a byproduct of uranium recovery. Great Lakes Nickel Ltd. indicated it may bring its Thunder Bay copper-nickel project into production in the early 1980's. Reserves have been estimated at 45.6 million tons of ore, grading 0.34% copper and 0.1% nickel, with minor amounts of palladium and platinum. However, late in 1977, an updated feasibility study recommended no change in the standby position of the mine-mill project for Thunder Bay. Noranda Mines Ltd. of Toronto announced that it was terminating its joint venture with INCO in Langmuir Township, Ontario, early in 1978. Exploration for additional nickel-bearing zones was suspended early in 1977, reportedly due to disappointing results. Also cited were declining ore grade and difficult ground conditions that had increased operating costs.

Colombia.—The Cerro Matoso nickel project appeared to make some headway in 1977 when Hanna Mining Co. and the Government of Colombia agreed to proceed with the project. However, long-term contracts had not been signed at yearend. A tentative date of March 1978 was set for beginning construction. Hanna estimated that about $50 million had been spent, mostly on exploration and ongoing maintenance of access and site roads. Of the three ore bodies explored, the best had proven reserves of 7.8 million tons of ore, consisting of saprolite and saprolized periodotite covered by iron-bearing mineral. The reserve averages 3.2% nickel mixed with iron, magnesium, and other minerals.

Cuba.—Reportedly, work was progressing on the new Punta Gorda plant in eastern Cuba during 1977, which is scheduled for completion in 1983. When completed, the plant will add 30,000 tons per year of nickel capacity to Cuba's output. Nickel production in Cuba during 1977 was reported as 40,800 tons. The output was evenly divided between the Nicaro and Moa Bay operations. Mine output was about 4 million tons; all going to feed the two operating plants.

Dominican Republic.—Falconbridge Dominicana, C. por A., shipped 45,477,000 pounds of contained nickel in 1977, compared with 56,471,000 pounds in 1976. The smelter operated at below capacity because of adverse market conditions. The ferronickel pigs produced are trucked 50 miles to the port of Haina for shipment to steelmakers in the United States, Canada, Sweden, the United Kingdom, and France. Typical analysis of the 50 pound pigs is 35% nickel and 65% iron.

Finland.—Outokumpu Oy shut down the nickel concentrator at the Vuonos mine in 1977. It accounted for 17% of the total Finnish nickel output in 1976. The company began experimental underground mining at the Vammal nickel prospect in 1977. The company expects output to decrease in the near future as ore grades fall. Finnish mines and concentrators have some of the highest recovery rates in the world, running over 90%. This figure becomes even more remarkable considering that average mill head grade was 0.78% nickel and 0.31% copper at the Kotalohti mine, and 0.4% nickel and 0.3% copper at the Vammala mine. The company's Harjovalta works increased cathode nickel production from 7,600 tons in 1976 to 9,400 tons in 1977.

Greece.—Société Minière et Mètallurgique de Larymna S.A. (LARCO) was struck for 106 days during 1977. Workers returned to work on May 16 after agreeing to a 17% wage increase. Large quantities of low-grade nickel laterite ore were discovered in the Triada-Makrykara area in the central part of the island of Euboea by Eleusis Bauxite Mines. Extensive drilling indicated a grade of 0.8% nickel. The company plans on mining about 1.2 million tons per year by open pit methods. The ore reportedly will be preconcentrated to 1.2% nickel and electrically smelted to produce about 40,000 tons per year of ferronickel (25% nickel content).

Guatemala.—President Kjell Eugenio Laugerud Garcia of the Republic of Guatemala officially dedicated the Exploraciones y Explotaciones Mineras Izabal, S.A. (Eximbal) project on July 12, 1977. At yearend, all of the mining and ore-processing facilities had been commissioned. Primary metal refined from the Eximbal matte was not expected to reach the marketplace before 1979. An initial shipment of matte was expected during the first quarter of 1978. The matte will contain 75% nickel and 22% sulfur. Reportedly, over one-half of Eximbal's operating costs will be for fuel, with much going to operate the powerplant. Total fuel storage at Eximbal is 147,000 barrels of fuel oil. Indicated ore reserves are sufficient for tripling production if needed. Basic Resources International S.A. reportedly discovered nickel reserves at its Buena Vista deposit in Guatemala that contain 37 million tons of ore averaging 1.81% nickel. A second deposit, the Chiis, has reserves estimated at nearly 10 million tons grading 1.71% nickel. Basic Resources conducted preliminary testing and laboratory work on a smelting process for the ore. A feasibility study including pilot plant testing would cost about $2.5 million. Discussions were being held with several prospective partners during 1977.

Indonesia.—President Suharto of the Republic of Indonesia dedicated the Soroako nickel project of P.T. International Nickel Indonesia on March 31, 1977. A small quantity of nickel matte was produced in the fourth quarter of 1977. Some mechanical and technical problems were encountered in the startup phase of the first process line. The most serious difficulty arose from refractory failure in the electric furnace and partial failure of internal lifters in the prereduction kiln. Production from the first stage of its design capacity was expected to occur in the second quarter of 1978. The second stage was not expected to start up before 1980.

P.T. Aneka Tambang (ANEKA) continued operation of its ferronickel smelter but was having trouble selling its output. The Japanese asked for a reduction in shipments during 1977. The reason given was poor demand and the fact that Japanese plants were operating about 50% below capacity. The Japanese continued to receive nickel ore from ANEKA's operation in the Pomalaa area in southeastern Sulawesi, Celebes, in 1977. Exploration in the Pomalaa area indicated sufficient nickel reserves to meet current yearly rates of production for the next 100 years. Indonesia has a 10-year contract to supply nickel ore to Japan.

Under rights granted to P.T. Pacific Nikkel Indonesia by the Indonesian Government, the company outlined minable reserves in excess of 190 million tons of laterite ore. During 1977, Amoco Minerals Co. tentatively agreed to equity participation in a consortium to develop a $1 billion project. The Indonesian Government agreed to take a 20% equity share in the project, which then qualified it for partial World Bank Financing. Newmont Mining Co. withdrew from the consortium in 1977. Sherritt Gordon and Muller Bros. A.G. of the Federal Republic of Germany withdrew earlier. Sherritt Gordon continued to provide refining expertise to the project, and Newmont technically retained about 28% equity in Pacific Nikkel. However, both will be inactive in management. United States Steel Corp. held about 48% of the shares in the original consortium. The consortium reportedly was given an 18-month to 2-year extension on the preconstruction phase of its 1969, second-generation mining contract. Without the extension, contruction would have had to start by yearend or the contract area would have had to be relinguished.

The Japanese-owned Indonesian Nickel Development Co. (INDECO) decided not to develop a ferronickel smelter on Gebe Island. The plan dates back to 1969 and was to produce 20,000 tons of nickel per year. The decision was made because of depressed nickel prices and the current outlook for nickel. In addition, a study concluded in 1976, showed that the project would not be as profitable as earlier studies indicated.

Japan.—With domestic demand for nickel predicted to drop below 90,000 tons, importers were seeking relief from contracts for nickel deliveries in 1977. Stainless steel and specialty steel producers were shopping for lower cost nickel during much of 1977. The net result was that Japanese stocks of nickel in various forms increased.

Japanese ferronickel smelters reached an agreement with New Caledonia ore shippers regarding price increases during 1977. The new price retroactive to January 1977, was an increase of 12 cents to $0.76 per pound of contained nickel. New Caledonia ore shippers were requesting $0.78 per pound of contained nickel. Further evidence of decreased demand was manifested in the decision by Japanese companies not to develop a ferronickel smelter in Indonesia and their refusal to take part in Colombia's Cerro Matoso ferronickel project. Four Japanese importers agreed to take 2,400 tons of nickel oxide and 3,600 to 4,400 tons of nickel-cobalt mixed sulfides from the Australian Greenvale operations during fiscal year 1978. After union agreement on the closure of the Shimura plant by Shimura Kako Co., Ltd., and the transfer of operations to Date, Hokkaido, construction began in late 1977 on a nickel refinery to be built beside the company's present ferronickel smelter.

New Caledonia.—Production of nickel ore in New Caledonia in 1977 was about 2% less than that produced in 1976, and totaled 6.4 million tons. Nickel smelter production decreased 17% in 1977 from that of 1976, and totaled 56,571 tons. Ferronickel production decreased nearly 26% and totaled 31,176 tons, while matte production decreased 3% from that of 1976. Exports of nickel ore to Japan decreased 3% in 1977, compared with exports in 1976. Exported ore averaged 2.39% nickel plus cobalt.

SLN operated four main mining centers on New Caledonia during 1977. SLN began an expansion program in 1977 to raise its capacity to 100,000 tons of nickel per year. Two mining centers will be expanded. The largest, Nepoui, will be increased to around 2.2 million tons of ore per year, while Kouaoua will be doubled to about 1.3 million tons of ore per year. Reportedly, smelter output will be increased by improvements in ore preparation and calcining prior to smelting. Company officials stated that the territorial assembly of New Caledonia has guaranteed SLN a stable tax system until 1989. Stocks held by SLN were reported to be equivalent to 6 months' normal production. Production was reduced during 1977 by closing down two smelters. The territorial assembly passed legislation that will require the gradual reduction in atmospheric pollution at the Noumea smelter. The project as estimated would cost $33 million and was to be completed by 1981.

At yearend, AMAX was close to signing an agreement with the Bureau de Recherches Géologiques et Minières (BRGM) for the development of a new nickel project in New Caledonia. Reportedly, annual output would be 26,000 tons of ferronickel. A purer form of nickel may be produced later. AMAX would have less than 50% interest in the operation. Ore reserves were estimated at 55 million tons grading 2.5% to 2.6% nickel in garnierite. The ore ore would be mined at a rate of about 1 million tons per year.

INCO concluded an agreement with the French Government for the exploration of the Goro nickel deposits. INCO was to undertake a large-scale program of geological, mining, and metallurgical studies. The company must inform the French Government by June 30, 1982, whether it plans to build a processing plant or give up its rights to the Goro deposit.

Philippines.—Depressed nickel demand and its resulting downward pressures on prices in 1977 caused Marinduque Mining and Industrial Corp. to fall into technical noncompliance with the terms of its 1975 loan agreement for refinancing its nickel project on Nonoc Island. In May, it was announced that Marinduque obtained financial help from the State-owned Development Bank of the Philippines. The bank agreed to help the company meet its debt and working-capital needs through 1978. Production during the first 9 months of 1977 averaged about 63% of rated capacity, compared with 48% during the first 9 months of 1976. Annual capacity was reported to be 68.4 million pounds of pure nickel and mixed sulfide concentrates containing about 6.6 million pounds of nickel and 3.3 million pounds of cobalt.

Japanese ferronickel producers took the first shipment of ore from the newly developed Palawan project in 1977. Total shipment contracts to Japan in 1977 were for 385,000 tons of ore. The ore was reported as grading 2.4% nickel. Reserves were estimated at 24 million tons of ore containing over 2.2% nickel. The mine was operated by Rio Tuba Mining Corp.

Rhodesia, Southern.—Anglo-American Corp. of South Africa Ltd., parent company of Rhodesia Nickel Corp. (Rhonickel), announced that it was withdrawing its prospecting teams from field operations in Rhodesia because of a steady deterioration in the security situation in that country. The decision would affect about 100 of its geological staff. The company was expected to continue operation of its three nickel mines— Trojan and Madziqa in the Bindura-Shamba area, and the Epoch mine at Filabusi. At yearend, nickel production from the Shangani mine was cut by 50% as a result of the depressed nickel market.

South Africa, Republic of.—One of the country's two major nickel producers, Rustenburg Platinum Mines Ltd., announced in late 1977 that it was cutting platinum output by 10% to 20%. This would directly affect the production of byproduct nickel. At yearend, the other producer, Impala Platinum Ltd., had made no commitment to reduce production.

U.S.S.R.—Work continued in 1977 on development of the Norilsk nickel mine. Reportedly, the nonferrous metals complex in northern Siberia, which is the major producer of nickel and platinum-group metals in Russia, would undergo an 80% expansion by 1980.

Yugoslavia.—The major portion of a pelletizing plant at Kavadarci was to be supplied by a U.S. firm. The plant will have a capacity to produce pellets at a rate sufficient to meet the demand of a 70,000-ton-per-year ferronickel (25% nickel content) plant. The total facility was to begin production in 1979. A complete wet-scrubbing system for each of the two ferronickel electric furnaces was supplied for installation at the plant.

TECHNOLOGY

Bureau of Mines scientists investigated sulfuric acid leaching characteristics of a copper-nickel flotation concentrate, matte, and roasted matte produced from the Duluth gabbro ore of Minnesota.[2] Autoclave leaching of flotation concentrates with aerated, 100-gram-per-liter H_2SO_4 at 220° C and 550 psig of compressed air resulted in extraction of over 90% of the nickel and copper in 6 hours. Best results were obtained by leaching the matte at elevated pressures and a temperature of 180° C. At pressures of 350 psig, over 90% of the copper and nickel were extracted from matte containing 1.2% to 4.7% iron. Residues remaining after the leach were considerably less than those left after leaching flotation concentrates and suggested a substantial concentration of the precious metals (90 ounces per ton). The Bureau continued work on defining engineering and cost factors related to a process developed to recover nickel and cobalt from low-grade domestic laterites. Scientists at Bureau facilities supplied Raney nickel inserts for large-scale testing at the Pittsburgh (Pa.) Energy Center. The Bureau was attempting to increase both the resistance to poisons and the methanation activity of the basic Raney nickel formula by alloying and heat treating. It is estimated that wastes containing over 20 million pounds of chromium and 8 million pounds of nickel are generated annually in the production of stainless steel in the United States. The Rolla (Mo.) Metallurgy Research Center of the Bureau of Mines developed a method for recovering up to 90% of the iron, chromium, and nickel contained in pelletized mixtures of these stainless steel wastes. Rolla researchers continued their search for methods to recover nickel, cobalt, and copper from mattes and drosses generated during the smelting of Missouri lead ore concentrates and to develop beneficiating procedures for recovering cobalt and nickel from commercial lead, zinc, and copper concentrates by modifying milling procedures now practiced in the Missouri Lead Belt. The Reno (Nev.) Metallurgy Research Center conducted investigations into the extraction of copper, nickel and cobalt from complex sulfide concentrates (such as the Duluth gabbro) using a ferrous chloride/oxygen leach system. Scientists at the College Park (Md.) Metallurgy Research Center reported on a study to produce corrosion-resistant alloys on the surface of ordinary steel.[3] The process used an ion accelerator to bombard the surface of a host metal with chromium or nickel ions. By penetrating the surface of the metal with particular metal ions, a layer of alloy steel is created. During 1977, the Western Field Operation Center at Spokane, Wash., conducted photogeological work on possible extensions of mapped laterites on Eight Dollar Mountain, Woodcock Mountain, Free and Easy Pass, and Red Flats, Oreg. Similar work was done on deposits in the Gasquet area, Del Norte County, Calif.

Westinghouse Electric Corp. developed an iron-nickel battery system which was tested during 1977 at the Triple-B coal mine in eastern Kentucky.[4] Reportedly, the new iron-nickel battery offers 80% more usable energy onboard a coal hauler than an equivalent volume lead-acid battery. The iron-nickel battery weighs 38% less than the lead-acid battery and can be charged in 1 to 3 hours compared with 8 or more hours for the lead-acid battery. Spacecraft batteries in the 1980's will apparently have nickel-hydrogen electrodes.[5] The U.S. Air Force was to receive 50 cells from Hughes Aircraft Co. for evaluation in 1977. The batteries were reported as having twice the usable energy per pound of nickel-cadmium batteries despite the heavy containers required for hydrogen storage. The hydrogen electrode makes the battery relatively insensitive to overcharging and totally insensitive to overdischarging. The Pesses Co. planned to expand its new Pulaski, Pa. plant to recover nickel and cadmium from nickel-cadmium batteries.[6] The expansion was built to handle an estimated 8% growth per year in the scrap nickel-cadmium battery business.

Research continued through 1977 on the development of ceramic components as substitutes for superalloys for turbine applications. The ceramic components being investigated included rotor blades, vanes, shrouds to combustor liners, and regenerators. Ceramics were being investigated as a means of increasing turbine temperatures above the 2,000° F limit specified for most superalloys. Hybrid systems will probably be used in future applications because metal support structures will be necessary to absorb shock and vibration.

According to reports from the Stainless Steel '77 conference held in London, England, the nickel-free stainless steels are gaining popularity.[7] The newly developed stainless steel alloys are finding use in welded tubing and solar-concentrator panels. Nippon Metal Industry Co., Ltd., developed a new stainless steel which is resistant to pitting corrosion. In this respect, it is said to be superior to both 304 and 316 stainless steels with a higher resistance to stress corrosion and cracking in chloride environments. It was selected over such austenitic stainless steels as Type 304 for use in heat exchangers cooled by industrial, river, or underground water. It was shown to exhibit excellent resistance to seawater corrosion and was adopted by the Ishikawajima-Harima Heavy Industry Organization for tubing in ship condensers. In this use, it replaces aluminum, bronze, and cupronickel tubing. A second alloy (18Cr-2Mo) developed by Nippon was finding applications in hot-water tanks, chemical process equipment, water-storage tanks, refrigerators, and tanks for "sake." Researchers at INCO determined that mechanical alloying was superior to other methods of alloying.[8] Mechanical alloyed materials reportedly have mechanical- and antioxidation-corrosion properties superior to conventionally produced alloys. The process involved simultaneous milling of all constituents in a special, high-intensity ball mill. Three superalloys, INCONEL alloy MA754, INCOLOY alloy MA956E, and INCOLOY MA600E, were extensively investigated. Alloy MA754 may find application as a replacement for TD nickel in gas turbine blades; MA956E's oxidation resistance makes it suitable for burner-housing applications in jet engines; and MA600E alloys may be used in 10 to 15 years in advanced gas turbine blades. A new nickel alloy for use in thermostats, controls, instrumentation, and the electronics industry was developed by the Minerals, Pigments, and Metals Division of Pfizer Inc. The alloy contains 36% nickel and was designed for use where minimal size change with temperature fluctuations is critical. A new nickel-copper alloy, developed by the National Aeronautical and Space Administration (NASA), was said to retain catalytic properties needed for the reduction of nitrogen oxides while providing improved mechanical properties needed by auto emissions catalysts. Its stress rupture life is more than four times that of other nickel-copper alloys.[9]

Scientists at the Denver Research Institute developed a metal powder composed of rare earths and nickel which was claimed to have wide applications for storing and transferring hydrogen.[10] The powder was described as a pentanickel intermetallic compound containing 62% lanthanum, 25% neodymium, 8% praseodymium, and 5% nickel. The compound was said to absorb six atoms of hydrogen for each compound molecule. Other laboratories working on hydrogen storage and conversion included the Argonne National Laboratory in Chicago, Ill.; MPD Technology, a unit of INCO's Sterling Forest Laboratory in New York State; Billings Energy Research, Provo, Utah; Brookhaven Laboratory in Brookhaven, N.Y.; Lawrence Radiation Laboratories, Livermore, Calif.; and Sandia Laboratories, New Mexico.

FALCO researchers reported on a new process which yields high-purity nickel chloride by selectively dissolving nickel from copper-nickel converter matte with hydrochloric acid.[11] Solvent extraction was used to purify the solution with the nickel chloride being crystallized by the further addition of acid. An oxide was then produced by high-temperature hydolysis of the separated nickel chloride. Subsequent reduction produced a high-purity, granular metal product, Nickel 98. Scientists at Minemet Recherche described a pilot plant study on a hydrometallurgical process to treat high-grade nickel matte or a nickel-cobalt sulfide precipitate to produce high-purity electrolytic nickel.[12] The initial step was the oxidation leach of nickel-bearing material with nitric acid. The crude, nickel sulfate-nitrate solution was then purified and denitrified. An electrolyte was prepared from the nitrate-free material, and nickel was recovered by electrolysis. A new, highly stable, electrolysis nickel-plating process was announced by Enthone Inc. The process produced a deposit of smooth, bright nickel-phosphorous alloy. The coating was said to be corrosion resistant in both rack and barrel plating installations at a rate of 0.5 to 0.8 mil per hour. The deposit had a hardness of 46 to 48 Rockwell C. Heating for 1 hour at 750° F produced a hardness of 66 to 70 Rockwell C.

---

[1]Physical scientist, Division of Ferrous Metals.

[2]Haas, L.A., R. B. Schulter, and W.M. Mahan. Leaching Duluth Complex Concentrates, Mattes, and Roasted Mattes With H_2SO_4. Eng. Min. J., v. 178, No. 4, April 1977, pp. 80-82.

[3]Wesson, Sheldon. Steel Corrosion Resistance Raised With Beams of Ions. Am. Metal Market, v. 85, No. 244, Dec. 19, 1977, p. 12.

[4]American Metal Market. Westinghouse Iron-Nickel Battery System Being Tested. V. 86, No. 1, Jan. 2, 1978, p. 23.

[5]Thorton, J. Spacecraft Battery of Future Seen Using Nickel-Hydrogen Electrodes. Am. Metal Market, v. 85, No. 221, Nov. 14, 1977, p. 40.

[6]Mari, A. Pesses to Reclaim Battery Nickel-Cadmium. Am. Metal Market, v. 85, No. 169, Aug. 31, 1977. p.8.

[7]Irving, R.R. New Alloys in Stainless: That's Where the Action Is. Iron Age, v. 220, No. 19, Nov. 7, 1977, pp. 57-67.

[8]Journal of Metals. Mechanical Alloyed High Temperature Materials. V. 29, No. 12, December 1977, pp. 9-11.

[9]Industry Week. New Alloy Has Potential in Auto "Cat" Reactors. V. 192, No. 5, Feb. 28, 1977, p. 33.

[10]Mari, A. New Metal Powder Stores Hydrogen for Energy Savings Applications. Am. Metal Market, v.85, No. 101, May 25, 1977, p. 11.

[11]Hougen, L. R., R. Parkinson, J. Saetre, and G. Van Weert. Operating Experiences With a Pilot Plant for the Electrowinning of Nickel From All-Chloride Electrolyte. CIM Bull., v. 70, No. 782, June 1977, pp. 136-143.

[12]Fossi, P., L. Gandon, C. Bozec, and J. M. Demarthe. Refining of High-Nickel Concentrates. CIM Bull., v. 70, No. 782, June 1977, pp. 188-197.

Nitrogen

By Russell J. Foster[1]

Production of fixed nitrogen, that is ammonia, in the United States rose 5% in 1977 to 14.6 million tons of contained nitrogen. Ammonia exports declined 4%, but total exports of all nitrogen compounds increased 6%. Imports of ammonia were up 48%, paralleling the 45% rise for all nitrogen-containing products. Domestic consumption of ammonia, including net imports of 538,000 tons of nitrogen content, was up 5%. Elemental nitrogen production reached 12 million tons, up 15% from the previous year. Consumption was assumed equal to production.

Legislation and Government Programs.—The Energy Research and Development Administration signed an agreement with W. R. Grace & Co. for a program to develop the commercial synthesis of ammonia from coal. The company selected the Texaco, Inc., coal gasification process for production of synthesis gas as part of the initial design and engineering phase of the project. Subsequent phases would include construction and operation of the plant in western Kentucky by 1982.[2]

The Tennessee Valley Authority (TVA) announced plans to construct a small demonstration gasifier, also based on Texaco technology, to produce synthesis gas as part of the raw material for its 225-ton-per-day ammonia plant currently fed by natural gas. The project may demonstrate the feasibility of retrofitting existing ammonia plants to use coal.[3] TVA awarded a contract to Air Products & Chemicals, Inc., for design and construction of an air separation unit for the coal gasification plant.[4]

The Federal Power Commission (FPC) placed restrictions on the dedication of specific portions of natural gas reserves by producers to ammonia and other chemical industry consumers.[5] The FPC also ruled that users of natural gas from Federal offshore areas for production of ammonia and other chemicals can be charged above the ceiling price set by the FPC when the gas is used as a feedstock rather than a fuel.[6]

The Food and Drug Administration (FDA) banned the use of soft drink bottles made from acrylonitrile. The FDA claimed that the bottles were unsafe because unreacted acrylonitrile monomer can leach into the contents under the agency's extraction test conditions.[7]

The Environmental Protection Agency temporarily revoked pH limitations for all effluent discharges of nitric acid so that the issue of total compliance within a fixed range of pH could be reconsidered.[8]

At yearend the outcome of comprehensive energy legislation, including the issue of natural gas price regulation, continued unresolved.[9]

Table 1.—Salient ammonia statistics

(Thousand short tons of contained nitrogen)

	1973	1974	1975	1976	1977[p]
United States:					
Production [1]	12,641	13,061	13,617	13,863	14,566
Exports	741	326	289	361	346
Imports for consumption	271	373	662	599	884
Consumption[2]	12,778	12,877	13,229	13,946	14,685
World: Production[e]	51,500	53,400	54,600	65,000	68,500

[e]Estimate. [p]Preliminary.
[1]Synthetic anhydrous ammonia and coke oven ammonia.
[2]Includes producers' stock change in synthetic anhydrous ammonia and coke oven ammonia.

DOMESTIC PRODUCTION

Domestic production of ammonia increased 5% in 1977 to 14.6 million tons of nitrogen content. Natural gas curtailments due to colder-than-normal temperatures during the winter of 1976-77 resulted in record losses of ammonia production. However, these losses were balanced by plentiful inventories and new plants coming onstream. A substantial expansion of anhydrous ammonia capacity occurred in the United States in 1977, which should cause industry capacity to rise well above the expected demand, perhaps for the next few years.

Oklahoma Nitrogen Co., a joint venture of W. R. Grace & Co., Gulf Oil Chemicals Co., and Terra Chemicals International, Inc., completed a 1,200-ton-per-day ammonia plant at Woodward, Okla.[10]

International Minerals & Chemical Corp. brought a 1,150-ton-per-day unit onstream at Sterlington, La.[11] An identical facility was started up by Monsanto Co. at Luling, La.[12]

Farmland Industries, Inc., brought a second anhydrous ammonia plant onstream at its Enid, Okla., complex. The new 1,000-ton-per-day unit was built adjacent to the original plant.[13] The cooperative also started up a plant with daily capacity of 1,250 tons at Pollock, La.[14]

Two 1,000-ton-per-day ammonia plants came onstream at the Donaldsonville, La., fertilizer complex of CF Industries, Inc. The new units bring to four the number of ammonia plants at the site.[15]

Verdigris, Okla., was the location of Agrico Chemical Co.'s new 1,150-ton-per-day ammonia plant which will provide feedstock for expanded urea-ammonium nitrate solutions and nitric acid capacity due onstream in 1979.[16]

At yearend, Union Oil Co. was in the process of starting up a second ammonia plant at Kenai, Alaska. The new plant will double capacity at the site to over 1 million tons per year.[17]

Car-Ren, Inc., opened a 68,000-ton-per-year plant at Columbus, Miss.[18] Jupiter Chemical Co. started up a 78,000-ton-per-year unit at Lake Charles, La.[19]

Allied Chemical Corp. purchased the fertilizer production facilities of Gardinier, Inc., at Helena, Ark., consisting of anhydrous ammonia and downstream products.[20]

Beker Industries Corp. closed its 175,000-ton-per-year ammonia plant and downstream urea unit at Carlsbad, N. Mex.[21] In Texas, Phillips Petroleum Co. shut down a 230,000-ton-per-year facility at Pasadena, Amoco Oil Co. closed 200,000 tons of annual capacity at Texas City, and N-Ren Corp. shut its 60,000-ton-per-year plant at Plainview.[22] Tipperary Corp. announced plans to close its 300-ton-per-day ammonia production facility at Lovington, N. Mex., effective February 1978.[23]

At Pittsburg, Kans., Gulf Oil Chemicals Co. began construction to expand ammonium nitrate production by 18% and reduce energy consumption. The project involves replacement of the 12 existing nitric acid units with 1 large facility by 1979. The new Oklahoma Nitrogen Co. plant will be the primary source of ammonia feedstock.[24] A total of about 370,000 tons per year of additional ammonium nitrate capacity came onstream during the year.[25]

Terra Chemicals International, Inc., announced the expansion of urea capacity at Port Neal, Iowa, by late 1978.[26] Total domestic urea capacity declined by nearly 315,000 tons per year in 1977 with the closing of three plants.[27]

Production of elemental nitrogen rose 15% to 12 million tons. Producers of industrial gases have embarked on a major capacity buildup, much of which is aimed at the merchant market.

Table 2.—Nitrogen production in the United States

(Thousand short tons of contained nitrogen)

	1973	1974	1975	1976	1977[p]
Anhydrous ammonia, synthetic plants[1]	12,508	12,939	13,504	13,748	14,456
Ammonium compounds, coking plants:					
Ammonia liquor	6	6	5	4	7
Ammonium sulfate	127	116	108	111	103
Ammonium phosphates	(2)	(2)	(2)	(2)	(2)
Total	12,641	13,061	13,617	13,863	14,566
Elemental nitrogen[1] [3]	8,229	8,814	9,142	10,464	12,010

[p]Preliminary.
[1]Current Industrial Reports, U.S. Department of Commerce, Bureau of the Census.
[2]Included with ammonium sulfate to avoid disclosing company proprietary data.
[3]Converted from reported volume (at 70°F and 1 atmosphere pressure) at 27,605 cubic feet per short ton.

Table 3.—Major nitrogen compounds produced in the United States

(Thousand short tons, gross weight)

Compound	1976	1977[p]
Acrylonitrile	759	821
Ammonium nitrate	7,186	7,177
Ammonium sulfate[1]	2,532	2,666
Ammonium phosphates	8,988	10,570
Nitric acid	7,791	7,951
Urea	3,928	4,446

[p]Preliminary.
[1]Includes ammonium sulfate from coking plants.

Sources: Bureau of the Census and International Trade Commission.

Table 4.—Domestic producers of anhydrous ammonia

(Thousand short tons per year of ammonia)

Company	Location	Capacity
Agrico Chemical Co.-Williams	Blytheville, Ark	407
Do	Donaldsonville, La	468
Do	Verdigris, Okla	840
Air Products & Chemicals, Inc	New Orleans, La	210
Do	Pace Junction, Fla	100
Allied Chemical Corp	LaPlatte, Nebr	200
Do	Hopewell, Va	340
Do	Geismar, La	340
Do	South Point, Ohio	160
American Cyanamid Co	Fortier, La	340
Amoco Oil Co	Texas City, Tex	522
Apache Powder Co	Benson, Ariz	15
Atlas Chemical Industries, Inc	Joplin, Mo	136
Beker Industries Corp	Conda, Idaho	100
Do	Carlsbad, N. Mex	170
Borden Chemical Co	Geismar, La	340
Camex, Inc	Borger, Tex	400
Car-Ren, Inc	Columbus, Miss	68
CF Industries, Inc	Donaldsonville, La	1,590
Do	Fremont, Nebr	48
Do	Terre Haute, Ind	150
Chevron Chemical Co	Pascagoula, Miss	510
Do	Richmond, Calif	130
Do	Fort Madison, Iowa	105
Do	El Segundo, Calif	20
Columbia Nitrogen Corp	Augusta, Ga	122
Diamond Shamrock Chemical Co	Dumas, Tex	160
Dow Chemical Co	Freeport, Tex	115
E. I. duPont de Nemours & Co	Beaumont, Tex	340
Do	Belle, W. Va	340
Do	Victoria, Tex	100
Duval Corp	Hanford, Calif	42
El Paso Products Co	Odessa, Tex	115
Farmers Chemical Association - CF Industries, Inc	Tunis, N.C	210
Do	Tyner, Tenn	170
Farmland Industries, Inc	Fort Dodge, Iowa	210
Do	Dodge City, Kans	210
Do	Hastings, Nebr	140
Do	Enid, Okla	840
Do	Lawrence, Kans	340
Do	Pollock, La	420
Felmont Oil Corp	Olean, N. Y	85
First Mississippi Corp	Fort Madison, Iowa	365
FMC Corp	South Charleston, W. Va	24
Gardinier, Inc	Tampa, Fla	120
Do	Helena, Ark	210
Goodpasture, Inc	Dimmitt, Tex	71
W. R. Grace & Co	Woodstock, Tenn	340
Do	Big Springs, Tex	100
Green Valley Chemical Co	Creston, Iowa	35
Hawkeye Chemical Co	Clinton, Iowa	138
Hercules, Inc	Louisiana, Mo	70

Table 4.—Domestic producers of anhydrous ammonia —Continued

(Thousand short tons per year of ammonia)

Company	Location	Capacity
Hooker Chemical Co	Tacoma, Wash	23
International Minerals & Chemical Corp	Sterlington, La	770
Jupiter Chemical Co	Lake Charles, La	78
Kaiser Agricultural Chemicals Co	Savannah, Ga	150
Mississippi Chemical Corp	Yazoo City, Miss	393
Do	Pascagoula, Miss	175
Monsanto Co	Luling, La	850
New Jersey Zinc Co	Palmerton, Pa	35
Nipak, Inc	Pryor, Okla	105
Do	Kerens, Tex	115
N-Ren Corp. (Cherokee Nitrogen, Inc.)	Pryor, Okla	94
N-Ren Corp. (St. Paul Ammonia Products Co.)	East Dubuque, Ill	238
N-Ren Corp	Carlsbad, N. Mex	68
Occidental Agricultural Chemical Co	Taft, La	90
Do	Lathrop, Calif	160
Do	Plainview, Tex	52
Olin Corp	Lake Charles, La	490
Pennwalt Chemical Co	Portland, Oreg	8
Phillips Pacific Chemical Co	Kennewick, Wash	155
Phillips Petroleum Co	Beatrice, Nebr	210
PPG Industries	Natrium, W. Va	50
Reichhold Chemicals, Inc	St. Helens, Oreg	90
Rohm and Haas Co	Deer Park, Tex	45
J. R. Simplot Co	Pocatello, Idaho	108
Swift Chemical Co	Beaumont, Tex	300
Tenneco Chemical Co	Houston, Tex	210
Tennessee Valley Authority	Muscle Shoals, Ala	74
Terra Chemicals International, Inc	Port Neal, Iowa	210
Tipperary Corp	Lovington, N. Mex	100
Triad Chemical Co	Donaldsonville, La	340
Union Oil Co	Kenai, Alaska	510
Do	Brea, Calif	280
U.S.A. Petrochemical Corp	Ventura, Calif	60
U.S.S. Agri-Chemicals, Inc	Clairton, Pa	325
Do	Cherokee, Ala	177
Do	Geneva, Utah	70
Valley Nitrogen Producers, Inc	El Centro, Calif	210
Do	Helm, Calif	176
Do	Chandler, Ariz	33
Do	Hercules, Calif	52
Vistron Corp	Lima, Ohio	475
Vulcan Materials Co	Wichita, Kans	35
Wycon Chemical Co	Cheyenne, Wyo	167
Total		21,497

Source: Distribution Economics Section, Tennessee Valley Authority. World Fertilizer Capacity, Ammonia. Muscle Shoals, Ala., Sept. 14, 1978.

CONSUMPTION AND USES

Consumption of ammonia in the United States increased 5% in 1977 to 14.7 million tons of contained nitrogen. Fertilizers accounted for over three-fourths of ammonia demand either in direct application or the manufacture of downstream nitrogen fertilizer compounds. Production of urea and ammonium phosphates gained substantially in 1977. Other uses of chemicals produced from ammonia included explosives, resins, fibers, plastics, and animal feeds.

Elemental nitrogen consumption, assumed to be equal to production, rose 15%. The two primary uses of elemental nitrogen were as a gas to exclude or purge air in the manufacture of certain chemicals, metals, electronic components, and glass, and as a liquid to provide low temperatures in food processing and scientific applications.

STOCKS

Ammonia stocks held by producers at yearend 1977 totaled nearly 2.3 million tons of contained nitrogen, up 23% from the previous year's ending inventory.[28]

PRICES

The average value of anhydrous ammonia shipped by producers, f.o.b. plant, was $107 per ton in 1977, essentially unchanged from the previous year, and 28% below the peak attained in 1975. Average prices for downstream nitrogen compounds at the producing plants increased in 1977.

Farm prices of urea, ammonium nitrate, ammonium sulfate, and nitrogen solutions rose 2% to 7% above 1976 levels, while ammonia declined 2%.[29] Ammonia prices weakened during the year because of increasingly abundant domestic and foreign supplies.

The average price of elemental nitrogen as pipeline gas was $12.70 per ton in 1977, an increase of 8%. The price of elemental bulk liquid nitrogen dropped 2% to $56.01 per ton.[30]

Table 5.—Price quotations for major nitrogen compounds in 1977

(Per short ton)

Compound	Price
Ammonium nitrate, domestic, fertilizer-grade, 33.5% nitrogen, bulk, delivered	$91-$115
Ammonium sulfate, standard-grade, commercial, bulk, f.o.b. works	60
Anhydrous ammonia, fertilizer, wholesale, tanks, delivered east of Rockies, except east coast	120-140
Aqueous ammonia, 29.4% NH_3, anhydrous basis, tanks, freight equalized east of Rockies	165-180
Sodium nitrate:	
Domestic:	
Agricultural, bulk, carlots, f.o.b. works	139
Agricultural, bags, carlots, f.o.b. works	150
Imported:	
Commercial, bulk, carlots, f.o.b. Atlantic and Gulf warehouses	118
Commercial, 100-pound bags, carlot, same basis	130
Agricultural, bulk, carlots, Atlantic and Gulf warehouses	100
Urea:	
Industrial, 46% nitrogen, bulk, 50-ton carlots, delivered East	160-175
Agricultural, 46% nitrogen, bulk, same basis	130-140
Agricultural, 45% nitrogen, bulk, 50-ton carlots, delivered East	120-130
Diammonium phosphate, fertilizer grade, 18-46-0, bulk, carlots, f.o.b. Florida works	110-125

Source: Chemical Marketing Reporter.

FOREIGN TRADE

The quantity of ammonia exported by the United States declined 4% in 1977, but greater exports of ammonium phosphates and urea contributed to a 6% total increase in exports of nitrogen-containing products.

The availability of foreign ammonia at low prices prompted a 48% rise in U.S. ammonia imports. Significant increases in imports of downstream ammonia products such as urea, ammonium nitrate, and nitrogen solutions also contributed to a 45% jump in the quantity of all imported nitrogen compounds.

Table 6.—U.S. exports and imports for consumption of major nitrogen compounds

(Thousand short tons and thousand dollars)

Compounds	1976 Gross weight	1976 Nitrogen content[e]	1976 Value	1977 Gross weight	1977 Nitrogen content[e]	1977 Value
EXPORTS						
Industrial chemicals: Anhydrous ammonia and chemical grade aqua (ammonia content)	133	109	11,167	108	89	8,938
Fertilizer materials:						
Ammonium nitrate	12	4	1,444	15	5	1,635
Ammonium phosphates	2,823	508	309,192	3,353	604	383,628
Ammonium sulfate	644	133	20,066	500	103	26,201
Anhydrous ammonia and aqua (ammonia content)	307	252	29,205	314	257	28,972
Nitrogenous chemical materials n.e.c	19	6	2,635	38	11	4,249
Sodium nitrate	2	(1)	183	2	(1)	273
Urea	532	242	45,241	578	263	56,935
Mixed chemical fertilizers	242	24	30,284	195	19	26,908
Total	4,714	1,278	449,417	5,103	1,351	537,739
IMPORTS						
Industrial chemicals: Ammonium nitrate	3	1	356	30	10	3,438
Fertilizer materials:						
Ammonium nitrate	312	105	24,146	361	121	31,664
Ammonium nitrate-limestone mixtures	29	6	1,439	60	13	3,597
Diammonium phosphates	142	26	18,642	171	31	19,264
Other ammonium phosphates	70	13	8,294	202	36	20,067
Ammonium sulfate	566	117	23,549	327	67	16,372
Calcium cyanamide or lime nitrogen	38	8	447	2	(1)	462
Calcium nitrate	64	10	3,875	81	13	4,716
Nitrogen solutions	302	91	21,797	495	149	40,273
Anhydrous ammonia	730	599	70,836	1,078	884	103,221
Potassium nitrate or saltpeter, crude	14	2	2,297	22	3	3,247
Potassium nitrate, sodium nitrate mixtures	40	6	5,345	54	8	5,101
Sodium nitrate	103	16	8,143	157	25	11,139
Urea	842	383	84,674	1,415	644	153,675
Nitrogenous fertilizers n.s.p.f	100	20	9,246	163	33	15,943
Mixed chemical fertilizers	112	11	13,728	120	12	14,871
Total	3,467	1,414	296,814	4,738	2,049	447,050

[e]Estimate.
[1]Less than 1/2 unit.

WORLD REVIEW

During 1977, additions to world ammonia capacity included significant increases in North America. Markets of traditional exporters were being diminished by greater self-sufficiency of many nations and the emergence of new export-oriented capacity. Plentiful supplies of ammonia kept world prices depressed in 1977, and raised concern regarding the status of plants with high operating costs.

Argentina.—Petrosur SAIC, the country's sole producer of urea, was expanding capacity at Campana to 99,000 tons per year.[31]

Austria.—Chemie Linz AG started up a urea plant with a capacity of 167,000 tons per year of nutrient. The existing facility at the site was shutdown.[32]

Brazil.—An ammonia plant with capacity of 300,000 tons per year of contained nitrogen and a urea plant with 133,000 tons of annual nutrient capacity came onstream at Camaçari.[33]

Bulgaria.—Construction of a new 1,500-ton-per-day ammonia plant at Dimitrovgrad has been scheduled.[34]

Canada.—With the startup of two 400,000-ton-per-year ammonia plants in Alberta, by Cominco, Ltd., at Carseland, and Canadian Fertilizers, Ltd., at Medicine Hat, Canada's ammonia capacity has jumped 70% since mid-1976. Much of the new Canadian ammonia and downstream products output will go to U.S. markets.[35] Canadian Industries, Ltd., the principal explosives manufacturer in western Canada, brought a 250,000-ton-per-year ammonium nitrate plant onstream at Carseland, Alberta. Feedstock ammonia will be supplied by pipeline from the adjacent facility of Cominco, Ltd.[36] Sherritt Gordon Mines Ltd. revealed a plan to build a 350-ton-per-day urea plant in 1978 at its Fort Saskatchewan, Alberta, complex.[37]

Chile.—The Chilean Corp. of Development has set up a joint venture with Garret Research & Development Co., Inc., to improve nitrate production methods.[38]

Costa Rica.— Fertilizantes de Centro America S.A. announced that its 81,000-ton-per-year nitric acid plant at Puntarenas was operational, effectively doubling onsite capacity.[39]

Egypt.—Abu Qir is the site of a new fertilizer complex under construction. Ammonia capacity being installed will be in excess of the requirements of the 550,000-ton-per-year urea plant.[40]

France.—The domestic fertilizer industry has suffered losses because of rising raw material prices and poor sales brought on by bad weather and low-cost imports. The Government was attempting to streamline the industry by reorganizing both the State and private sectors.[41]

Two of the five ammonia plants sanctioned by the Government 2 years ago apparently will proceed although under different ownership. A group of companies (Rhone-Poulenc Industries, CdF Chimie, Cie. Française de l'Azote, and the Bank Société Générale) have plans for a 1,100-ton-per-day plant at the Grand Quevilly site of Rhone-Poulenc, by late 1978 or 1979. Another 1,100-ton-per-day plant was planned at Villers-Saint-Paul by Produits Chimiques Ugine Kuhlmann.[42]

Instel France signed a $200 million contract with Soyuzchimexport for 330,000 tons per year of Soviet ammonia over a 10-year period beginning in 1979 or 1980. The ammonia will be supplied from the ports of Ventspils and Odessa as part of a compensation agreement for four ammonia plants built in the U.S.S.R. by Creusot-Loire.[43]

Germany, Federal Republic of.—Relatively high prices have encouraged enough nitrogen fertilizer imports to account for about one-third of nutrient consumption.

India.—The Fertilizer Corp. of India announced the expansion of the Trombay fertilizer complex. Trombay V will consist of a 990-ton-per-day ammonia plant and a 1,100-ton-per-day downstream urea unit, scheduled onstream by 1980. Naphtha feedstock has been planned with changeover to natural gas when it becomes available from the Bombay High field.[44]

The Government abandoned plans for a nitrogen fertilizer complex at Mathura, because of the proximity of historical monuments at nearby Agra. Rewas, a site with access to natural gas deposits, has been proposed as an alternative.[45]

Indonesia.—The PUSRI III complex, consisting of a 1,100-ton-per-day ammonia plant and a 1,900-ton-per-day urea unit, was commissioned at Palembang, South Sumatra. Construction of an identical facility, PUSRI IV, at Palembang, has been scheduled for completion in 1979.[46] A urea plant with annual capacity of 564,000 tons was slated for Aceh, North Sumatra.[47] The sale of Indonesian urea to the Philippines signaled the country's emergence as yet another Asian exporter.

Iran.—Construction of Shahpur Chemical Co.'s fertilizer complex at Bandar Shahpur was completed. Daily capacities were 1,100 tons of ammonia and 1,650 tons of urea.[48]

Iraq.—Construction of the first of four ammonia-urea facilities planned for Khor al-Zubair was completed.[49] The Iraq State Fertilizer Co. commissioned an 880-ton-per-day ammonia plant and a 2,090-ton-per-day urea unit at Abu Flus.[50]

Italy.—At Ferrara, Montedison commissioned a 544,000-ton-per-year ammonia plant to replace an obsolete unit, and a downstream urea plant with a capacity of 544,000 tons per year. Surplus ammonia will be shipped to Montedison's fertilizer complex at Porto Marghera. Construction proceeded on a 363,000-ton-per-year urea unit at Manfredonia, which will double onsite capacity.[51]

Japan.—A significant decline in the export market for urea over the past 2 years has forced Japanese plants to operate at less than 60% of capacity. The expense of running large plants at reduced rates has led to reductions or closures of ammonia-urea production lines.[52] Mitsubishi Gas Chemical Co. replaced an obsolete ammonia plant at Niigata with a new 291,000-ton-per-year unit.[53]

Korea, Republic of.—A huge fertilizer complex came onstream at Yochun for Namhae Chemical Co. Besides two 1,000-ton-per-day ammonia plants, downstream units included urea, nitric acid, and ammonium nitrate. This has created a problem of overcapacity, however, and the Government was considering production cutbacks at other plants and additional export markets to reduce supply.[54]

Kuwait.—Petrochemical Industries Co. has completed the expansion of its annual urea capacity at Shuaiba from 192,000 tons to over 330,000 tons.[55] Construction of a 1,100-ton-per-day ammonia plant at the site was under consideration.[56]

Libya.—Libyan National Oil Corp.'s 1,100-ton-per-day ammonia plant was completed at Marsa el Brega. Output from the natural gas based plant was slated for export until the downstream urea unit comes onstream in 1979.[57]

Mexico.—Petróleos Mexicanos (PEMEX) brought two 1,650-ton-per-day ammonia plants onstream at Cosoleacaque. Construction of another ammonia plant with a capacity of 1,100 tons per day was completed at Salamanca. PEMEX also announced plans to build two 1,650-ton-per-day ammonia plants at Cunduacan by 1980.[58] Mexico has become a major producer of ammonia and has entered world export markets.

Netherlands.—A 440,000-ton-per-year ammonium nitrate plant came onstream at Sluiskil.[59]

Pakistan.—Fauji Agrico Fertilizer Co., Ltd., will build a 1,100-ton-per-day ammonia plant and a 1,900-ton-per-day urea unit in Punjab with a loan from the World Bank. Natural gas will be supplied by pipeline from the Mari field.[60] Organization of Petroleum Exporting Countries (OPEC) financing was obtained for the construction of a 1,000-ton-per-day ammonia plant and downstream nitric acid and calcium ammonium nitrate units at Multan.[61]

Peru.—Air Products & Chemicals, Inc., has contracted to build an 80-ton-per-day gaseous nitrogen plant at Cuzco. The nitrogen will be used as feedstock in an ammonia plant at the site.[62]

Romania.—Two ammonia plants with capacities of 330,000 tons per year were commissioned at Arad and Turnu Magurele. The Arad plant will provide feedstock for two nitric acid units and a compound fertilizer plant. The addition at Turnu Magurele raised annual capacity there to 880,000 tons.[63]

Some earthquake damage was sustained in March at Turnu Magurele and Craiova, another major fertilizer production center, affecting the country's ability to meet urea export contracts.[64] The European Economic Commission dropped its antidumping procedure against nitrogen fertilizer imports from Romania following an agreement by Romania to exercise voluntary restraint in its sales to Western Europe.[65]

Sudan.—Sudan Fertilizer Corp. has scheduled construction of two 220-ton-per-day ammonia plants and a downstream urea unit at Khartoum, with an onstream date of late 1978.[66]

Taiwan.—A 330,000-ton-per-year ammonia plant and a 220,000-ton-per-year urea unit were due onstream in 1978 for Taiwan Fertilizer Co. at Miaoli. The country's annual ammonium sulfate capacity increased by 20,000 tons of nutrient with the addition of a new plant at Toufun.[67] Kaohsiung Ammonium Sulfate Corp. announced plans to expand its fertilizer complex at Kaohsiung. A 28,000-ton-per-year nitric acid plant was scheduled onstream in 1978, and future plans for ammonia and urea plants were proposed.[68]

Trinidad and Tobago.—Construction of a 400,000-ton-per-year ammonia plant was completed at Port Lisas. The plant is a joint venture between the Government and W. R. Grace & Co. and complements Grace's 250,000-ton-per-year plant at the site. Participation in this and other ammonia projects in the United States enabled the company to close its 135,000-ton-per-year plant at Aruba, Netherlands Antilles.[69]

Amoco has also agreed to an ammonia project in partnership with the Government. The 2,200-ton-per-day plant was slated onstream in 1980 at Port Lisas.[70]

Turkey.—Istanbul Gubre Sanayii AS started up a 365,000-ton-per-year, naphtha-fed ammonia plant and a urea unit with an annual nutrient capacity of 258,000 tons at Izmit. A similar complex has been planned for Kirikkale.[71]

U.S.S.R.—The Soviet fertilizer industry is being transformed into one dominated by large-capacity plants. Mitsui-Toyo of Japan was awarded a contract to construct 10 495,000-ton-per-year ammonia plants at Berezniki, Togliatti (3 plants), Rossoch, Salavat, Kirovo-Chepetsk, Kemerovo (2 plants), and Fergana.[72]

Plans were announced for another 495,000-ton-per-year ammonia plant at Angarsk. The naphtha-fed unit was scheduled onstream in 1980.[73] The fourth ammonia plant at Nevinnomyssk was commissioned, increasing the capacity of the complex to 1.3 million tons annually.[74]

Ammonium nitrate production capacity at Chirchik was expanded by 170,000 tons per year of nutrient, bringing total annual onsite nutrient capacity to 280,000 tons.[75] Construction of a 177,000-ton-per-year ammonia plant and downstream nitric acid and ammonium nitrate facilities was begun at Mary.[76] A 1,540-ton-per-day granular ammonium nitrate plant was commissioned at Cherkassy.[77]

United Kingdom.—Following the commissioning of a new natural gas based 330,000-ton-per-year ammonia plant at Billingham, Imperial Chemical Industries, Ltd. (ICI), closed its 100,000-ton-per-year, naphtha-fed unit at Heysham.[78] The company also brought a 182,000-ton-per-year nitric acid plant onstream at Billingham.[79] In addition, ICI announced plans to expand ammonium nitrate production by constructing a 250,000-ton-per-year nitric acid plant to feed a 430,000-ton-per-year ammonium nitrate plant, due onstream at Billingham by 1979.[80]

After a Government-urged price settlement between ICI and British Gas Corp., ICI will pay a new higher price for natural gas beginning in January 1978. The increased feedstock costs should raise fertilizer prices enabling smaller competitors to strengthen their financial posture.[81] Pending approval of the price hikes by the UK Economic Commission, Thames Nitrogen Co. announced at yearend plans to reopen its 440-ton-per-day ammonium nitrate plant at Rainham, which had been closed since March.[82] UKF Fertilizers, Ltd., and British Gas Corp. also agreed on a similar price agreement for natural gas supplies at Ince, clearing the way for the construction of the company's long-planned 385,000-ton-per-year ammonia plant at Merseyside.[83]

The projected ammonia plant at Peterhead, Scotland, by the Scandanavian group, Scanitro, has been shelved.[84]

Yugoslavia.—Plans were announced by INA-Petrokemija for a major fertilizer complex at Kutina. An ammonia plant and downstream urea, nitric acid, and ammonium nitrate units will be constructed at the site.[85]

Table 7.—Fertilizer nitrogen compounds: World production and consumption for years ended June 30, by country[1]

(Thousand short tons of contained nitrogen)

Country	Production			Consumption		
	1974-75	1975-76	1976-77[p]	1974-75	1975-76	1976-77[p]
North America:						
Canada	[e]987	[r] [e]854	[e]1,058	586	613	672
Costa Rica[e]	33	33	34	[2]37	[r] [2]34	[2]31
Cuba	[e]51	[e]90	[e]75	[r] [2]154	[2]172	[2]206
Dominican Republic	--	--	--	51	[e]33	39
El Salvador	[e]8	6	5	[e]69	[e]72	[e]85
Guatemala	[e]6	[e]6	[e]6	41	[r] [e]39	45
Jamaica[e]	3	3	3	[r] [2]10	[r] [2]7	[2]8
Mexico	[e]517	[e]640	717	721	918	982
Netherlands Antilles[e]	23	7	3	--	--	--
Nicaragua[e]	--	--	--	24	18	25
Trinidad and Tobago	[e]100	49	51	[2]6	[2]5	[2]7
United States (including Puerto Rico and U.S. Virgin Islands)	9,341	10,572	10,792	[e]8,608	[e]10,412	[e]10,643
Other[3]	--	--	--	42	43	38
South America:						
Argentina	28	20	20	46	31	43
Brazil[2]	[r]158	177	215	[r]428	427	515
Chile[2]	125	127	110	57	43	52
Colombia[2]	96	72	73	135	123	157
Ecuador	[e]2	2	2	24	15	39
Peru	22	[e]40	63	125	92	111
Uruguay[2]	--	--	--	11	12	23
Venezuela[2]	[e]53	[e]55	[e]82	64	71	82
Other[4]	--	--	--	21	13	17
Europe:						
Albania[e]	40	40	50	40	40	50
Austria	249	[e]282	[e]263	138	134	158
Belgium-Luxembourg	707	672	[e]719	204	201	209
Bulgaria[2]	654	741	731	363	419	384
Czechoslovakia	[e]533	[e] [2]546	[e] [2]620	472	[e]586	591
Denmark[5]	90	88	120	331	374	385
Finland	278	223	210	250	220	178
France	1,867	[e]1,500	[e]1,612	1,714	1,883	2,001
German Democratic Republic[2]	481	593	856	740	747	832
Germany, Federal Republic of	1,735	1,388	1,422	1,324	1,354	1,458
Greece	291	318	301	277	303	321
Hungary[2]	[e]459	464	542	608	591	576
Iceland[2]	8	10	12	15	16	16
Ireland	[e]107	[e]110	[e]100	147	168	185
Italy	1,247	1,102	1,086	741	798	740
Netherlands	[r]1,471	[e]1,272	[e]1,381	480	497	474
Norway	430	393	371	106	108	105
Poland	[2]1,607	[2]1,689	[2]1,706	1,260	1,354	1,337
Portugal	[e]211	[e]224	[e]194	140	[e]155	152
Romania[2]	1,080	1,424	1,467	540	869	675
Spain[2]	[e]796	[e]910	[e]974	787	796	915
Sweden[6]	194	187	167	259	284	286
Switzerland	32	32	35	42	49	56
U.S.S.R.[2]	8,605	9,333	9,404	7,381	8,090	7,994
United Kingdom[6]	1,099	1,163	[e]1,181	1,022	1,152	1,224
Yugoslavia[2]	409	394	429	388	397	421

See footnotes at end of table.

Table 7.—Fertilizer nitrogen compounds: World production and consumption for years ended June 30, by country[1] —Continued

(Thousand short tons of contained nitrogen)

Country	Production			Consumption		
	1974-75	1975-76	1976-77[p]	1974-75	1975-76	1976-77[p]
Africa:						
Algeria[e]	87	[r]34	36	[2]72	[2]69	[2]77
Egypt	[e,2]110	[2]166	[2]220	[e,7]397	[7]457	[7]535
Ivory Coast[2]	7	[e]5	[e]5	9	12	13
Kenya[2]	--	--	--	21	24	25
Libya[e,2]	--	--	--	11	17	14
Malawi[2]	--	--	--	8	14	21
Mauritius	[e]1	[e]4	[e]8	[e]10	[e,2]11	[2]13
Morocco[e,2]	12	21	15	68	70	91
Mozambique	[e]3	[e]3	[e]5	4	[e]4	7
Nigeria[e]	--	--	--	15	33	54
Rhodesia, Southern[e]	72	72	72	[r]83	83	88
Senegal[e]	6	10	10	10	11	12
South Africa, Republic of[2]	[e]299	[e]331	[e]366	254	314	336
Sudan[2]	--	--	--	66	[e]105	[e]116
Tanzania[2]	4	5	[e]6	15	16	16
Tunisia[2]	--	--	[e]6	[r]25	26	27
Zambia[e]	8	6	8	40	[r]37	44
Other[8]	--	--	--	72	72	84
Asia:						
Afghanistan	21	16	29	27	31	34
Bangladesh	36	145	[e]144	91	162	183
Burma	48	52	61	42	47	47
China, People's Republic of[9]	[r]3,196	3,263	3,968	[r]4,154	4,553	4,743
Cyprus[2]	--	--	--	8	[e]17	[e]17
India	1,308	1,662	2,047	1,947	2,369	2,708
Indonesia	[e]183	229	[e]276	[e]380	[e]377	[e]387
Iran	144	139	172	208	209	224
Iraq	[r]37	[e]27	[e]28	30	28	[e]39
Israel	43	50	53	36	41	41
Japan	[e]2,580	1,716	1,267	761	720	811
Korea, North[e,2]	276	287	298	278	291	298
Korea, Republic of[2]	566	596	[e]563	493	516	398
Kuwait	304	285	251	--	--	--
Lebanon[2]	--	[e]1	[e]1	21	[e]8	[e]20
Malaysia[e]	[10]41	[10]37	[10]43	76	85	102
Pakistan	343	349	341	[r]400	489	552
Philippines[2]	59	68	53	196	159	195
Qatar	61	[e]96	[e]95	--	--	--
Saudi Arabia	[e]89	[e]110	[e]93	6	6	7
Sri Lanka[2]	--	--	--	[e]82	42	52
Syria	14	29	29	40	43	47
Taiwan[11]	[r]211	234	250	[r]256	255	217
Thailand	[e]7	[e]5	[e,2]7	88	87	150
Turkey[2]	161	189	234	312	532	746
Vietnam[e,2]	--	--	--	134	214	266
Other[12]	--	--	--	19	20	24
Oceania:						
Australia[e]	218	198	243	196	184	235
New Zealand	--	--	--	20	11	22
Other[13]	--	--	--	14	12	15
World total	[r]46,788	48,291	50,565	[r]42,524	47,661	49,696

[e]Estimate. [p]Preliminary. [r]Revised.

[1]All countries reporting production are listed individually; all countries reporting consumption only are listed individually if the quantity consumed in any year listed totals 16,500 short tons or more; countries reporting no production and less than 16,500 short tons consumption in all years are included in "Other."

[2]Calendar year referring to the first part of the split year.

[3]Includes Bahamas, Barbados, Belize, Guadeloupe, Haiti, Honduras, Martinique, Panama, St. Kitts-Nevis-Anguilla, St. Lucia, and St. Vincent.

[4]Includes Bolivia, Guyana, Paraguay, and Surinam.

[5]Fertilizer year: August to July.

[6]Fertilizer year: June to May.

[7]Fertilizer year: November to October.

[8]Includes Angola, Benin, Botswana, Burundi, Central African Empire, Chad, Congo, Equatorial Guinea, Ethiopia, The Gambia, Ghana, Guinea, Liberia, Malagasy Republic, Mali, Niger, Reunion, Rwanda, Sierra Leone, Somalia, Swaziland, Togo, Uganda, the United Republic of Cameroon, Upper Volta, and Zaire.

[9]United States Bureau of Mines estimate based on United Nations estimate for the People's Republic of China and Taiwan (reported as a single figure) less the British Sulphur Corp. Ltd., reported figure for Taiwan alone.

[10]Data for West Malaysia only.

[11]Source: The British Sulphur Corp. Ltd., Statistical Supplement No. 16, November-December 1977, p. 15.

[12]Includes Kampuchea, Jordan, Laos, Mongolia, Nepal, Oman, Singapore, the United Arab Emirates, Yemen Arab Republic, and the People's Democratic Republic of Yemen.

[13]Includes Fiji Islands and Papua New Guinea.

Source: Statistical Office of the United Nations, Statistical Yearbook, 1977 (New York, 1978, pp. 297-298, 637-639) unless otherwise specified.

TECHNOLOGY

Researchers around the world are investigating a variety of routes to improve the natural process of nitrogen fixation in plants. Some of the methods include genetic engineering, choosing the best strains of plants and nitrogen-fixing bacteria, expanding the use of blue-green algae, and investigating the feasibility of associative symbiosis.[86]

Scientists continued to debate the effects of nitrogen fertilizers on the earth's ozone layer. Estimates of potential ozone depletion resulting from fertilizers as a source of nitrous oxide vary widely because of many unknown factors regarding the amount of denitrification and conversion to nitrous oxide, and contributions from other sources.[87]

Research at the University of California at San Diego has led to the production of ammonia from nitrogen and water in a prototype solar cell. In sharp contrast to the industrial process, the catalyzed reaction proceeds at low temperatures and atmospheric pressure. The efficiency of the catalyst must be improved, however, for the process to be commercially attractive.[88]

The first cryogenic hydrogen recovery unit specifically designed for an ammonia plant was started up by Vistron Corp. at Lima, Ohio. The unit, engineered by Petrocarbon Developments, Inc., increases plant efficiency by recycling most of the hydrogen contained in purge gas back to the synthesis loop to produce more ammonia. A larger system is planned for the ammonia facilities of American Cyanamid Co. at Fortier, La.[89]

The Swedish shipbuilding company, Gotaverken, in cooperation with Haldor Topsoe of Denmark has completed design and engineering studies for a floating, barge-mounted ammonia plant to exploit offshore natural gas deposits or associated gas from offshore oilfields.[90]

An energy-saving new catalyst that effectively lowers the operating temperature of the water gas shift reaction has been reported. The reaction increases the hydrogen concentration of ammonia synthesis gas, and converts its carbon monoxide to the more readily removed carbon dioxide.[91]

Results of a new survey of ammonia plant shutdowns and their causes was presented at the Pacific Chemical Engineering Congress. Plants surveyed represented 83% of the large plants onstream in the United States and Canada before 1975. The average downtime in 1975-76 was 50 days, primarily for major equipment failure and preventive maintenance. Downtime due to other causes, especially natural gas curtailments, was on the increase.[92]

---

[1]Physical scientist, Division of Nonmetallic Minerals.
[2]Chemical Marketing Reporter. Ammonia From Coal: Grace in Pact. V. 212, No. 10, Sept. 5, 1977, pp. 3, 52.
[3]Chemical Week. TVA Researching Coal as Ammonia Feedstock. V. 120, No. 22, June 1, 1977, p. 9.
[4]Green Markets. TVA Awards Coal-Ammonia Contract. V. 1, No. 39, Nov. 7, 1977, p. 8.
[5]———. Cuffs Put on Dedication of Gas to Ammonia. V. 1, No. 5, Mar. 14, 1977, p. 1.
[6]Chemical Marketing Reporter. FPC on Gas Feedstocks: Chemical Prices Raised. V. 211, No. 11, Mar. 14, 1977, pp. 4, 53.
[7]Chemical Week. FDA Bans AN Bottles. V. 121, No. 13, Sept. 28, 1977, p. 22.
[8]Chemical Marketing Reporter. Fertilizer Producers Win a Major Battle with EPA. V. 211, No. 13, Mar. 28, 1977, p. 4.
[9]———. Energy Legislation is Left in Limbo; Senate Deadlocked. V. 212, No. 25, Dec. 19, 1977, pp. 3, 53.
[10]Tulsa Daily World. Grace's Biggest Chemical Plant Near Completion at Woodward. Feb. 20, 1977.
[11]Chemical & Engineering News. Checkoff. Plants Completed. V. 55, No. 28, July 11, 1977, p. 12.
[12]Chemical Marketing Reporter. Anhydrous Ammonia Unit Onstream for Monsanto. V. 211, No. 23, June 6, 1977, p. 4.
[13]———. Farmland Ammonia Unit Starts Up in Oklahoma; Plant Is Second of Two. V. 211, No. 3, Jan. 17, 1977, pp. 7, 45.
[14]———. Farmland Ammonia Unit Onstream in Louisiana; Output Is 1,250 Tons. V. 211, No. 19, May 9, 1977, pp. 5, 50.
[15]———. Ammonia Unit Starts at Donaldsonville, La. V. 211, No. 20, May 16, 1977, p. 3.
———. CFI's New Ammonia Unit Onstream in Louisiana. V. 212, No. 7, Aug. 15, 1977, p. 4.
[16]Chemical Week. Agrico Counting on an Expanding UAN Market. V. 121, No. 10, Sept. 7, 1977, p. 9.
[17]Distribution Economics Section, Tennessee Valley Authority. World Fertilizer Capacity. Ammonia. Sept. 14, 1978.
[18]Green Markets. New U.S. Nitro Capacity Arriving on Schedule. V. 1, No. 19, June 20, 1977, p. 7.
[19]Work cited in footnote 17.
[20]Chemical Marketing Reporter. Allied Buys Up Plant for Ammonia Production. V. 212, No. 15, Oct. 10, 1977, pp. 3, 44.
[21]———. Beker Stops Ammonia Output; Poor Market Idles Two Plants. V. 212, No. 21, Nov. 21, 1977, pp. 27-28.
[22]Work cited in footnote 17.
[23]Green Markets. Tipperary to Close Ammonia Plant. V. 1, No. 44, Dec. 12, 1977, p. 3.
[24]Chemical Engineering. Chementator. V. 84, No. 25, Nov. 21, 1977, pp. 112-113.
[25]Distribution Economics Section, Tennessee Valley Authority. World Fertilizer Capacity. Ammonium Nitrate. Oct. 17, 1977.
[26]European Chemical News. Weatherly Builds Plant for Terra Chemicals. V. 31, No. 801, Sept. 2, 1977, p. 41.
[27]Distribution Economics Section, Tennessee Valley Authority. World Fertilizer Capacity. Urea. Oct. 17, 1977.
[28]Bureau of the Census, U.S. Department of Commerce. Current Industrial Reports. Inorganic Fertilizer Materials and Related Products. January-February 1978.
[29]Economics, Statistics, and Cooperative Service, U.S. Department of Agriculture. 1978 Fertilizer Situation. December 1977, pp. 8-9.
[30]Bureau of the Census, U.S. Department of Commerce. Current Industrial Reports. Industrial Gases. August 1977.
[31]European Chemical News. New Projects. In Brief. V. 30, No. 769, Jan. 14, 1977, p. 29.
[32]Nitrogen. New Plants and Projects. No. 108, July/August 1977, p. 12.
[33]———. New Plants and Projects. No. 107, May/June 1977, p. 14.

[34]European Chemical News. Bulgaria Gets Soviet Help for Fertilizer Expansion. V. 30, No. 782, Apr. 15, 1977, p. 43.

[35]Chemical Week. Canadians Hike Ammonia Capacity. V. 120, No. 26, June 29, 1977, p. 40.

[36]Chemical Marketing Reporter. Ammonium Nitrate Plant Put Onstream by CIL; Serving Mineral, Builder. V. 211, No. 24, June 13, 1977, pp. 7, 24.

[37]Nitrogen. New Plants and Projects. No. 105, January/February 1977, p. 11.

[38]Industrial Minerals. Company News & Mineral Notes. No. 115, April 1977, p. 49.

[39]Page 12 of work cited in footnote 37.

[40]Nitrogen. The Nile Valley—Focus of Major Urea Production by 1980. No. 108, July/August 1977, pp. 18-21.

[41]Chemical & Engineering News. French Fertilizer Industry Gets Revamping. V. 55, No. 23, June 6, 1977, p. 13.

[42]European Chemical News. Two French Ammonia Projects Ready to Go Ahead. V. 30, No. 783, Apr. 22, 1977, p. 44.

[43]———. Big Intsel Deal Will Bring Soviet Ammonia to France. V. 31, No. 800, Aug. 19-26, 1977, p. 4.

[44]———. Snamprogetti Fertilizer Orders in India. V. 30, No. 768, Jan. 7, 1977, p. 33.

[45]Nitrogen. New Plants and Projects. No. 109, September/October 1977, pp. 14-15.

[46]Chemical Marketing Reporter. Ammonia-Urea Complex Onstream in Sumatra. V. 211, No. 1, Jan. 3, 1977, pp. 3, 23.

[47]European Chemical News. New Projects. In Brief. V. 31, No. 814, Dec. 2, 1977, p. 45.

[48]Nitrogen. Major Expansion Nears Completion in Iran. No. 108, July/August 1977, pp. 24-26.

[49]Fertilizer International. Third Ammonia Plant Comes Onstream in Iraq. No. 96, June 1977, p. 1.

[50]European Chemical News. Market Report. In Brief. V. 30, No. 775, Feb. 25, 1977, p. 10.

[51]Nitrogen. Italian Urea Capacity on the Increase. No. 110, November/December 1977, pp. 23-26.

[52]European Chemical News. Recession Forces Mitsui to Scrap Fertilizer Plants. V. 30, No. 770, Jan 21, 1977, p. 11.

[53]Fertilizer International. Plant & Project News. No. 102, December 1977, p. 11.

[54]Chemical Week. South Korea Battles Fertilizer Glut. V. 120, No. 15, Apr. 13, 1977, p. 26.

[55]European Chemical News. Market Report. In Brief. V. 30, No. 791, June 17, 1977, p. 12.

[56]Chemical Age. Kuwait Plans Ammonia Unit for Shuaiba. V. 115, No. 3043, Nov. 11, 1977, p. 1.

[57]European Chemical News. Libya Commissions New Ammonia, Methanol Plants. V. 31, No. 811, Nov. 11, 1977, p. 12.

[58]Chemical Week. More Ammonia Plants Coming in Mexico. V. 121, No. 18, Nov. 2, 1977, p. 25.

Nitrogen. Into the 0.5 Million T.P.A. Ammonia Surplus Era in Mexico. No. 107, May/June 1977, pp. 19-21.

[59]Chemical Marketing Reporter. Ammonium Nitrate Unit Comes on Line in Holland. V. 212, No. 17, Oct. 24, 1977, p. 5.

[60]Green Markets. World Bank Approves Pakistan Loan. V. 1, No. 11, Apr. 25, 1977, p. 2.

[61]European Chemical News. New Projects. In Brief. V. 31, No. 810, Nov. 4, 1977, p. 44.

[62]Chemical Marketing Reporter. Air Products Building Cuzco Nitrogen Plant. V. 212, No. 8, Aug. 22, 1977, pp. 4, 65.

[63]Page 15 of work cited in footnote 32.

[64]European Chemical News. Romanian Fertilizer Exports Hit by Earthquake. V. 30, No. 779, Mar. 25, 1977, p. 6.

[65]———. Romania to Limit EEC Fertilizer Sales. V. 30, No. 770, Jan. 21, 1977, p. 4.

[66]Work cited in footnote 40.

[67]Nitrogen. More Capacity on the Way in Taiwan. No. 110, November/December 1977, p. 30.

[68]———. New Plants and Projects. No. 106, March/April 1977, p. 16.

[69]Fertilizer International. No. 95, May 1977, p. 1.

Page 13 of work cited in footnote 32.

[70]Chemical Marketing Reporter. Ammonia Joint Venture Is Undertaken by Amoco and Trinidad & Tobago. V. 212, No. 2, July 11, 1977, pp. 7, 32.

[71]Page 14 of work cited in footnote 68.

[72]European Chemical News. Soviet Union Seeks Fortieth Big Ammonia Plant. V. 30, No. 789, June 3, 1977, p. 32.

[73]Work cited in footnote 72.

[74]Fertilizer International. Plant & Project News. No. 93, March 1977, p. 9.

[75]Page 15 of work cited in footnote 68.

[76]Page 12 of work cited in footnote 33.

[77]Nitrogen. New Plants and Projects. No. 110, November/December 1977, p. 14.

[78]Chemical Marketing Reporter. ICI Closes Heysham Unit; Billingham Unit Onstream. V. 211, No. 11, Mar. 14, 1977, p. 46.

[79]Chemical Age. ICI Starts Up Nitric Acid Plant at Billingham. V. 115, No. 3031/3032, Aug. 19/26, 1977, p. 3.

[80]Chemical Marketing Reporter. ICI Confirms Expansion of Fertilizer Facilities; Small Firm Threatened. V. 211, No. 15, Apr. 11, 1977, pp. 4, 53.

[81]European Chemical News. ICI Will Pay Higher Gas Price, Big AN Price Increase Soon. V. 31, No. 807, Oct. 14, 1977, p. 4.

———. ICI Bows to Higher Gas Prices, Ammonia Divorce With Fisons? V. 31, No. 810, Nov. 4, 1977, p. 4.

[82]Chemical Age. Thames Nitrogen to Restart Fertilizer Unit if UK Prices Increase. V. 115, No. 3046, Dec. 2, 1977, p. 8.

[83]Chemical Marketing Reporter. Fertilizer Concern in UK Slates Plant Following Feedstock Resolution. V. 212, No. 26, Dec. 26, 1977, pp. 4, 12.

[84]Chemical Age. Peterhead is Shelved. V. 114, No. 3017, May 13, 1977, p. 16.

[85]Chemical Marketing Reporter. Fertilizer Construction Slated for Yugoslavia; a Quintet of Plants. V. 212, No. 12, Sept. 19, 1977, p. 4.

[86]Chemical Week. Can Genetics Bridge the Fertilizer Gap? V. 121, No. 16, Oct. 19, 1977, pp. 61-62.

[87]———. New Threat to Ozone? V. 120, No. 11, Mar. 16, 1977, p. 24.

[88]Chemical & Engineering News. Prototype Solar Cell Used in Ammonia Process. V. 55, No. 40, Oct. 3, 1977, p. 19.

[89]Banks, R. Hydrogen Recovery Unit Ups NH_3-Plant Efficiency. Chem. Eng., v. 84, No. 21, Oct. 10, 1977, pp. 90-92.

[90]European Chemical News. Floating Plant Design Completed. V. 30, No. 781, Apr. 8, 1977, p. 29.

[91]Nitrogen. Catalysts. No. 108, July/August 1977, p. 41.

[92]Chemical Week. PACHEC Means Energy in Any Language. V. 121, No. 10, Sept. 7, 1977, pp. 46-47.

Peat

By Richard H. Singleton[1]

United States peat production, from 102 operations, increased 1% in 1977 to about 781,000 tons. Production in Florida increased while production in Indiana decreased. Michigan remained the top producing State with 34% of output. The top four producing States, Michigan, Florida, Illinois, and Indiana, accounted for 69% of production. Reed-sedge peat, the major type of peat mined, comprised 54% of production; the remainder was humus, 21%, and moss peat, 25%.

Sales by domestic producers was about 726,000 tons or 1.66 million cubic yards. About 55% of the domestic peat sold was packaged. Soil improvement and potting soils accounted for 72% and 18%, respectively, of domestic peat sales. The average 1977 price for domestic bulk peat was $12.22 per ton or $6.07 per cubic yard. The average price for the three types of peat varied less on a volume basis than on a weight basis.

Peat imports, 98% premium-grade sphagnum moss peat from Canada, remained at about 330,000 tons. Apparent consumption of peat was 1.06 million tons with no significant change from 1976. Imports comprised 31% of apparent consumption on a tonnage basis and 71% on a value basis.

Estimated world production remained at approximately 224 million tons, about 94% of which was in the U.S.S.R. Other significant producers were Ireland and the Federal Republic of Germany.

Table 1.—Salient peat statistics

	1974	1975	1976[r]	1977
United States:				
Number of operations	102	109	102	102
Production thousand short tons	731	772	774	781
Sales by producers do	706	746	731	726
Bulk do	327	332	272	325
Packaged do	379	414	459	401
Value of sales thousands	$10,989	$12,294	$12,079	$12,520
Average per ton	$15.56	$16.49	$16.52	$17.25
Average per ton—bulk	$10.78	$12.00	$14.00	$12.22
Average per ton—packaged or bailed	$19.69	$20.09	$18.02	$21.32
Imports thousand short tons	327	290	338	330
Apparent consumption[1] do	1,033	1,036	1,069	1,056
World: Production do	220,509	[r]223,987	222,745	223,577

[r]Revised.
[1]Sales plus imports.

DOMESTIC PRODUCTION

Peat production increased 1% in 1977 to about 781,000 tons. The peat-type breakdown was reed-sedge peat, 54%; humus, 21%; and moss peat, 25%, with no significant change from 1976. Tonnage production in Florida, principally moss and humus peat, increased 76%.

Michigan remained the largest of the 22 producing States with 34% of the Nation's output. The next three largest producing States, in order of volume, were Florida, Illinois, and Indiana. Peat production on a small scale resumed in New Mexico after a 2-year stoppage.

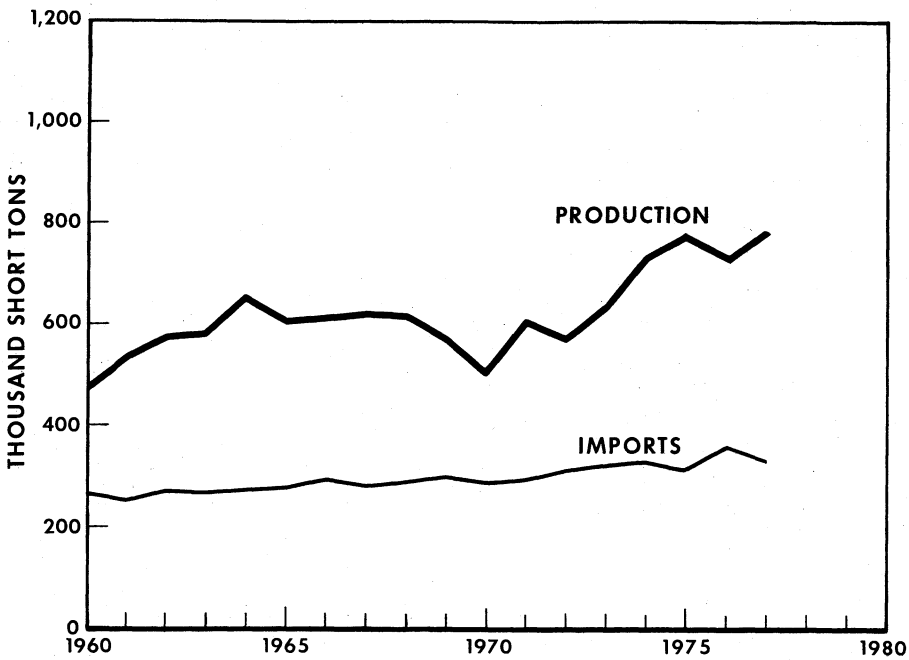


Figure 1.—Production and imports of peat in the United States.

A total of 106 peat operations were known to be active in the United States in 1977, however, four of these operations did not report and their data are not included in this report. Three of the 102 reporting operations did not mine peat during 1977 but sold from stocks. Twenty-four operations were reported to be idle during 1977.

Approximately 54% of U.S. production was from eight large plants with annual capacities greater than 25,000 tons.

Table 2.—U.S. peat production, by kind and State, in 1977

(Thousand short tons)

State	Active plants	Moss	Reed-sedge	Humus	Total
Colorado	8	26	W	W	36
Florida	8	79	26	40	145
Illinois	6	18	W	W	80
Indiana	11	W	W	--	47
Iowa	3	W	W	--	16
Maine	3	W	--	W	5
Maryland	1	--	2	1	3
Massachusetts	1	--	2	--	2
Michigan	16	9	233	25	[1]268
Minnesota	4	W	W	--	28
New Jersey	4	--	5	24	29
New Mexico	1	--	--	2	2
New York	5	--	W	W	35
North Dakota	1	--	([2])	--	([2])
Ohio	7	W	--	W	13
Pennsylvania	8	1	9	6	16
South Carolina	1	--	--	16	16
Washington	5	4	3	5	12
Wisconsin	4	W	--	W	14
Other States[3]	5	55	141	48	14
Total	102	[1]193	421	167	781

W Withheld to avoid disclosing individual company confidential data; included with "Other States."
[1]Data do not add to total shown due to independent rounding.
[2]Less than 1/2 unit.
[3]Includes California, Georgia, Montana, and production indicated by symbol W.

Table 3.—Relative size of peat operations in the United States

Size in tons per year	Number of active plants 1976	Number of active plants 1977	Production (thousand tons) 1976	Production (thousand tons) 1977
Over 25,000	r6	8	r365	447
15,000 to 24,999	r9	5	r172	89
10,000 to 14,999	5	7	64	85
5,000 to 9,999	11	12	72	92
2,000 to 4,999	r23	18	r73	60
1,000 to 1,999	10	16	13	20
Under 1,000	38	33	15	11
Capacity unknown	--	3	--	--
Total	102	102	r774	781

rRevised.

CONSUMPTION AND USES

Domestic sales in 1977 by domestic producers was 726,000 tons or 1.66 million cubic yards. The breakdown by peat type on a tonnage basis was moss peat, 24%; reed-sedge peat, 52%; and humus, the balance. Michigan, with 31%, of U.S. sales, was the leading State followed by Florida, Illinois, and Indiana in order of tonnage sales. About 55% of domestically produced peat was sold in packaged form. The portion of each type packaged was moss peat, 28%; reed-sedge peat, 69%; and humus, 53%.

Soil improvement and potting soil remained the largest uses for peat sold by domestic producers accounting for 72% and 18% of total sales, respectively. About 62% of the peat for soil improvement and 48% of the peat for potting soil was packaged. Peat was supplied, mainly in bulk form, for flower packing in Florida, primarily humus, and in Indiana, mainly moss peat. Peat use in mushroom beds and seed innoculants increased. Mushroom bed use was mainly reed-sedge peat in Michigan; moss peat in Minnesota; and humus in New Jersey. Seed innoculant use was mainly in Wisconsin and in Ohio; humus was used almost exclusively. Moss peat continued to be used in Florida in growing earthworms.

Apparent consumption of peat was about 1.06 million tons with no significant change from 1976; of this, about 31%, on a tonnage basis, was imported. The end use breakdown of imported material, mostly sphagnum moss peat from Canada, was unknown. Imported peat was generally of better quality than domestic peat. Small quantities of similar high-quality moss peat were produced in Minnesota, Maine, and California.

Table 4.—U.S. peat sales by producers in 1977, by use

Use	In bulk Quantity (short tons)	In bulk Value (thousands)	In packages Quantity (short tons)	In packages Value (thousands)	Total Quantity (short tons)	Total Value (thousands)
Soil improvement	195,871	$2,425	324,263	$6,559	520,134	$8,984
Seed inoculant	826	6	3,859	107	4,685	113
Packing flowers, shrubs, etc	27,186	229	4,648	114	31,834	343
Ingredient for potting soil	68,109	1,025	62,541	1,358	130,650	2,383
Mushroom beds	5,909	99	2,649	223	8,558	322
Earthworm culture medium	5,142	57	21	1	5,163	58
Mixed fertilizers	14,717	94	--	--	14,717	94
Other	6,985	33	3,086	190	10,071	223
Total	324,745	3,968	401,067	8,552	725,812	12,520

Table 5.—U.S. peat sales[1] by producers, in 1977, by kind and State

Producing State	Moss			Reed-sedge			Humus			Total		
	Quantity (short tons)	Value (thousands)	Percent packaged	Quantity (short tons)	Value (thousands)	Percent packaged	Quantity (short tons)	Value (thousands)	Percent packaged	Quantity (short tons)	Value (thousands)	Percent packaged
Colorado	26,057	$161	1	W	W	W	W	W	W	32,221	$195	17
Florida	61,248	828	1	25,582	W	--	38,430	W	2	125,260	1,396	1
Illinois	17,789	463	85	W	W	W	W	W	W	82,356	1,478	90
Indiana	17,200	206	22	W	W	W	W	W	W	50,594	759	38
Iowa	W	W	W	W	W	W	--	--	--	15,685	266	--
Maine	W	W	W	--	--	--	W	W	W	4,543	80	83
Maryland	--	--	--	1,690	W	11	860	W	10	2,550	W	11
Massachusetts	--	--	--	2,000	W	25	--	--	--	2,000	W	25
Michigan	8,877	197	26	191,168	$3,546	87	25,488	$174	47	225,533	3,917	80
Minnesota	W	W	W	W	W	W	--	--	--	27,916	1,280	89
New Jersey	--	--	--	5,000	100	--	25,168	669	52	30,168	769	43
New Mexico	--	--	--	--	--	--	2,181	55	--	2,181	55	--
New York	--	--	--	W	W	W	W	W	W	39,347	569	89
North Dakota	--	--	--	150	W	67	--	--	--	150	W	67
Ohio	W	W	W	--	--	--	W	W	W	14,650	107	88
Pennsylvania	1,157	W	78	9,035	W	--	5,611	115	83	15,803	353	35
South Carolina	--	--	--	--	--	--	16,035	W	83	16,035	W	83
Washington	4,162	73	--	3,413	16	--	4,665	28	--	12,240	117	--
Wisconsin	W	W	W	--	--	--	W	W	W	13,854	196	30
Other States[2]	36,186	1,548	69	140,946	2,802	66	55,714	1,539	87	12,726	983	50
Total	172,676	3,476	28	378,984	6,464	69	174,152	2,580	53	725,812	12,520	55

W Withheld to avoid disclosing individual company confidential data; included with "Other States."

[1]F.o.b. producing plant.

[2]Includes California, Georgia, and Montana; and quantities, values, and percent packaged indicated by symbol W.

Table 6.—U.S. peat sales by producers in 1977, by use and kind

Use	Moss			Reed-sedge			Humus			Total		
	Quantity		Value (thousands)	Quantity		Value (thousands)	Quantity		Value (thousands)	Quantity		Value (thousands)
	Weight (short tons)	Volume (cubic yards)		Weight (short tons)	Volume (cubic yards)		Weight (short tons)	Volume (cubic yards)		Weight (short tons)	Volume (cubic yards)	
Soil improvement	100,487	309,328	$2,240	293,742	661,871	$4,703	125,905	233,476	$2,041	520,134	1,204,675	$8,984
Seed inoculant	60	200	1	--	--	--	4,625	6,208	112	4,685	6,408	113
Packing flowers, shrubs, etc	15,991	32,270	226	823	1,729	11	15,020	19,900	106	31,834	53,899	343
Ingredient for potting soils	38,452	82,439	488	78,805	192,655	1,661	13,393	20,708	234	130,650	295,802	2,383
Mushroom beds	2,649	19,622	223	4,902	11,804	79	1,007	1,677	20	8,558	33,103	322
Earthworm culture medium	3,570	7,544	42	712	1,543	10	881	1,063	6	5,163	10,150	58
Mixed fertilizers	7,700	14,000	42	--	--	--	7,017	8,310	52	14,717	22,310	94
Other	3,767	19,092	214	--	--	--	6,304	12,509	9	10,071	31,601	223
Total	172,676	484,495	3,476	378,984	869,602	6,464	174,152	303,851	2,580	725,812	1,657,948	12,520

PRICES AND SPECIFICATIONS

The average 1977 price for bulk peat decreased 13% to $12.22 per ton or $6.07 per cubic yard. Less price variation by peat type occurred on a volume basis than on a weight basis. The packaged or bailed moss peat consisted mainly of low-density, premium-grade sphagnum moss peat. The high density and low price of bulk moss peat suggests that it was primarily hypnum moss peat. The high density and low price of bulk humus, compared with packaged humus, suggests that it had a lower organic content than packaged humus. The price of imported peat, mostly low-density, premium-grade sphagnum moss from Canada, increased 7% to $93.62 per ton.

Table 7.—Prices for peat in 1977, by type

(Dollars per unit)

	Moss	Reed-sedge	Humus	Total
Domestic:				
Bulk:				
Per ton	$10.68	$15.29	$10.16	$12.22
Per cubic yard	5.11	6.86	6.43	6.07
Packaged or bailed:				
Per ton	44.99	17.85	18.94	21.32
Per cubic yard	9.60	7.68	10.02	8.51
Total:				
Per ton	20.13	17.05	14.81	17.25
Per cubic yard	7.18	7.43	8.49	7.55
Imported, total, per ton	93.62	XX	XX	93.62

XX Not applicable.

Table 8.—Average density of domestic peat sold in 1977

(Pounds per cubic yard)

	Moss	Reed-sedge	Humus
Bulk	960	900	1,260
Packaged	430	860	1,060
Bulk and packaged	710	870	1,150

FOREIGN TRADE

Peat imports, 98% from Canada, remained at about 330,000 tons. Approximately 55% of imports entered into the Northeastern United States through New York State and New England ports; 23% entered the Midwest mainly through Great Lakes ports; and 20% entered the Northwest through Seattle, Wash., and Great Falls, Mont. The Federal Republic of Germany remained the second largest source of peat imported by the United States. Imports from other countries were insignificant.

Transportation of imported peat from port to local distributors remained a problem. The low density and high volume of bailed Canadian peat, coupled with its relatively low market value, required low freight rates such as those available by backhauling. Deliveries were up to 6 months behind schedule because of unavailability of low-cost transportation.

Table 9.—U.S. imports for consumption of peat moss, by grade and country

Country	Poultry- and stable-grade		Fertilizer-grade		Total	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
1976						
Canada	5,012	$507	324,334	$28,305	329,346	$28,812
Chile	56	5	38	4	94	9
China, People's Republic of	17	1	--	--	17	1
Finland	--	--	35	5	35	5
Germany, Federal Republic of	530	39	7,868	576	8,398	615
Ireland	--	--	22	1	22	1
Netherlands	3	1	--	--	3	1
Norway	--	--	13	36	13	36
Sweden	--	--	76	7	76	7
Switzerland	--	--	1	1	1	1
U.S.S.R	--	--	23	2	23	2
United Kingdom	--	--	23	2	23	2
Total	5,618	553	332,433	28,939	338,051	29,492
1977						
Canada	5,292	508	317,191	29,828	322,483	30,336
China, People's Republic of	37	1	--	--	37	1
Finland	--	--	114	10	114	10
Gaza	--	--	18	2	18	2
Germany, Federal Republic of	888	74	6,599	447	7,487	521
Honduras	--	--	26	1	26	1
Ireland	--	--	22	1	22	1
Netherlands	1	(1)	--	--	1	(1)
Norway	20	22	--	--	20	22
Sweden	14	7	31	16	45	23
U.S.S.R	--	--	21	2	21	2
United Kingdom	--	--	23	2	23	2
Yemen, People's Democratic Republic of (Aden)	--	--	13	1	13	1
Total	6,252	612	324,058	30,310	330,310	30,922

[1]Less than 1/2 unit.

Table 10.—U.S. imports for consumption of peat moss in 1977, by grade and customs district

Customs district	Poultry- and stable-grade		Fertilizer-grade		Total	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Baltimore, Md	16	$2	211	$18	227	$20
Boston, Mass	--	--	116	7	116	7
Buffalo, N.Y	70	5	31,646	4,338	31,716	4,343
Charleston, N.C	17	3	198	12	215	15
Chicago, Ill	--	--	63	15	63	15
Detroit, Mich	2,255	170	32,869	2,919	35,124	3,089
Duluth, Minn	7	1	9,481	1,154	9,488	1,155
Great Falls, Mont	--	--	25,086	2,161	25,086	2,161
Houston, Tex	152	32	224	24	376	56
Los Angeles, Calif	7	4	587	59	594	63
Miami, Fla	--	--	71	5	71	5
Milwaukee, Wis	--	--	17	1	17	1
Mobile, Ala	29	3	296	21	325	24
New Orleans, La	--	--	1,325	86	1,325	86
New York, N.Y	110	11	399	29	509	40
Norfolk, Va	--	--	351	23	351	23
Ogdensburg, N.Y	57	4	87,624	7,459	87,681	7,463
Pembina, N. Dak	763	96	31,120	3,001	31,883	3,097
Philadelphia, Pa	42	5	453	8	495	13
Portland, Maine	2,024	223	35,430	3,442	37,454	3,665
Portland, Oreg	16	1	--	--	16	1
Providence, R.I	--	--	26	2	26	2
St. Albans, Vt	--	--	23,518	1,969	23,518	1,969

Table 10.—U.S. imports for consumption of peat moss in 1977, by grade and customs district —Continued

Customs district	Poultry- and stable-grade		Fertilizer-grade		Total	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
San Francisco, Calif	296	$25	16	$1	312	$26
San Juan, P.R	91	10	969	65	1,060	75
Savannah, Ga	17	1	--	--	17	1
Seattle, Wash	112	8	40,479	3,383	40,591	3,391
Tampa, Fla	--	--	1,483	108	1,483	108
Wilmington, N.C	171	8	--	--	171	8
Total	6,252	612	324,058	30,310	330,310	30,922

Table 11.—Peat moss imported for consumption from Canada and the Federal Republic of Germany in 1977, by grade and customs district

Customs district	Canada				Federal Republic of Germany			
	Poultry- and stable-grade		Fertilizer-grade		Poultry- and stable-grade		Fertilizer-grade	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Baltimore, Md	--	--	--	--	16	$2	211	$18
Boston, Mass	--	--	--	--	--	--	116	7
Buffalo, N.Y	70	$5	31,646	$4,338	--	--	--	--
Charleston, N.C	--	--	--	--	17	3	198	12
Chicago, Ill	--	--	16	11	--	--	--	--
Detroit, Mich	2,255	170	32,822	2,915	--	--	--	--
Duluth, Minn	7	1	9,481	1,154	--	--	--	--
Great Falls, Mont	--	--	25,053	2,158	--	--	20	2
Houston, Tex	--	--	--	--	125	7	200	13
Los Angeles, Calif	--	--	20	1	--	--	567	58
Miami, Fla	--	--	--	--	--	--	45	4
Milwaukee, Wis	--	--	17	1	--	--	--	--
Mobile, Ala	--	--	--	--	29	3	296	21
New Orleans, La	--	--	--	--	--	--	1,325	86
New York, N.Y	--	--	--	--	72	10	356	26
Norfolk, Va	--	--	--	--	--	--	351	23
Ogdensburg, N.Y	57	4	87,583	7,455	--	--	--	--
Pembina, N. Dak	763	96	31,120	3,001	--	--	453	8
Philadelphia, Pa	--	--	--	--	42	5	--	--
Portland, Maine	2,024	223	35,430	3,442	--	--	--	--
Portland, Oreg	--	--	--	--	16	1	--	--
Providence, R.I	--	--	26	2	--	--	--	--
St. Albans, Vt	--	--	23,498	1,967	--	--	--	--
San Francisco, Calif	21	2	--	--	275	23	16	1
San Juan, P.R	--	--	--	--	91	10	969	65
Savannah, Ga	--	--	--	--	17	1	--	--
Seattle, Wash	95	7	40,479	3,383	17	1	--	--
Tampa, Fla	--	--	--	--	--	--	1,476	103
Wilmington, N.C	--	--	--	--	171	8	--	--
Total	5,292	508	317,191	29,828	888	74	6,599	447

WORLD REVIEW

Canada.—Peat production, mainly sphagnum moss, remained at about 433,000 tons, about the same as in 1976. Value of production increased 9% to Can$26.7 million. Approximately two-thirds of production was in Quebec Province and the Eastern Maritime Provinces and one-fifth was in British Columbia and Alberta in western Canada. Three large producers were supplemented by many small cottage industries. About 74% of Canada's peat production was exported to the United States. Interest in the use of peat as a fuel was shown in the Provinces of Manitoba, New Brunswick, and Newfoundland.

Finland.—A 30,000-ton-per-year peat briqueting plant began operation in 1977 at Peraseinajoki in southwestern Finland. A 30,000-ton-per-year peat metallurgical coke plant had begun operation at the same site in the fall of 1976. This plant required the mining of 175,000 tons of sod peat per year.

Ireland.—Ireland remained the world's second largest producer of peat. Eleven peat-fired electrical powerplants supplied about one-quarter of the Nation's electrical energy needs. Significant quantities were briquetted and used in domestic heating.

Sweden.—Three peat-fueled electric powerplants were under construction in Sweden. The plants were designed to use other fuels, such as wood waste, as well as peat.

U.S.S.R.—Very large quantities of peat continued to be used in agriculture and as fuel in the U.S.S.R. About 4,000 megawatts of electrical energy was generated at 79 electric powerplants in 1975, some of which were in the 300-megawatt size. Several new peat-fueled powerplants, with a capacity of 600 megawatts each, were being constructed. Peat was also used in domestic heating.

Table 12.—Peat: World production, by country

(Thousand short tons)

Country[1]	1975	1976	1977[p]
Argentina	10	11	14
Australia	[r]5	1	2
Canada, agricultural use	398	435	433
Denmark, agricultural use[2]	39	43	44
Finland:			
Agricultural use[e]	132	159	255
Fuel	220	238	397
France, agricultural use[e]	[r]200	[r]200	220
Germany, Federal Republic of:			
Agricultural use	2,419	2,406	[e]2,490
Fuel	250	263	[e]240
Hungary, agricultural use[e]	72	80	80
Ireland:			
Agricultural use	74	78	[e]80
Fuel	7,579	6,225	[e]6,720
Israel, agricultural use[e]	22	22	22
Japan[e]	80	72	65
Korea, Republic of, agricultural use[e]	4	4	--
Netherlands[e]	440	450	450
Norway:			
Agricultural use[e]	66	66	66
Fuel[e]	1	1	1
Poland:			
Agricultural use[e]	40	40	40
Fuel	5	5	5
Spain	38	[e]39	[e]39
Sweden:			
Agricultural use	84	98	[e]100
Fuel	37	35	[e]33
U.S.S.R.:			
Agricultural use[e]	145,000	145,000	145,000
Fuel[e]	66,000	66,000	66,000
United States, agricultural use	772	774	781
Total	[r]223,987	222,745	223,577
Fuel peat included in total	[r]74,092	72,767	73,396

[e]Estimate. [p]Preliminary. [r]Revised.

[1]In addition to the countries listed, Austria, Iceland and Italy produce negligible quantities of fuel peat, and the German Democratic Republic is a major producer, but output is not officially reported and available information is inadequate for formulation of estimates of output levels.

[2]Sales.

TECHNOLOGY

The Institute of Gas Technology continued an experimental program for development of peat gasification for the Minnesota Gas Co. under a contract with the U.S. Department of Energy. Tests confirmed peat's high reactivity compared with coal indicating that reactor volume, temperature, or pressure could be decreased or the methane content of the gas product could be increased using the same conditions as that used for the gasification of coal. It was planned to continue bench-scale experimentation.

The Federal Bureau of Mines began a study on hydraulic mining and dewatering of peat.

First Colony Farms, Inc. continued development of its plant to mine peat on about 200 square miles of peatland in a 600-square-mile area within four counties of northeastern North Carolina. The primary intent was to supply fuel to four 150-megawatt electrical powerplants in that fuel-devoid State. Reserves were estimated to be approximately 0.4 billion tons. Experimental mining began in the fall to determine feasibility of mining the "woody" peat, indigenous to the area, and prepare it in an air-dried form suitable for burning. North Carolina Electrical Membership Corp., a conglomerate of 28 utility cooperatives, contracted for an engineering study to construct one of the four powerplants. The U.S. Air Force held a lease on about 70 square miles of First Colony's peatland in Dare County, and had been using it for many years as a bombing range. The lease was due to expire at yearend 1977. The Air Force began condemnation proceedings with the intent of permanently acquiring the 70-square-mile area. First Colony reportedly stated that the remaining peatlands have sufficient reserves to supply the four powerplants for about half a century. First Colony intended to reclaim the mined land for farming. Further experimental mining during the 1978 warm season was planned.

---

[1]Physical scientist, Division of Nonmetallic Minerals.

Perlite

By A. C. Meisinger[1]

The U.S. perlite industry established record highs in crude and expanded production in 1977. Total crude ore mined was 871,000 tons, or 144,000 tons more than 1976. The quantity and value of crude perlite sold and used by producers totaled 597,000 tons and $10.8 million, respectively, both record highs. New Mexico continued to be the major perlite-producing State with 89% of the total crude perlite mined.

Producers of expanded perlite at 80 plants in 33 States also established a record high production in 1977 to meet the increasing demand for perlite insulation products. The total quantity of expanded perlite sold or used was 498,000 tons valued at nearly $53.6 million, or increases of 15% and 31% over the previous records established in 1976. Illinois continued to be the leading State in output of expanded perlite.

Average value of crude perlite sold or used in 1977 was $18 per ton compared with $17 per ton in 1976. Average value of expanded perlite sold or used increased from $94.87 per ton in 1976 to $107.60 per ton, in line with rising costs of production, energy use, pollution control, and transportation.

Market demand remained strong for nearly all perlite end uses in 1977 with insulation board products showing the greatest increase (33%) over that of 1976.

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 or used	
		Quantity	Value	Quantity	Value			Quantity	Value
1973	759	238	2,771	306	2,819	544	424	418	28,005
1974	676	275	3,544	280	3,480	555	423	419	30,808
1975	706	239	3,407	273	3,874	512	401	394	34,258
1976	727	288	4,908	265	4,489	553	438	432	41,017
1977	871	298	5,514	299	5,239	597	504	498	53,558

DOMESTIC PRODUCTION

A record 871,000 tons of crude perlite was mined by 11 companies from 12 operations in 6 States in 1977. Five mining operations in New Mexico produced a record total of 776,000 tons of ore, or 89% of the U.S. total, followed by Arizona, California, Idaho, Colorado, and Nevada in descending order of production. The quantity of crude perlite sold or used by producers in New Mexico was a record 521,000 tons, or 8% greater than the previous record quantity (481,000 tons) established in 1976.

Crude perlite sold or used by domestic producers in 1977 also established record highs in quantity (597,000 tons) and value ($10.8 million). The 8% increase in quantity in 1977 was primarily due to the increased demand for use of perlite in the construction industry, and the 14% increase in value reflected for the most part the rising costs for mining, processing, and shipping of perlite encountered by domestic producers during the year.

Producers of crude perlite during the year were Filters International, Inc., Harborlite Corp., and Guzman Construction Co. in Arizona; American Perlite Corp. in California; Persolite Products, Inc. in Colorado; Oneida Perlite Corp. in Idaho; Delamor Perlite Co. (Delamar-Mackie) and United States Gypsum Co. in Nevada; and Grefco, Inc., Johns-Manville Sales Corp., Silbrico Corp., and United States Gypsum Co. in New Mexico.

Alltime highs were also set for expanded perlite produced in 1977, and both quantity and value of perlite sold by expanders. Compared with 1976, expanded perlite produced at 80 plants in 33 States totaled 504,000 tons, or an increase of 15%, and the quantity and value of expanded perlite sold or used increased 15% and 31%, respectively.

Leading States in descending order of the quantity of expanded perlite produced in 1977 were Illinois, Mississippi, California, Virginia, Texas, Pennsylvania, Kentucky, Colorado, New Jersey, Florida, Indiana, and Ohio. In descending order of the value of expanded perlite sold or used, the leading States were Illinois, California, Kentucky, Texas, Pennsylvania, New Jersey, Mississippi, Virginia, Florida, and Colorado. California had nine producing plants in 1977, followed by Texas with seven, Pennsylvania and Indiana with six each, and Illinois with five.

Table 2.—Expanded perlite produced and sold or used by producers in the United States

State	1976				1977			
	Quantity produced (short tons)	Sold or used			Quantity produced (short tons)	Sold or used		
		Quantity (short tons)	Value (thousands)	Average value per ton[1]		Quantity (short tons)	Value (thousands)	Average Value per ton[1]
Arkansas	--	--	--	--	613	600	$90	$150.00
California	28,050	27,359	$3,282	$119.97	41,547	40,924	4,886	119.38
Florida	23,784	23,611	1,552	65.73	27,439	26,193	2,175	83.04
Indiana	15,171	15,102	1,228	81.28	19,757	19,757	1,828	92.53
Kansas	991	932	140	150.00	1,027	976	154	157.27
Missouri	5,700	5,644	689	122.08	5,250	5,105	715	140.06
New York	6,776	6,715	878	130.68	6,270	6,155	838	136.21
Ohio	11,714	11,703	952	81.34	12,830	12,977	1,012	77.99
Pennsylvania	33,085	33,122	2,707	81.74	35,262	34,916	3,467	99.29
Texas	38,073	37,830	3,857	101.97	35,553	34,786	3,721	106.97
Other States[2]	274,745	270,327	25,732	95.19	318,894	315,376	34,672	109.94
Total	438,039	432,345	41,017	94.87	504,442	497,765	53,558	107.60

[1]Average value per ton based on unrounded data.
[2]Includes Colorado, Georgia, Idaho, Illinois, Iowa, Kentucky, Louisiana, Maine, Maryland, Massachusetts, Michigan, Mississippi, Nevada, New Hampshire, New Jersey, North Carolina, Oregon, Tennessee, Utah, Virginia, West Virginia, Wisconsin, Wyoming, and unidentified quantity and value sold or used in 1977 only.

CONSUMPTION AND USES

Domestic consumption of expanded perlite increased 15% in quantity over that of 1976 and totaled 498,000 tons to set a record for the second straight year. The new record consumption total in 1977 was largely due to the increased demand for insulation board products using perlite for energy conservation in new construction. The distribution of expanded perlite by end-use categories is shown in percent in table 3. In descending order of quantity sold or used, the principal uses of expanded perlite in 1977 were roof-insulation board, filter aids, acoustical ceiling tile, plaster aggregates, horticultural aggregates, and concrete aggregates. Expanded perlite sold or used for the three leading end uses (insulation board, filter aids, and acoustical tile) combined accounted for 347,000 tons, or 70% of the total quantity and 62% of the total sales value.

Although, as shown in table 3, three end-use categories declined in percent of use, three increased, and three remained unchanged, the market pattern for nearly all end uses of expanded perlite remained strong in 1977. Compared with 1976, sales for filter aids decreased from 21% to 17%, but declined by only 6,700 tons; horticultural aggregates decreased from 9% to 7%, but showed a gain of 5,400 tons; concrete aggregates declined from 7% to 5%, but increased in quantity by 4,800 tons; plaster aggregates increased from 6% to 8%, a gain of only 1,000 tons; masonry and cavity fill insulation increased from 3% to 4%, or a gain of 5,900 tons; and "other" uses increased from 41% to 46%, primarily because of a 33% increase in roof insulation board. The three end uses that remained unchanged—low-temperature insulation (2%), fillers (1%), and formed products (10%)—had a combined 9,900-ton increase in sales in 1977.

Table 3.—End use of expanded perlite

(Percent)

Use	1976	1977
Filter aid	21	17
Plaster aggregate	6	8
Concrete aggregate	7	5
Horticultural aggregate	9	7
Low-temperature insulation	2	2
Masonry and cavity fill insulation	3	4
Fillers	1	1
Formed products	10	10
Other (including insulation board)	41	46

PRICES

Processed (crushed, cleaned, and sized) crude perlite was sold by producers to expanders at an average price of $18.50 per ton, or an increase of $1.46 per ton over that in 1976. Crude perlite used by producers in their own expanding plants was valued at $17.52 per ton, or an increase of $0.58 per ton compared with that of 1976. Compared with 1976, the weighted average price of crude processed perlite increased $1.02 per ton to $18.01.

Expanded perlite sold or used, according to producers, was valued at $107.60 per ton, or an increase of $12.73 per ton compared with that in 1976. Average values for expanded perlite by State ranged from $60 to $228 per ton compared with the 1976 range of $40 to $167 per ton. Average prices for expanded perlite end uses in 1977 ranged from $60 per ton for acoustical tile to $224 per ton for low-temperature insulation products.

WORLD REVIEW

Hungary.—Crude perlite production in 1976 was reported to be 106,000 tons, a 34% increase over the 1975 quantity mined. The crude perlite was processed and expanded at plants in Tokaj and Balaton. Approximately 70% of the crude ore production is exported annually to European countries.

Philippines.—Crude perlite output in 1977 was 1,645 tons, or 10% lower than in 1976. Two companies mined perlite on the northern island of Luzon. Perlite Industries and Minerals Corp. (Pimcor) mined perlite near Legaspi and expanded perlite at Muntinlupa, and Trinity Lodge Mining Corp. mined near Albay and expanded the ore at San Pedro, Laguna.

Turkey.—A number of perlite deposits in eastern and western Turkey are commercially exploited. Approximately 58,000 tons of crude perlite was produced in 1977, primarily for local construction industry uses. Plans have been formulated to construct a processing plant and an expanding plant at Cumaovasi in western Turkey to meet a growing demand for perlite in the country.[2]

United Kingdom.—Imports of crude processed perlite ore, primarily from Greece and Italy (94%), were 117,500 tons in 1977, or a decline of 13% from the 135,000 tons imported in 1976. The imported ore was expanded in Great Britain, primarily for use in plaster aggregate products.

TECHNOLOGY

In 1977, the Perlite Institute, Inc., New York, published separately revised information on perlite loose fill insulation and perlite plaster aggregate. Technical data sheet No. 2-4 on loose fill insulation describes the insulation qualities of expanded perlite in high- and low-temperature and cryogenic applications at various densities. Catalog 90 on perlite plaster is a revised edition of information pertaining to perlite-portland cement and perlite-gypsum plaster applications.

[1]Industry economist, Division of Nonmetallic Minerals.
[2]Industrial Minerals (London). Turkey. Foundations Laid for Perlite Plant. No. 114, March 1977, p. 12.

Phosphate Rock

By W. F. Stowasser[1]

U.S. phosphate rock mines produced a record 47.3 million metric tons in 1977. All of this production was strip mined, except for a small tonnage from an underground mine in Montana and recovery from soft-rock-tailings basins in Florida. After beneficiation by various systems, a raw material for agricultural and industrial markets was available for conversion to useful and necessary products.

Because strip-mining phosphate rock is a highly visible operation, and because large volumes of water are used to wash and beneficiate the phosphate matrix in Florida and North Carolina, the industry has received attention from environmentalists and all levels of government.

In Florida, four companies that prospected and applied for preference-right leases to mine phosphate rock in the Osceola National Forest in the late 1960's have not received a response from the U.S. Department of the Interior. In central Florida, a moratorium was imposed on constructing new mines until the areawide environmental impact statement (EIS) is completed in 1978. At least six companies are in various stages of the permitting procedure, but they will defer plans until it is possible to obtain final approval.

During the past 4 years, a task force composed of Federal agencies prepared an EIS on southeastern Idaho phosphate-mining plans and, during this period, the U.S. Department of the Interior did not issue prospecting permits for phosphates and did not issue or renew phosphate leases in the Caribou National Forest.

Production of phosphate rock in Tennessee has proceeded on private land, and all mined land is reclaimed.

One company in North Carolina that is planning to mine phosphate rock received all necessary State permits and a dredge and fill permit from the U.S. Army Corps of Engineers to dredge a waterway.

Phosphate rock exports, which had been decreasing, increased in 1977. Exports from the United States were 12.6, 11.1, 9.4, and 13.2 million metric tons in 1974, 1975, 1976, and 1977, respectively. Of the total exports in 1977, 12.8 million tons were exported

Table 1.—Salient phosphate rock statistics

	1973	1974	1975	1976	1977
United States:					
Mine production ---------- thousand metric tons--	126,720	141,353	170,077	154,278	166,893
Marketable production ---------- do--	38,218	41,437	44,276	44,662	47,256
Value ---------- thousand dollars--	238,667	501,429	1,122,184	r949,379	821,657
Average per metric ton ----------	$6.24	$12.10	$25.35	$21.26	$17.39
Sold or used by producers ---- thousand metric tons--	40,854	43,931	42,120	40,522	47,437
Value ---------- thousand dollars--	254,846	529,141	1,052,995	857,189	829,084
Average per metric ton ----------	$6.24	$12.04	$25.00	$21.15	$17.48
Exports ---------- thousand metric tons--	12,585	12,605	11,131	9,433	13,230
P_2O_5 content ---------- do--	4,083	4,052	3,587	3,022	4,251
Value ---------- thousand dollars--	82,983	194,015	429,222	272,823	288,603
Average per metric ton ----------	$6.59	$15.39	$38.56	$28.92	$21.81
Imports for consumption[1] ---- thousand metric tons--	59	165	33	r42	158
Value ---------- thousand dollars--	1,288	8,999	r1,578	r2,209	6,079
Average per metric ton ----------	$21.83	$54.54	$47.82	r$52.60	$38.47
Consumption, apparent[2] ---- thousand metric tons--	28,328	31,491	31,022	r31,131	34,365

rRevised.
[1]Bureau of the Census data.
[2]Measured by sold or used plus imports minus exports.

from Florida. This surge in exports was the demand factor that made the year outstanding for Florida producers.

Although world and U.S. demand for phosphatic fertilizer sustained production in Florida and North Carolina, and part of the production from the Western States, overall production from the Western States and Tennessee continued to decline from 1974 levels because the demand for phosphorus in detergents was markedly reduced either voluntarily or by legislation.

The industry in all producing regions was able to supply domestic and export demand, and each producing area had a considerable amount of unused capacity. In all probability, the industry will continue to operate existing mines and plants that were constructed in the 1950's and 1960's until the reserves are depleted to take full advantage of the relatively low investment in these older plants. Given the unused capacity in the Eastern U.S. plants, the declining markets for elemental phosphorus from Tennessee and Western States producers, and the high cost of new plants, no new phosphate mines are expected to be authorized until a demand develops and the price in the marketplace becomes sufficient to encourage investments in new plants. Expansion plans for merchant phosphate rock will be shelved until these conditions are met.

Morocco's Office Cherifien des Phosphates (OCP) was again a major factor in the current international trade in phosphate rock and discussed plans for new agreements for the future. OCP shipped about 300,000 metric tons into the United States to meet one fertilizer producer's demand. OCP discussed a long-term barter arrangement with the U.S.S.R. Moroccan rock shipments to the U.S.S.R. would, over a 10-year span, increase to 10 million tons per year and, in return, the U.S.S.R. would supply Morocco with fuels, ammonia, and credits to develop phosphate rock deposits in southern Morocco. This agreement was expected to be finalized in 1978. Production from the Bu-Craa mine in the Western Sahara was again curtailed. The conveyor belt that moved the ore to the port (about 100 kilometers) was not repaired in 1977. Morocco's plans to increase production of phosphoric acid at Safi and Jorf Lasfar will increase production from 780,000 metric tons of P_2O_5 in 1977 to a maximum of 2,500,000 metric tons of P_2O_5 in the 1985 to 1990 period.

Morocco produced 17 million metric tons in 1977, about 15% of the estimated world production of 116 million tons. In 1978, a production level of 22 to 23 million tons is planned. If expansion plans materialize, Morocco will be producing in 1990 an estimated 40 to 45 million tons of phosphate rock and from 5 to 10 million tons from the Bu-Craa mine in the Sahara.

Legislation and Government Programs.—The Bureau of Land Management, U.S. Department of the Interior, proposed to amend Title 43 of the U.S. Code of Federal Regulations, Part 3520, to provide that a sodium, phosphate, potash, or sulfur preference right lease applicant or lessee may in certain situations exchange the preference right lease to which he is entitled, or the lease he holds, for a mineral lease to another deposit of the same mineral of comparable value.[2] These provisions should be available in cases where the production from the existing or preference right lease would not be in the public interest because of adverse effects, damage or destruction to environmental, land, and resource values.

The U.S. Department of the Interior announced on August 2, 1977, that prospecting permits for coal and phosphate under the Mineral Leasing Act of 1920 are invalid in areas covered by prior mining claims. In a formal legal opinion, the Department's Solicitor concluded that the Mineral Leasing Act authorizes the issuance of coal and phosphate prospecting permits only in unclaimed areas. If permits were issued for areas covered by mining claims under the Mining Act of 1872, they are invalid as to those areas. The ruling does not affect noncompetitive preference right leases already issued. However, the opinion could invalidate in part many of the 183 pending preference right lease applications covering 466,000 acres and 9 billion tons of coal and 40 preference right lease applications covering 35,000 acres and 130 million tons of phosphate. The impact of this ruling on pending applications will depend on a review of each case. Holders of prospecting permits for coal and phosphate are entitled to noncompetitive leases if they find commercial quantities of coal or valuable deposits of phosphate. Congress has, in effect, said that prospecting permits for these two minerals should be issued only where little information about mineral values is available, that is, where prospecting is required. Areas covered by mining claims already have been explored. Congress did not intend to authorize issuance of prospecting permits and ultimately noncompetitive leases for coal and phosphate in areas that already have been explored. The interpretation means that if coal or phosphate exists in areas where there are prior mining claims, a noncompetitive lease cannot be issued. Any leasing would have to be on a competitive basis.

After an 18-month investigation, a Federal Grand Jury in Chicago concluded that there was no basis for criminal indictments against phosphate rock producing and exporting companies.

During 1977, the contractor selected to prepare the draft EIS on the central Florida phosphate industry, completed a set of working papers. The first of the working papers was an unnumbered volume with suggestions by the contractor for program improvements. The other 12 volumes in the series covered archaeology, history, and recreation; pertinent laws and regulations; demography, economics, and culture; existing land use; water; land; atmosphere; industry description; description of scenarios; future land use; impacts on social, economic, and natural environmental systems; and comparisons of impacts and selection of preferred scenario.

The purpose of preparing and distributing working papers was to improve the quality of information for decisionmakers in the short time frame available without diminishing the thoroughness of making available all sources of data and information pertinent to effects assessment. The working papers were intended to increase the decisionmakers' understanding of the information and assist in resolving the issues.

Alternatives were proposed as a basis for assessing the effects of the central Florida phosphate industry. Scenarios were formulated that intended to convey separate themes and intent of administrative action. Each scenario was described in operational terms to assess environmental effects. A final scenario will be selected by the Environmental Protection Agency with recommendations from both Advisory and Steering Committees and will be the scenario for a draft EIS in 1978.

The final EIS, "Development of Phosphate Resources in Southeastern Idaho," prepared by the U.S. Department of the Interior, was issued in the last quarter of the year. A task force led by the Geological Survey, with contributions from the Bureau of Land Management and Forest Service of the U.S. Department of Agriculture, spent the past 3-1/2 years analyzing the broad cumulative impacts of existing and proposed phosphate-resource development in southeastern Idaho, as well as an analysis of specific applications pending before the Federal Government. Since the preparation of the draft statement, the expansion plans for phosphate were modified from an estimated 18 million metric tons in 2000 to 13.6 million metric tons, which was the basis and justification for the EIS. Since 1974, when production in the Western States was 5.7 million metric tons, production has declined in each succeeding year and in 1977 was 4.6 million metric tons. The industry probably has adequate installed capacity in existing mines and plants to meet a projected demand of 7.3 million metric tons at the end of the century. Because the demand for sodium tripolyphosphate is expected to continue to decline as zeolites are substituted in detergent formulations, the Western phosphate industry will probably remain relatively stable for the next several decades. In this event, the environmental impacts associated with the 13.6- to 18-million-metric-ton production level as described in the EIS will not occur.

The U.S. Geological Survey prepared, in cooperation with the Bureau of Land Management, Bureau of Mines, and U.S. Forest Service, an Administrative Report following a 2-year study entitled "Impact of Potential Phosphate Mining on the Hydrology of Osceola National Forest, Florida."

It was estimated that the reserve of phosphate rock in the Osceola National Forest would support two logical mining units and associated beneficiation plants in the western half of the forest. Water demand would be similar to that of other phosphate mines in Florida. Each mining unit would pump 31,000 liters per minute from the Floridan aquifer for 6 months prior to startup, and about 19,300 liters per minute would be pumped after startup. The lowering of the Floridan potentiometric surface would be less than 1.5 meters at Lake City, White Springs, and Taylor, the nearest sources of public water supply to the proposed mines. No appreciable change in the quality of water in the Floridan aquifer was expected if no plant effluent was discharged into Falling Creek, which recharges the aquifer through a sinkhole. No sinkholes were found in the forest. The flow of the Suwannee River would not be affected.

A digital model of two-dimensional ground-water flow was used to simulate projected changes in the Floridan aquifer potentiometric surface in 1985 and 2000 caused by proposed ground-water demands by the phosphate mining industry in west-central Florida.[3] The model was calibrated under steady-state conditions to simulate the September 1975 potentiometric surface. Under one plan, existing phosphate mines in Polk County would continue to withdraw ground water at 1975 rates until they phased out of operation as ore was depleted; no new mines would start up. The preliminary indications were that, under this scenario, the maximum simulated recovery of the potentiometric surface is 3.6 meters by 1985 and 11.1 meters by 2000. Under an alternate plan, all proposed mines in Polk, Hardee, DeSoto, Hillsborough, and Manatee Counties would start up, and existing mines would continue to operate until depleted. The results indicate that the potentiometric surface would generally recover in Polk County and decline elsewhere in the model area. Maximum simulated recovery is 1.4 meters by 1985 and 9 meters by 2000 in Polk County. The maximum simulated drawdown is 4.6 meters by 1985 and 4.4 meters by 2000 in areas outside of Polk County.

The Florida State Legislature doubled the severance tax on phosphate rock on June 24, 1977, and added the following to the law: "The excise tax upon persons engaged in the business of severing phosphate rock from the soils and waters of this State for commercial use shall be 10 percent of the value at the point of severance of the identifiable phosphate rock severed. The proceeds from the tax imposed by this subsection, excluding the amount credited for ad valorem tax payments, shall be paid into the State Treasury as follows: (a) seventy-five percent to the credit of the General Revenue Fund of the State; and (b) twenty-five percent to the credit of the Land Reclamation Trust Fund established for refunds under provisions of S. 211.32(3)."

The severance tax bill also included a provision for a seven-member commission to study the reclamation of phosphate lands.

DOMESTIC PRODUCTION

Marketable phosphate rock production was 47,256,093 metric tons, an increase of 2,594,533 metric tons or 5.8% more than that of 1976. The value of marketable rock was $821,657,000 in 1977 compared with $949,379,000 in 1976. The average grade of phosphate ore mined in the United States was 12.2% P_2O_5, similar to that of 1976. The average weight recovery of concentrate and rock marketable as mined was 28.3%, similar to the 28.9% weight recovery obtained in 1976. The average P_2O_5 recovery was 71.6%, somewhat less than a 75.4% P_2O_5 recovery achieved in 1976. In the United States, Florida and North Carolina produced 40,575,041 metric tons, 85.9% of the total marketable phosphate rock; the Western States produced 4,934,130 metric tons, 10.4%; and Tennessee produced 1,746,922 metric tons, 3.7%.

Florida and North Carolina.—Production of marketable phosphate rock was 40,575,041 metric tons, an increase of 7.7% over that of 1976. The value of marketable rock was $718,393,000, a decrease of $148,699,000 or 17.1% less than that of 1976.

The average grade of phosphate ore mined was 11.6% P_2O_5, similar to 11.0% P_2O_5 in 1976 and 11.8% P_2O_5 in 1975. The average grade of marketable rock was 31.2% P_2O_5, similar to the 31.3% P_2O_5 marketable rock average in 1976.

The average weight recovery of concentrates and phosphate rock marketable as mined was 26.2%, similar to a 26.4% weight recovery in 1976. The average P_2O_5 recovery was 70.7%, somewhat less than the 75% P_2O_5 recovery achieved in 1976.

Agrico Chemical Co., Asamera Minerals, Inc., Borden, Inc., Brewster Phosphates, Florida Agglite Corp., Gardinier, Inc., W. R. Grace and Co., International Minerals and Chemical Corp., T. A. Minerals Corp., Mobil Chemical Co., Occidental Chemical Co., Swift Chemical Co., and USS Agri-Chemicals produced marketable phosphate rock from the Bone Valley Formation in central Florida and a similar type matrix in northern Florida. Howard Phosphate Co., Kellogg Co., Loncala Phosphate Co., and Manko Co., Inc., mined about 24,000 metric tons of soft rock from tailing ponds associated with past hard rock phosphate mines in central Florida.

In North Carolina, Texasgulf, Inc., was the only company producing phosphate rock. During the year, the rate of production increased as new mining capacity was utilized. North Carolina Phosphate Corp., jointly owned by Agrico Chemical Co. and Kennecott Copper Corp., obtained a permit from the U.S. Army Corps of Engineers to dredge South Creek. Mining plans and schedules for this development have not been announced. FMC Corp. is studying the feasibility of slurry mining deep phosphate deposits north of the Pamlico River with proprietary equipment.

Occidental Chemical Co., a division of Occidental Petroleum Corp., produced phosphate rock from its Suwannee River mine in north Florida but did not operate the new Swift Creek mine during the year. The superphosphoric acid plant capacity at the Suwannee River mine is being increased, and a new superphosphoric acid plant and chemical complex will be constructed in 1978 and 1979 at the Swift Creek mine, about 5 kilometers west of the Suwannee River complex. A new chemical-handling facility will be constructed on Wigmore Street at the Port of Jacksonville to handle the superphosphoric acid storage and loading into 30,000-metric-ton-capacity vessels from the U.S.S.R. This facility will be fully operational by January 1980. The Swift Creek mine is scheduled to start producing again in 1979, and the combined mines are projected to 4.5 million metric tons per year of phosphate rock for conversion into superphosphoric acid.

In central Florida, the moratorium on new mines continued pending completion of the central Florida areawide EIS authorized by President Ford. Agrico Chemical Co. operated the Payne Creek and Fort Green mines. The Saddle Creek mine was shutdown in March 1977 and was reactivated in late 1977. Asamera Minerals, Inc., purchased 85 acres of phosphate debris land and a flotation plant near Lakeland, Fla. The plant produced from June-October 1977 and was shutdown. Borden, Inc., stopped production at its Tenoroc mine in September 1977. Its new Big Four mine in Hillsborough County was scheduled to start production at yearend. Brewster Phosphates continued to operate the Haynsworth mine and the new Fort Lonesome mine at less than capacity during 1977, its first full production year. CF Industries continued to work toward opening the first phosphate mine in Hardee County in January 1979. All permits have been obtained and mine and plant development will be completed in 1978. Initial production will be 1.1 million metric tons per year. Gardinier, Inc., announced plans to construct a uranium-extraction facility at its chemical complex south of Tampa, Fla. The construction schedule would permit testing the new plant in late 1979, and commercial production was expected in 1980. W. R. Grace produced phosphate rock from the Bonny Lake mine and began producing from the new Hookers Prairie mine in May 1977. Anticipating the depletion of the Bonny Lake mine reserve in 1982, W. R. Grace started to obtain permits for a new mine that would be located in southeast Hillsborough County, northeast Manatee County, Polk County, and Hardee County. The reserve, which is called the Four Corners mine, would permit mining 4.5 million metric tons per year for 15 years if this level of production is required. Projected startup for the Four Corners mine is 1984. International Minerals & Chemical Corp. (IMC) started construction of a 400,000-metric-ton-per-year calcium and ammonium phosphate livestock and poultry feed plant in Polk County, Fla. IMC's Florida phosphate chemicals plant completed its first full year of operations producing over 600,000 metric tons of P_2O_5 equivalent. IMC announced an agreement with a 10-year option to purchase an 8,500-hectare site in east-central Florida for future possible phosphate development. The deposits that will be studied are in Brevard County.

Western States.—Production of marketable phosphate rock was 4,934,130 metric tons, 7.6% less than the 5,338,658 metric tons produced in 1976. It is also useful to compare the production used for agricultural purposes with that used for industrial markets in the Western States. In 1976, production for agricultural markets was 1,650,000 metric tons, which increased to 2,222,000 metric tons in 1977, an impressive gain of 34.7%. On the other hand, phosphate rock used in elemental furnaces declined from 2,575,000 million metric tons in 1976 to 2,026,000 metric tons in 1977, a reduction of 549,000 metric tons or 21.3%. It is not clear how much of the lost production for elemental phosphorus in 1977 was caused by power restrictions and how much was caused by less demand for phosphorus in detergents. It is probable that the legislation limiting phosphorus in detergents or voluntary reductions in phosphorus levels in detergents by detergent manufacturers has not shown a decisive trend as yet for producers of sodium tripolyphosphate.

The value of marketable phosphate rock increased from $67,746,000 in 1976 to $89,011,000 in 1977, a gain of 31.4%. The average grade of mined phosphate ore was 20.6% P_2O_5. The average grade of mined phosphate rock used without beneficiation was 26.9% P_2O_5. The average grade of

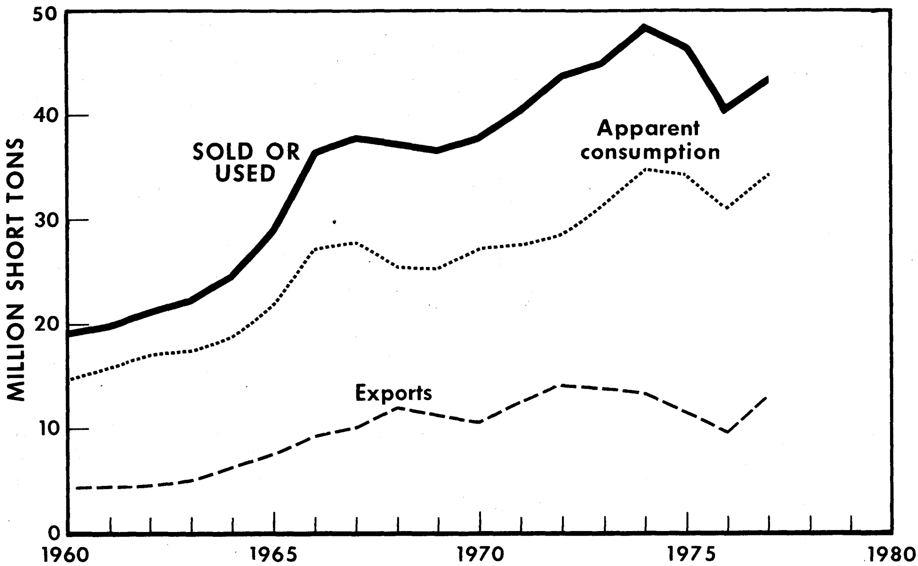


Figure 1.—Phosphate rock (sold or used), apparent consumption, and exports.

beneficiated phosphate rock was 32.2% P_2O_5. The average grade of all used-as-mined and beneficiated phosphate rock was 29.2% P_2O_5. Of the total phosphate rock produced in the Western States, 56.9% was used without beneficiation and 43.1% was beneficiated. The weight recovery of the beneficiated concentrates was 37.5%; the P_2O_5 recovery was 69.4%.

Beker Industries Corp., Monsanto Industrial Chemicals, Inc., J. R. Simplot Co., and Stauffer Chemical Co. mined and processed phosphate rock in Idaho. In Montana, Cominco American, Inc., operated an underground phosphate rock mine near Garrison. Stauffer Chemical Co. operated two mines in Utah but closed the Crawford Mountain mine in January 1977. Operations at Vernal, Utah, continued throughout the year. Stauffer Chemical Co. also mined phosphate rock in Wyoming. In California, the California Phosphate Corp. mined phosphate rock from the Cuyama property during the first quarter of the year. Meramec Mining Co., Sullivan, Mo., discontinued recovering apatite concentrates from the Pea Ridge iron ore mine tailings.

Beker Industries Corp. and Western Co-Operative Fertilizers signed a tentative agreement to form a joint venture. The Canadian Western Co-Operative Fertilizers will purchase Beker Industries Corp.'s phosphate properties in Bear Lake and Caribou Counties in Idaho to secure a long-term phosphate rock supply for its two fertilizer plants in Western Canada. Beker Industries Corp. would retain the Conda chemical complex.

The final EIS, Development of Phosphate Resources in Southeastern Idaho, was issued in 1977. No new mines were developed in the Western States in 1977.

Tennessee.—Production of marketable phosphate rock was 1,746,922 metric tons, an increase of 113,636 metric tons or 7% over that of 1976. The value of marketable rock in 1977 was $14,253,000 compared with a value of $14,541,000 in 1976.

The average grade of ore mined was 20.1% P_2O_5, the average weight recovery of concentrates was 52.8%, and the P_2O_5 recovery was 66.5%. The average grade of marketable phosphate rock was 25.3% P_2O_5.

Hooker Chemical Co., Monsanto Industrial Chemicals, Inc., and Stauffer Chemical Co. mined and beneficiated phosphate rock in Tennessee for reduction to elemental phosphorus in electric furnaces.

Table 2.—Production of phosphate rock in the United States, by State

(Thousand metric tons and thousand dollars)

	Mine production		Mine production used directly		Beneficiated production		Marketable production		
	Rock	P_2O_5 content	Rock	P_2O_5 content	Rock	P_2O_5 content	Rock	P_2O_5 content	Value
1976:									
Florida and North Carolina	142,985	15,728	27	5	37,663	11,787	37,690	11,792	867,092
Tennessee	3,023	618	45	11	1,588	410	1,633	421	r14,541
Western States[1]	8,270	1,848	3,516	920	1,822	579	5,339	1,499	67,746
Total[2]	154,278	18,194	3,588	936	41,073	12,776	44,662	13,712	r949,379
1977:									
Florida and North Carolina	155,114	17,922	24	5	40,551	12,674	40,575	12,679	718,393
Tennessee	3,307	665	--	--	1,747	442	1,747	442	14,253
Western States[1]	8,472	1,741	2,807	756	2,127	684	4,934	1,440	89,011
Total[2]	166,893	20,328	2,832	761	44,424	13,800	47,256	14,561	821,657

rRevised.
[1]Includes California, Idaho, Missouri, Montana, Utah, and Wyoming.
[2]Data may not add to totals shown because of independent rounding.

CONSUMPTION AND USES

Apparent consumption of marketable phosphate rock, defined as "the quantity sold or used plus imports minus exports," increased from 31,131,000 metric tons in 1976 to 34,365,000 metric tons in 1977, an increase of 10.4%. According to producers' reports, the quantity of phosphate rock sold or used in 1977 was 47,437,040 metric tons, a significant increase over the 40,521,819 metric tons sold or used in 1976 and more than that reported in any prior year. Of the total sold or used in 1977, 72.1% was consumed domestically; 27.9% was exported.

The consumption pattern as reported by producers is shown in table 3. Of the total sold or used, including both domestic and export markets, the distribution pattern in 1977 for the domestic segment was wet-process phosphoric acid 57.0%, normal superphosphate 1.9%, triple superphosphate 3.9%, defluorinated rock 0.6%, direct applications 0.1%, elemental phosphorus 8.2%, and ferrophosphorus 0.4% for a total of 72.1% or 34,206,749 metric tons.

The percent distribution by grade of marketable phosphate rock consumed in the United States and sold in the export market in 1977 is compared with the distribution patterns for 1974-76 in the following tabulation. The data indicate a gradual increase in the 66% to 70% BPL fraction at the expense of both lower and higher grades.

Grade, percent BPL[1] content	Distribution (percent)			
	1974	1975	1976	1977
Less than 60	5.6	9.4	7.8	5.7
60 to 66	20.8	14.7	14.6	11.6
66 to 70	42.0	48.4	53.8	57.3
70 to 72	12.2	10.8	9.4	12.2
72 to 74	11.6	10.7	8.3	7.4
Over 74	7.8	6.0	6.1	5.8

[1]1.0% BPL (bone phosphate of lime or tricalcium phosphate) = 0.458% P_2O_5.

Florida and North Carolina.—The quantity of phosphate rock sold or used increased substantially from 33,914,723 metric tons in 1976 to 40,994,482 metric tons in 1977. Of the total sold or used in 1977, 68.9% was consumed domestically and 31.1% was exported. Of the total consumed domestically, 24,866,873 metric tons (88.1%) was used to produce wet-process phosphoric acid, 910,378 metric tons (3.2%) was used to produce normal superphosphate, 1,796,795 metric tons (6.4%) was used for triple superphosphate, 298,165 metric tons (1.1%) was used to produce defluorinated rock, 28,362 metric tons (0.1%) was used in direct applications, and 362,694 metric tons (1.3%) was used in electric furnaces to produce elemental phosphorus and ferrophosphorus.

The percent distribution by grade of the marketable rock sold or used from Florida and North Carolina, including exports, is tabulated below for 1974 through 1977.

Grade, percent BPL[1] content	Distribution (percent)			
	1974	1975	1976	1977
Less than 60	0.2	0.1	0.2	0.1
60 to 66	17.0	14.8	13.4	10.5
66 to 70	47.2	55.0	60.2	62.7
70 to 72	14.3	11.2	11.2	14.1
72 to 74	11.9	11.5	7.7	5.9
Over 74	9.4	7.4	7.3	6.7

[1]1.0% BPL (bone phosphate of lime or tricalcium phosphate) = 0.458% P_2O_5.

Western States.—The quantity of marketable phosphate rock sold or used decreased from 4,876,868 metric tons in 1976 to 4,719,131 metric tons in 1977. Of the total sold or used in 1977, 90% was consumed in the United States and 10% was exported to Canada.

Of that consumed in the United States, expressed as a percent of the total sold or used from the Western States, 2,157,016 metric tons (45.7%) was used for wet-process phosphoric acid, about 2,367 metric tons (0.1%) was used to produce normal superphosphate, about 55,181 metric tons (1.2%) was used to produce triple superphosphate, 7,495 metric tons (0.2%) was used in direct applications, 1,965,567 metric tons (41.7%) was used to produce elemental phosphorus, and 60,791 metric tons (1.3%) was collected in ferrophosphorus.

The percent distribution by grade of marketable rock sold or used from the Western States from 1974 through 1977 is shown in the following tabulation:

Grade, percent BPL[1] content	Distribution (percent)			
	1974	1975	1976	1977
Less than 60	35.8	38.8	37.7	29.7
60 to 66	22.5	13.2	18.5	16.3
66 to 70	23.5	25.9	28.5	31.5
70 to 72	3.5	12.2	--	--
72 to 74	14.3	9.9	15.3	22.6
Over 74	.4	--	--	--

[1]1.0% BPL (bone phosphate of lime or tricalcium phosphate) = 0.458% P_2O_5.

Tennessee.—The quantity of marketable phosphate rock sold or used was 1,723,427 metric tons compared with 1,730,228 sold or used in 1976. All of this rock was used in electric furnaces to produce elemental phosphorus and industrial chemicals. Most of the phosphorus from electric furnaces was converted into an intermediate phosphoric acid, the base for sodium, calcium, and potassium chemicals.

The percent distribution by grade of marketable rock sold or used in Tennessee from 1974 through 1977 is shown in the following tabulation:

Grade, percent BPL[1] content	Distribution (percent)			
	1974	1975	1976	1977
Less than 60	19.7	80.9	72.1	75.4
60 to 66	75.6	17.5	26.8	24.6
66 to 70	4.7	1.6	1.1	--

[1]1.0% BPL (bone phosphate of lime or tricalcium phosphate) = 0.458% P_2O_5.

Table 3.—Phosphate rock sold or used by producers in the United States, by use

(Thousand metric tons)

Use	1976 Rock	1976 P_2O_5 content	1977 Rock	1977 P_2O_5 content
Domestic:				
Wet process phosphoric acid	r23,609	r7,274	27,024	8,377
Normal superphosphate	1,072	334	913	283
Triple superphosphate	r1,364	r442	1,852	587
Defluorinated rock	290	96	298	99
Direct applications	40	8	36	7
Elemental phosphorus	4,515	1,178	3,904	1,011
Ferrophosphorus	199	51	180	46
Total[1]	31,089	9,383	34,207	10,410
Exports	9,433	3,022	13,230	4,251
Grand total[1]	40,522	12,405	47,437	14,660

rRevised.
[1]Data may not add to totals shown because of independent rounding.

Table 4.—Phosphate rock sold or used by producers in the United States in 1977, by grade and State

(Thousand metric tons and thousand dollars)

Grade, percent BPL[1] content	Florida and North Carolina Rock	Florida and North Carolina P_2O_5 content	Florida and North Carolina Value	Tennessee Rock	Tennessee P_2O_5 content	Tennessee Value
Below 60	25	5	504	1,300	318	10,226
60 to 66	4,320	1,233	79,496	424	118	3,838
66 to 70	W	W	W	--	--	--
70 to 72	5,785	1,887	113,304	--	--	--
72 to 74	W	W	W	--	--	--
Plus 74	2,733	949	65,000	--	--	--
Total[2]	40,994	12,843	727,454	1,723	436	14,064

Grade, percent BPL[1] content	Western States Rock	Western States P_2O_5 content	Western States Value	Total United States Rock	Total United States P_2O_5 content	Total United States Value
Below 60	1,400	349	16,848	2,725	672	27,578
60 to 66	767	213	9,111	5,511	1,564	92,445
66 to 70	W	W	W	27,196	8,415	444,060
70 to 72	--	--	--	5,785	1,887	113,304
72 to 74	W	W	W	3,488	1,174	86,696
Plus 74	--	--	--	2,733	949	65,000
Total[2]	4,719	1,382	87,566	47,437	14,660	829,084

W Withheld to avoid disclosing company proprietary data.
[1]1.0% BPL (bone phosphate of lime or tricalcium phosphate)= 0.458% P_2O_5.
[2]Data may not add to totals shown because of independent rounding.

Table 5.—Phosphate rock sold or used by producers, by use and State

(Thousand metric tons)

Use	Florida and North Carolina		Tennessee		Western States		Total United States	
	Rock	P_2O_5 content	Rock	P_2O_5 content	Rock	P_2O_5 content	Rock	P_2O_5 content
1976:								
Domestic:								
Agricultural	r24,724	r7,629	--	--	1,650	525	26,375	8,154
Industrial	409	120	1,730	448	2,575	661	4,714	1,229
Total[1]	25,133	7,749	1,730	448	4,225	1,186	31,089	9,383
Exports[2]	8,781	2,825	--	--	651	197	9,433	3,022
Grand total[1]	33,915	10,574	1,730	448	4,877	1,383	40,522	12,405
1977:								
Domestic:								
Agricultural	27,901	8,637	--	--	2,222	716	30,123	9,353
Industrial	334	98	1,723	436	2,026	523	4,084	1,056
Total[1]	28,235	8,735	1,723	436	4,248	1,239	34,207	10,409
Exports[2]	12,759	4,108	--	--	471	143	13,230	4,251
Grand total[1]	40,994	12,843	1,723	436	4,719	1,382	47,437	14,660

rRevised.
[1]Data may not add to totals shown because of independent rounding.
[2]Exports reported to Bureau of Mines by companies.

Table 6.—Florida phosphate rock sold or used by producers, by kind

(Thousand metric tons and thousand dollars)

Year	Land pebble[1]				Soft rock				Total[2]			
	Rock	P_2O_5 content	Value: Total	Value: Average per ton	Rock	P_2O_5 content	Value: Total	Value: Average per ton	Rock	P_2O_5 content	Value: Total	Value: Average per ton
1973	33,463	10,626	205,328	$6.14	20	4	154	$7.70	33,483	10,630	205,482	$6.14
1974	36,170	11,380	436,587	12.07	37	7	571	15.43	36,207	11,387	437,158	12.07
1975	34,369	10,782	926,813	26.97	25	5	503	20.12	34,394	10,787	927,316	26.96
1976	33,886	10,568	774,517	22.86	29	6	580	20.00	33,915	10,574	775,096	22.85
1977	40,970	12,838	726,950	17.74	25	5	504	20.16	40,994	12,843	727,454	17.75

[1]Includes North Carolina.
[2]Data may not add to totals shown because of independent rounding.

Table 7.—Tennessee phosphate rock sold or used by producers

(Thousand metric tons and thousand dollars)

Year	Rock	P_2O_5 content	Value: Total	Value: Average per ton
1973	2,417	634	13,812	$5.71
1974	2,364	642	20,594	8.71
1975	2,171	560	29,921	13.78
1976	1,731	448	15,326	8.85
1977	1,723	436	14,064	8.16

STOCKS

Stocks of marketable phosphate rock in the United States were stable during 1977. Stocks were 13,776,799 metric tons at the beginning of the year; at the end of the year, the reported stocks were 13,682,431 metric tons. Producers minimized moving material from stocks and shipped and used current production to meet demand in 1977. In Florida and North Carolina, stocks at the beginning of the year were 12,110,425 metric tons, and at the end of the year were 11,822,135 metric tons. In Tennessee stocks changed from 214,034 metric tons at the beginning of the year to 240,827 metric tons at yearend. Stocks increased in the Western States from 1,452,340 to 1,619,469 metric tons during the year.

PRICES

The selling price of phosphate rock sold in domestic or export markets is not published. Selling prices are negotiated between buyer and seller, and the content of the contract is not public information. Some phosphate rock producers publish price lists; however, these do not reflect the effects of long-term contracts or adjustments privately negotiated. The Phosphate Rock Export Association, Tampa, Fla., and the Moroccan Office Cherifien des Phosphates (OCP) published phosphate rock prices in January 1976 but did not publish prices in 1977 as the international market became more competitive. The Chemical Marketing Reporter publishes prices of Florida land-pebble phosphate rock, dried, unground, in bulk, carload lots, f.o.b. mine; examples of these prices have been published in prior chapters on phosphate rock from the Minerals Yearbook. This will be discontinued and replaced by price data obtained by the Bureau's semiannual survey of the industry.

Producing companies report the value[4] of each grade of marketable phosphate rock sold or used semiannually to the Bureau of Mines. The average 1977 unit value of marketable phosphate rock reported by producers, or estimated if not reported, was $17.39 per metric ton f.o.b. plant. This unit value was 18.2% less than the $21.26 per metric ton value reported in 1976. The average unit value of land-pebble phosphate rock reported sold or used in the domestic and export markets from Florida and North Carolina decreased from $22.85 per metric ton in 1976 to $17.74 per metric ton in 1977. In the Western States, the unit value of marketable phosphate rock sold or used increased from $13.69 per metric ton in 1976 to $18.56 per metric ton in 1977. The unit value of marketable rock used in Tennessee was $8.16 per metric ton in 1977 compared with $8.85 per metric ton in 1976.

The average unit value of phosphate rock exported from the United States decreased from $28.92 per metric ton in 1976 to $21.81 per metric ton in 1977, f.o.b. mine, which represents a 25% decrease. The unit value of marketable rock exported from Florida and North Carolina decreased from $29.03 per metric ton in 1976 to $21.64 per metric ton, f.o.b. mine. The unit value of phosphate rock exported from the Western States decreased from $27.39 per metric ton in 1976 to $26.45 per metric ton in 1977. Tennessee rock was not exported. The average price or value of Tennessee phosphate rock was as follows, per metric ton, f.o.b. mine: 60% BPL, $7.87; and 60% to 66% BPL, $9.06; the average cost of the two categories was $8.16. Tables 8 and 9 show the price or value of phosphate rock domestically sold or consumed and exported, by grade, for Florida and North Carolina, and the Western States in dollars per metric ton, f.o.b. mine.

Table 10 shows the price or value of phosphate rock domestically sold or used and exported, by grade, for the United States, in dollars per metric ton, f.o.b. mine.

Table 8.—Price or value of Florida and North Carolina phosphate rock

(Dollars per metric ton, f.o.b. mine)

Grade, percent BPL[1] content	Domestic	Exports	Average
60 to 66	18.53	17.45	18.40
66 to 70	14.91	20.11	16.04
70 to 72	17.81	20.89	19.59
72 to 74	21.20	24.01	23.44
Over 74	19.54	27.89	23.78
Average	15.98	21.64	17.74

[1]1.0% BPL (bone phosphate of lime or tricalcium phosphate)= 0.458% P_2O_5.

Table 9.—Price or value of Western States phosphate rock

(Dollars per metric ton, f.o.b. mine)

Grade, percent BPL[1] content	Domestic	Exports	Average
Less than 60	12.03	--	12.03
60 to 66	8.57	27.43	11.88
66 to 70	19.94	26.06	21.33
72 to 74	28.06	--	28.06
Average	17.68	26.45	18.56

[1]1.0% BPL (bone phosphate of lime or tricalcium phosphate)= 0.458% P_2O_5.

Table 10.—Price or value of United States phosphate rock

(Dollars per metric ton, f.o.b. mine)

Grade, percent BPL[1] content	Domestic	Exports	Average
Less than 60	10.03	--	10.03
60 to 66	16.41	19.51	16.78
66 to 70	15.18	20.45	16.33
70 to 72	17.81	20.89	19.59
72 to 74	25.91	24.01	24.85
Over 74	19.54	27.89	26.71
Average	15.80	21.81	17.48

[1]1.0% BPL (bone phosphate of lime or tricalcium phosphate)= 0.458% P_2O_5.

FOREIGN TRADE

In 1977, producers reported that exports from the United States totaled 13,230,291 metric tons. This was 40% more than the 9,432,568 metric tons exported in 1976 and was the largest export tonnage recorded. The export distribution pattern was 96.4% from Florida and North Carolina, 3.6% from the Western States, and none from Tennessee. Exports of phosphate rock from Florida and North Carolina increased from 8,781,472 metric tons in 1976 to a record high of 12,759,577 metric tons in 1977. Except for a small amount, all of the tonnage originated in Florida. Exports from the Western States totaled 470,714 metric tons.

The average unit value of phosphate rock exported from the United States declined from $28.92 per metric ton in 1976 to $21.81 per metric ton in 1977, f.o.b. plant.

Imports of phosphate rock increased from 42,000 metric tons in 1976 to 158,000 metric tons in 1977, according to U.S. Bureau of the Census reports. The distribution pattern of imports was 70% from Morocco, 22% from the Netherlands Antilles, and 8% from Mexico. This was the first year that significant commercial quantities of phosphate rock were imported from Morocco.

Table 11.—U.S. exports of phosphate rock, by country

(Thousand metric tons and thousand dollars)

Destination	1976 Quantity	1976 Value	1977 Quantity	1977 Value
Florida phosphate rock:				
Austria	97	4,173	151	4,310
Belgium-Luxembourg	750	26,610	899	22,797
Brazil	645	25,655	558	16,500
Canada	1,787	41,566	2,049	41,583
Colombia	16	573	53	1,626
Costa Rica	11	325	--	--
Denmark	--	--	25	724
Ecuador	20	704	10	304
El Salvador	11	426	11	270
France	534	16,480	1,051	23,486
German Democratic Republic	16	401	--	--
German, Federal Republic of	506	14,085	978	21,895
India	237	11,218	249	8,556
Iran	277	9,349	366	12,279
Ireland	23	656	23	598
Italy	95	3,157	297	7,149
Japan	1,375	53,311	1,479	48,094
Korea, Republic of	692	30,059	1,165	36,344
Mexico	394	12,378	566	14,126
Netherlands	688	19,852	824	18,922
Norway	55	2,104	154	4,024
Peru	5	184	16	494
Philippines	76	2,950	100	3,322
Poland	190	6,328	935	21,151
Portugal	4	129	5	121
Qatar	--	--	15	635
Romania	153	4,926	259	6,590
Spain	16	424	142	3,246
Sweden	103	3,876	120	3,349
Switzerland	24	871	--	--
Taiwan	45	1,727	32	1,208
United Kingdom	164	5,416	405	10,187
Other	2	139	([2])	1
Total	9,011	300,052	12,937	333,891
Other phosphate rock:[1]				
Belgium-Luxembourg	11	314	83	2,048
Brazil	64	2,068	15	363
Canada	674	18,402	613	16,102
France	31	620	8	231
Germany, Federal Republic of	80	1,568	38	800
Guyana	1	56	1	83
Mexico	([2])	3	1	28
Netherlands	33	1,647	--	--
Poland	29	804	--	--
Romania	58	1,845	307	8,359
Spain	--	--	8	129
United Kingdom	--	--	3	75
Other	2	31	([2])	114
Total	983	27,358	1,077	28,332
Grand total	9,994	327,410	14,014	362,223

[1]Includes colloidal and sintered matrix, Tennessee, Idaho, Montana, and soft phosphate rock.
[2]Less than 1/2 unit.

Table 12.—U.S. exports of superphosphates, by country

(Thousand metric tons and thousand dollars)

Destination	1976		1977	
	Quantity	Value	Quantity	Value
Algeria	41	2,959	--	--
Argentina	4	352	14	1,259
Australia	6	634	10	922
Bangladesh	31	3,889	--	--
Belgium-Luxembourg	33	2,760	55	5,123
Brazil	369	30,365	359	33,022
Canada	50	4,928	60	5,700
Chile	83	7,466	68	5,729
Colombia	5	579	15	1,734
Costa Rica	8	803	7	644
Denmark	23	1,790	--	--
Dominican Republic	19	2,138	8	820
Egypt	--	--	10	1,011
Finland	--	--	15	384
France	127	12,072	101	9,523
German Democratic Republic	4	413	--	--
Germany, Federal Republic of	97	9,941	88	8,119
Guyana	1	179	5	570
Hungary	133	13,638	86	8,502
Indonesia	--	--	51	5,436
Ireland	24	1,906	39	4,124
Italy	32	2,787	5	507
Jamaica	2	154	1	192
Japan	40	3,064	41	3,965
Kenya	--	--	15	1,416
Malaysia	--	--	2	215
Mexico	1	60	([1])	5
Netherlands	5	410	8	696
Niger	1	58	--	--
Panama	2	289	([1])	17
Peru	--	--	12	903
Poland	--	--	19	1,803
Portugal	([1])	4	5	391
Singapore	3	378	2	225
South Africa, Republic of	4	2	([1])	1
Spain	10	1,202	--	--
Taiwan	2	189	1	95
Thailand	2	127	3	224
Turkey	--	--	24	2,297
United Kingdom	4	404	4	417
Venezuela	1	215	2	214
Yugoslavia	39	4,069	44	3,914
Other	r4	r611	2	415
Total	1,210	110,835	1,181	110,534

rRevised.
[1]Less than 1/2 unit.

Table 13.—U.S. exports of diammonium phosphates, by country

(Thousand metric tons and thousand dollars)

Destination	1976		1977	
	Quantity	Value	Quantity	Value
Afghanistan	18	2,328	--	--
Algeria	14	1,327	--	--
Argentina	33	4,162	28	3,593
Australia	29	3,961	35	4,212
Belgium-Luxembourg	165	19,155	236	29,215
Brazil	324	36,564	430	56,106
Canada	113	13,849	133	16,479
Chile	4	476	--	--
Colombia	([1])	2	13	1,824
Costa Rica	20	2,648	27	2,840
Dominican Republic	11	1,646	17	2,063
Ecuador	--	--	4	626
El Salvador	43	5,056	45	5,274
Ethiopia	7	412	12	1,593
France	242	32,282	189	23,607
Germany, Federal Republic of	7	902	33	4,076
Guatemala	2	324	6	903
India	--	--	307	43,581
Iran	3	250	49	5,937
Ireland	12	1,230	34	4,635
Italy	385	49,305	311	41,727

See footnotes at end of table.

Table 13.—U.S. exports of diammonium phosphates, by country —Continued

(Thousand metric tons and thousand dollars)

Destination	1976		1977	
	Quantity	Value	Quantity	Value
Ivory Coast	8	990	10	1,171
Japan	140	17,168	135	17,041
Kenya	--	--	8	1,122
Malaysia	6	775	4	504
Mauritania	3	358	3	375
Mexico	(1)	2	22	2,671
Netherlands	--	--	9	1,270
New Zealand	15	1,892	9	1,148
Nicaragua	4	408	30	3,344
Pakistan	266	34,923	70	9,628
Peru	--	--	7	937
Portugal	7	879	12	1,520
Singapore	--	--	23	2,462
South Africa, Republic of	6	788	4	520
Spain	35	3,733	25	2,494
Switzerland	--	--	15	1,763
Taiwan	15	1,677	--	--
Thailand	11	1,890	34	3,450
Turkey	49	5,466	190	27,722
United Kingdom	20	4,388	2	192
Uruguay	50	5,724	45	6,089
Yugoslavia	111	12,295	--	--
Other	4	r620	15	2,169
Total	2,182	269,855	2,581	335,883

rRevised.
1Less than 1/2 unit.

Table 14.—U.S. exports of mixed chemical fertilizers, by country

(Thousand metric tons and thousand dollars)

Destination	1976		1977	
	Quantity	Value	Quantity	Value
Austria	2	147	(1)	26
Bahamas	5	792	5	897
Belgium-Luxembourg	18	1,718	(1)	3
Brazil	14	2,047	1	375
Canada	77	10,239	56	9,123
Dominican Republic	5	867	7	880
Ecuador	3	277	1	200
El Salvador	11	1,326	11	1,271
France	5	692	(1)	9
Germany, Federal Republic of	7	2,332	14	2,805
Ghana	10	1,197	--	--
Greece	(1)	122	1	331
Guatemala	8	1,279	5	1,037
Honduras	1	115	3	451
Japan	(1)	183	1	365
Kenya	--	--	3	453
Mexico	1	146	3	361
New Zealand	3	330	(1)	74
Nicaragua	1	216	2	596
Panama	5	699	1	191
Peru	(1)	100	2	112
Singapore	(1)	90	2	457
Sweden	15	1,418	--	--
Thailand	22	2,189	43	3,995
Venezuela	(1)	3	10	1,425
Other	6	r1,760	6	1,471
Total	219	30,284	177	26,908

rRevised.
1Less than 1/2 unit.

Table 15.—U.S. exports of elemental phosphorus, by country

Destination	1976		1977	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Australia	226	$311	214	$257
Belgium-Luxembourg	275	154	75	74
Brazil	3,041	3,470	2,630	2,860
Canada	4,476	4,761	2,222	2,485
Chile	3	1	4	3
Denmark	200	239	--	--
France	11	5	2	1
Germany, Federal Republic of	--	--	17	5
Israel	50	24	--	--
Italy	41	45	4	2
Japan	5,012	6,313	4,608	5,862
Mexico	12,908	14,993	8,042	9,036
Netherlands	40	20	10	5
Switzerland	14	7	34	32
United Kingdom	32	36	83	85
Other	8	8	9	15
Total	26,337	30,387	17,954	20,722

Table 16.—U.S. imports for consumption of phosphate rock and phosphatic materials

(Thousand metric tons and thousand dollars)

Fertilizer	1976		1977	
	Quantity	Value	Quantity	Value
Phosphates, crude and apatite[1]	r42	r2,209	158	6,079
Phosphatic fertilizers and fertilizer materials	43	6,631	54	5,095
Ammonium phosphates, used as fertilizers	r317	r44,250	338	39,331
Bone ash, bone dust, bone meal and bones ground, crude or steamed	3	689	5	945
Dicalcium phosphate	1	177	(2)	9
Basic slag	--	--	(2)	2
Manures including guano	(2)	17	(2)	2
Phosphorus	1	1,604	(2)	1,461
Phosphoric acid	(2)	149	1	175

rRevised.
[1]Adjusted by the U.S. Bureau of Mines.
[2]Less than 1/2 unit.

WORLD REVIEW

The downward trend in world production from 110 million metric tons in 1974 to 107 million in 1975 and 1976, was reversed in 1977. Estimated world production was 116 million metric tons. In addition to the increased demand for phosphate rock, it was estimated that world trade in phosphoric acid exceeded 1.5 million metric tons P_2O_5, a significant increase over 1.1 million tons P_2O_5 traded in 1976.

Brazil, India, and Colombia were the major markets for U.S. exports of phosphoric acid. Exports from Mexico declined in 1977 compared with those of 1976. Exports by Fertilizantes Fosfatados Mexicanos (FFM) from Coatzacoalcos were, for the most part, to India. Tunisian exports of acid declined in 1977 as domestic consumption of fertilizer and sodium tripolyphosphate increased and demand from Turkey, Tunisia's largest market, declined.

Morocco has become the second largest supplier of phosphoric acid, marketing acid from the OCP plants at Safi and marketing some of Fosforico Español S.A. (FESA) production at Huelva and acid from the Rouen plant of Azotes et Produits Chimiques (APC).

Exports from the Republic of South Africa have increased. Fedmis exported principally to Brazil and Iran. Triomf shipments were, for the most part, to Brazil and Japan.

Conversion of phosphate rock into phosphoric acid by countries basic in rock is a trend that is expected to become an increasing part of international trade in the next decade.

Both domestic and export demand for phosphate rock improved in the first half of 1977 and, with the momentum carrying through into the second half of the year, it was estimated that production reached 116 million metric tons in 1977, exceeding the record production of 1974. The principal difference between 1974 and 1977 was that in 1974 both phosphate rock and derived fertilizers were in part stockpiled, whereas in 1977 the phosphate rock production was directly consumed.

The principal events that occurred in the phophate industry in 1977 are discussed in the following listing of countries.

Algeria.—Another in the series of interesting chemical trades was the announcement that Algeria's National Mining Co. will supply 60,000 metric tons per year of phosphate rock to Finland's Kemira Oy and, in return, for the years 1977-79, Kemira Oy will ship Vicose fiber of equal value to Algeria. Kemira Oy's fertilizer production in the past was based on imported U.S.S.R. apatite. Kola apatite exports to Finland will terminate in 1979.[5]

The Brazilian national company, INTERBRAS, has contracted to purchase 150,000 to 200,000 metric tons of phosphate rock from Algeria. The Algerian mining company, SONAREM, will supply the contract over a 2-year period.[6]

Australia.—Queensland Phosphate Ltd., a subsidiary of Broken Hill South, cut production of phosphate rock from the Duchess mine to a rate of 350,000 metric tons per year in 1977. The design capacity of the mine was to be 1 million tons per year; however, with technical problems developing in domestic phosphoric acid plants that attempted to use Duchess rock instead of rock from Christmas, Nauru, and Ocean Islands, and with a drop in demand, the decision was made to reduce production and reduce the accumulated 200,000-ton stockpile.[7]

Brazil.—The three phosphate rock mines that were operating in Brazil have not been able to meet the demand that developed in the 1970's and, as a result, phosphate rock and phosphoric acid imports increased. In addition to the Jacupiranga mine and the smaller mines at Araxá and Serrote, Arafetil increased the capacity of the Araxá apatite mine to 600,000 metric tons per year in 1977. Scheduled for startup in 1979 is the Catalão mine in Goias that will produce 500,000 metric tons per year. This mine is being financed by Brasimet and Agrico Chemical Co. The Valep mine at Tapira is scheduled to produce 900,000 metric tons of concentrates annually starting in mid-1978.[8]

China, People's Republic of.—The Commercial Division, Canadian Embassy in Peking reported on May 24, 1977, that the Geological Bureau of Shantung Province, east China, located more than 300 sites of phosphorus ore in 59 counties. It was indicated that 150 small mines have been activated and 90 additional mines are planned. An unconfirmed source reported that a large phosphate rock deposit was found at Fanshan in Chonsien County, Hopei Province, northern China. If this find is utilized, the dependence of the Province on phosphate rock from Hunan and Kwiechow Provinces can be terminated.

Egypt.—The Red Sea Phosphate Co. reported that the El Shugaila mine on the Red Sea coast started producing in mid-1977. Reported reserves are 46 million metric tons and, if the mine operates for the projected 30 years, the capacity will be about 1.5 million tons per year.[9]

The new Hamrawein phosphate mine on the Red Sea coast, a Romanian economic assistance project, is not scheduled to attain full production before mid-1978. If negotiations are successful, the reported capacity of 600,000 metric tons per year may be exported to the People's Republic of China.[10]

NASR Phosphate, which produces 300,000 metric tons annually from the Mahamid phosphate deposits in northern Egypt, plans to increase production to 600,000 metric tons per year if development assistance can be obtained from the United States.[11]

Finland.—Kemira Oy, the country's largest chemical and fertilizer company, operated a 10-ton-per-hour pilot plant at Siilinjarvi near Kuopio, eastern Finland. The pilot plant was designed to concentrate a 10%-P_2O_5 apatite deposit that is 15 kilometers long and 600 meters wide. The depth of the deposit is greater than 800 meters. Concentrates have been produced analyzing 33% P_2O_5 that are satisfactory for producing phosphoric acid and compound fertilizers.[12]

Rautaruukki Oy plans a pilot plant to determine the feasibility of concentrating phosphate minerals from the Sobli ore deposit in eastern Lapland. The pilot plant was scheduled to start operating in mid-1978, and the studies will be made during an 18-month period.[13]

It is unlikely that commercial production from either the Siilinjarvi or Sobli deposits will occur for several years because of uncompleted research programs, the declining price of phosphate rock in international markets, and Finland's tight domestic monetary situation.[14]

Table 17.— Phosphate rock: World production, by country

(Thousand metric tons)

Country[1]	1975	1976	1977[p]
Phosphate rock:			
Algeria	[r]707	820	1,055
Australia	[r]124	258	485
Brazil	406	490	605
China, People's Republic of[e]	3,400	3,750	4,100
Christmas Island (Indian Ocean)	1,391	1,033	1,186
Colombia	13	10	[e]10
Egypt	[r]536	443	581
France	18	18	28
Germany, Federal Republic of	81	86	65
India	459	682	[e]750
Israel	882	639	1,232
Jordan	[r]1,352	1,717	1,781
Korea, North[e]	450	450	500
Mexico	282	224	200
Morocco	13,548	15,656	17,027
Nauru	1,534	755	1,146
Netherlands Antilles (Curacao)	82	54	79
Ocean Island	516	417	416
Peru	--	2	--
Philippines	5	12	[e]12
Rhodesia, Southern	130	130	140
Senegal	1,801	1,799	1,869
South Africa, Republic of[2]	1,646	1,702	2,403
Spanish Sahara[3]	[r]2,682	173	232
Sweden[4]	30	25	50
Syria	857	511	425
Togo	1,161	2,009	2,857
Tunisia	[r]3,481	3,294	3,614
Uganda[e]	15	15	5
U.S.S.R.[e 5]	24,150	24,200	24,200
United States	[r]44,276	44,662	47,256
Venezuela	116	80	139
Vietnam[e]	1,400	1,500	1,500
Total	107,531	107,616	115,948
Guano:			
Argentina	1	--	--
Chile	14	16	[e]16
Philippines	126	2	[e]2
Seychelles Islands[6]	[e]6	6	[e]6
Total	147	24	24

[e]Estimate. [p]Preliminary. [r]Revised.

[1]In addition to the countries listed, Belgium, Indonesia, and Tanzania may have produced phosphate rock, and the Territory of South-West Africa produced guano, but output is not officially reported and available information is inadequate for formulation of reliable estimates of output levels.

[2]Total of local sales and exports of phosphate concentrates and direct-sale ore.

[3]Effective December 31, 1975, this area ceased to be a territory of Spain, being officially administered thereafter by Mauritania and Morocco; production is still reported under the the title "Spanish Sahara" to provide for statistical continuity until decisions are finalized regarding the status of the phosphate mine area.

[4]As reported by International Superphosphate Manufacturer's Association; official Swedish statistics show no production of phosphate rock, but do indicate output of phosphatic slag from steel plants (Thomas slag).

[5]Estimate by International Superphosphate Manufacturer's Association on the basis of a marketable product averaging 34.8% P_2O_5; differs with data reported in the U.S.S.R. chapter of Volume III of the Minerals Yearbook, which are reported in terms of two products of differing grade.

[6]Exports.

Iraq.—As part of an order for a complete fertilizer complex, the State Organization for Minerals will receive a phosphate rock beneficiation plant designed to treat 3.4 million metric tons of ore annually. The complex is scheduled for completion in 1981. The beneficiation plant will receive ore analyzing 21% P_2O_5 and, after crushing, screening, calcining, slaking, and washing, produce a concentrate for the fertilizer complex. The ore will be crushed and screened to minus 16 millimeters. Two rotary kilns, 6.6 and 6.0 meters in diameter and 175 meters long, will be used to calcine the 16 millimeter feed. The cooled calcine will be slaked, washed, and centrifuged before shipping or stockpiling.

Jordan.—The plans of the Jordan Phosphate Mines Co. to increase capacity of phosphate rock plants and the infrastructure to export 3 million metric tons in 1977 were not met. Only 1.7 to 1.8 million tons were exported and, with constraints remaining, 1978 capacity will probably not exceed 2.75 million metric tons.

Mexico.—The Government purchased Fertilizantes Fosfatados Mexicanos (FFM) for approximately $110 million. Guanos y Fertilizantes (Guanomex), the Government-owned company, will act as director of the merged FFM and Guanomex.[15]

The phosphate rock deposits and beach sands in Baja California have been studied since the 1950's. Between 1974 and 1976, an outcropping of phosphate rock near the village of San Hilario was intensely explored. Although the exploration program identified an estimated 330 million tons with an average P_2O_5 content of 12.6%, the resource was not considered economically attractive because of low grade and unfavorable beneficiation characteristics, the cost of an infrastructure to move a product out of the area, and unfavorable mining conditions.

A favorable deposit on La Paz Bay, about 60 kilometers north of the City of La Paz, has been drilled. The zone, called San Juan de la Costa, includes the "Humboldt" and "Del Rio" strata, which have been identified as economically attractive to mine. These two strata, if mined at a combined rate of 1.6 million tons per year, would yield 700,000 tons per year of 30% P_2O_5 concentrates. A reserve of 12 million tons can be mined from the surface. The quantity available, if underground mining is considered, has not been established. Production at capacity is planned for 1980-81.[16]

Morocco.—The OCP awarded contracts in mid-1977 to construct Maroc Phosphore 2 at Safi. Maroc Phosphore 2 will consist of three 1,700-ton-per-day sulfuric acid plants and three 500-ton-per-day phosphoric acid plants. The phosphate rock for this new facility will be supplied by the new Ben Guerir mine.[17]

In 1976, Maroc Phosphore 1 became fully operational. Maroc Phosphore 1 consists of three 1,500-ton-per-day sulfuric acid plants, three 500-ton-per-day phosphoric acid plants, and two 600-ton-per-day monoammonium phosphate plants. At Maroc Phosphore 1, about one-third of the phosphoric acid production is used to produce monoammonium phosphate; the balance is exported. All of the phosphoric acid production from Maroc Phosphore 2 will be exported after its scheduled startup in August 1980. These developments confirm OCP's intention to convert at least one-third of Morocco's phosphate rock production to intermediate products prior to export. It is estimated, therefore, that Morocco will be able to export about 1.5 million tons per year of phosphoric acid after 1980.

Reports during 1977 of an agreement between the Governments of Morocco and the U.S.S.R. indicate that an agreement was reached to barter Moroccan rock for Soviet oil and for U.S.S.R. financial and technical assistance to develop a new phosphate mine in the Meskala region, south of Marrakech. It was understood that shipments of phosphate rock could start in 1978 and increase to 10 million metric tons near the end of the century. Shipments of rock would be made from Casablanca until the Meskala development, planned to be completed in the mid-1980's or after 1990, would participate in the supply of rock to the U.S.S.R.[18]

Sahara.—Production from the Bu-Craa mine in the former Spanish Sahara, which was awarded to Morocco and Mauritania by the Spanish Government, was negligible in 1977. Much of the installations required to move the ore from the mine to the port of El Aauin was destroyed by the local independence movement identified as the "Polisario Front." The 110-kilometer conveyor belt was not repaired during the year, and movement of ore by trucks was not feasible. For the second year, the Bu-Craa mine did not produce and contribute to world supply.[19]

Senegal.—Reserves of 50 million metric tons of recoverable calcium phosphate have been identified in the Tobene deposit, located approximately 80 kilometers north of Dakar. The Tobene deposit is adjacent to the Taiba deposit that is currently mined. Production from Taiba is about 1.5 million tons per year of concentrates. If the Government increases production to 2 million tons per year, the Taiba deposit will be depleted in about 10 years. It is probable that the Tobene deposit will be developed near the end of mining and processing Taiba ore to utilize the infrastructure, equipment, and personnel that will become available.[20]

South Africa, Republic of.— The French shipping and marketing group Gazocean backed out of the contract with Triomf Fertilizer of South Africa to market phosphoric acid. Triomf agreed to release Gazocean from its agreement for $35 million. The phosphoric acid will be marketed by Phillipp Brothers of the United States. Phosphoric acid from the recently completed plant on Richards Bay was shipped to Brazil in mid-February, inaugurating the first shipment of a 10-year arrangement with Gazocean. Gazocean had two phosphoric acid vessels under construction, which were acquired by Triomf on long-term time charter.[21]

Syria.—Phosphate rock is mined from three deposits near Palmyra in central Syria. The capacity of the plant, constructed with Romanian, Polish, and Bulgarian assistance, is 2 million tons per year. The rock is trucked to Tartous for export. A railway from the phosphate deposits to Tartous is scheduled for completion in the 1980's. The ore is high in clorine (0.15% to 0.25%) and must be washed and dried before shipping. Production in 1977 was about 500,000 metric tons.[22]

Togo.—Phosphates are Togo's largest export. In 1974, when the international price of phosphate rock abruptly increased, phosphate rock export revenues reached $139.7 million, equal to three-quarters of the country's export receipts in that year. Phosphate receipts were two-thirds of the export receipts in 1975 and about one-half in 1976 as prices declined in those years. The mine has been expanded with the expectation of exporting close to 3 million metric tons of phosphate rock in 1977. A feasibility study was completed for a phosphoric acid plant and fertilizer complex that would use one-third of Togo's annual phosphate rock production. Financing has not been arranged.[23]

Tunisia.—Compagnie des Phosphates de Gafsa (CPG) revised its future plans for production and processing phosphate rock. Production in 1973, 1974, 1975, and 1976 was 3.47, 3.90, 3.48, and 3.29 million metric tons, respectively. The present plan is to produce 6.6 million tons by 1980 and 7 million tons by 1981. The increase in production will be accomplished by increasing the capacities of mines in the Gafsa Basin. Production from Kalaa Djerda will remain at 240,000 tons per year through 1981.

In the Gafsa Basin, production from the beneficiation plants at Metlaoui will be increased by adding to the concentrates from Metlaoui ore from the open pit Kef es Schfair mine and concentrating in a new washing plant. With four washing plants at Metlaoui, the beneficiation capacity will exceed mining capacities of Metlaoui and Kef es Schfair combined. A new washing plant is scheduled in 1979 to receive ore from the M'rata underground mine. The washer will be located at the Moulares mine and supplement the two air separation plants at this mine. The M'rata mine is scheduled to increase production to 1 million metric tons per year by 1980. Moulares, with M'rata ore, will be producing 1.3 million metric tons per year by 1981. The Redeyf mine has two air separation plants and is not expected to produce more than 1 million metric tons per year before 1981. The air separation and washing plants at the M'dilla mine will be supplemented with a new washing plant. By 1981, the M'dilla concentration plants will be producing 1 million metric tons per year. At the Sehib mine, the decision to mine with a continuous longwall machine, room and pillar, or open pit will be made in 1978. It is probable that longwall mining will be selected. The beneficiation plant of the mine is scheduled for completion in 1979 and will be able by 1981 to process 2 million metric tons of ore to produce about 1.5 million metric tons of 65% to 68% BPL concentrates. By 1981, if all of the programs are completed, CPG will have a capacity of 7 million metric tons of concentrates.[24]

U.S.S.R.—There are indications that, because of diminishing reserves of apatite in the Kola peninsula and high magnesium levels in the concentrates produced from the Kovdor mining and beneficiation complex, it may be necessary for the Soviets to blend Kovdor apatite with concentrates from the Apatite combine, U.S.S.R.'s main source of high-purity phosphate, to maintain production of fertilizer.[25]

From the Kola Peninsula, the estimated 1976 production of phosphate ore was 37 million metric tons, analyzing 17.7% P_2O_5, and 34 million metric tons of sedimentary rock averaging 13% P_2O_5 from Karatau in Kazakstan. Deposits of phosphorite also occur in Upper Kama in the Urals, Egor'evsk and Lopatino in Moscow Oblast', Kingisepp in Leningrad Oblast', and in other regions, but the P_2O_5 levels are low. A phosphorite, ground-rock flour, is produced that assays about 19% P_2O_5, and used in direct applications.

The Khibney apatite nepheline Kola deposits represent the U.S.S.R.'s largest single phosphate source. Mined ore averages 16% to 21% P_2O_5 and is beneficiated to 39.4% P_2O_5 with 92% P_2O_5 recovery. The apatite complex produced an estimated 15.9 million metric tons of concentrates in 1976 from one open pit and three underground mines. In 1976, the first stage of the Yukspor mine, with an annual capacity of 0.9 million tons of apatite ore, was commissioned, and the 27th section of the beneficiation plant, designed to produce 230,000 tons per year of concentrates, was completed.

A new apatite mine, the Koashva, located at Mount Koashva, was under development in 1976. The first stage of the mine will be completed in 1978 and linked to Kirovsk by rail. When completed, the mine will have an annual output of 7 million tons of ore.

Construction of an experimental beneficiation plant continued through 1977 at the Zabaykal'sk complex in Buryat, U.S.S.R. When completed, the mill will test and produce an apatite concentrate from the Oshuskovo deposit. Although reserves are large, the ore analyzes only 4% P_2O_5. If successful, a Zabaykal'sk apatite complex will be constructed that would produce 1.3 to 1.5 million tons of concentrates after 1980.

In 1975, an apatite-concentrating plant was constructed at the Kovdor iron ore plant in the Kola Peninsula. The first stage, commissioned in 1975 and designed to recover apatite from the iron ore beneficiation plant tailings, was to have an annual capacity of 800,000 tons of ore. The second stage of equal capacity was constructed in 1976.

In summary, by 1980 the U.S.S.R. plans to produce 18.2 million tons of concentrates at the Apatit Association and 1.38 million tons at the Kovdor mining and concentration complex.

The 45 commercial deposits in the Karatau area of Kozabhstan contain an estimated 1,500 million tons of minable phosphate ore. The five largest deposits, the Dzhantas, Aksay, Chulaktau, Koksu, and Kokdzhone, contain more than half the total reserves.

Seven open pits at the Aksay and Dzhantas deposits and the Molodezhnyy underground mine at the Chulaktau deposit produced an estimated 9.6 million tons of ore in 1976. About 6.7 million tons came from the Dzhantas deposit. The ore analyzed 21% to 25% P_2O_5 and was concentrated to 28.5% P_2O_5 with low P_2O_5 recovery. In early 1977, new facilities to mine 1.7 million tons per year and produce 0.65 million tons per year of marketable phosphate rock were started at the Tsentral'nyy mine. Between 1977 and 1980, the U.S.S.R. plans to open the Kok-Dzhon mine to produce 4.75 million tons per year of ore, the T'esay mine to produce 2 million tons per year, and the Kod-Su, Ur-Bas, Geres, Kis-Tas and others with smaller capacities. By 1980, the Karatau area will mine about 20 million tons of ore and produce 13 million tons of marketable phosphate rock.[26]

TECHNOLOGY

One of the principal outlets for fluorine recovered from phosphate processing now appears to be restricted as concern increased in 1977 regarding the effect of chlorofluorocarbons that diffuse into the stratosphere and enter into photochemically initiated reactions that reduce the natural ozone concentration below its current equilibrium level. In all probability, bans on nonessential uses of chlorofluorocarbon propellants will be established by the U.S. Food and Drug Administration for aerosol consumer products such as deodorants, hair sprays, cosmetics, and food products that contain fluorocarbons 11, 12, and 114. The reason for the curb on fluorocarbons is to maintain ozone concentrations that protect terrestrial life from solar radiation and maintain the overall pattern of world climate in the lower atmosphere. In phase two of the plan to reduce fluorocarbon use and reduce depletion of ozone in the stratosphere, regulatory agencies are considering banning fluorocarbons in refrigeration and air conditioning units and blowing agents used to produce plastic foams. If this proposal is implemented, serious problems will develop because there are no satisfactory substitutes, particularly in the field of refrigerants because the alternatives for ammonia, methyl chloride and sulfur dioxide, are highly toxic and flammable.

The growing interest in recovering uranium oxide from phosphoric acid is undoubtedly caused by recent increases in the selling price of yellowcake and projections for higher prices in future years. Apart from being economically attractive, uranium recovery from phosphoric acid would help to eliminate any potential environmental or health problem that may be identified from using uranium-bearing phosphoric acid in fertilizer production and consumption. Uranium Recovery Corp. is currently recovering uranium oxide from W. R. Grace's phosphoric acid plant in Polk County, Fla. Wyoming Minerals Corp., a subsidiary of Westinghouse Electric Corp., has a contract to construct a uranium recovery plant at Farmland Industries' phosphoric acid plant in Florida. Freeport Minerals is constructing a recovery plant in Louisiana, and Gardinier, Inc., is constructing a recovery plant south of Tampa, Fla. Oak Ridge National Laboratory, Tennessee, has developed two processes to recover the uranium content of filter-grade (32% P_2O_5) phosphoric acid. The DEPA-TOPA process involves reductive stripping with a mixture of di (2-ethylhexyl) phosphoric acid (DEPA) and trioctylphosphine oxide (TOPO); the other process, the OPAP process, is an oxidative technique, which uses a mixture of mono- and di-octyl-phenyl phosphoric acid.

A new process to recover uranium from phosphoric acid has been developed by the Japanese Power Reactor and Nuclear Fuel Corp. and demonstrated on an experimental scale. The details of the solvent extraction process have not been published, and there is no indication that the problem of solvent residues in the treated phosphoric acid that have occurred in similar systems are a problem for this process.[27]

A process for purifying wet-process phosphoric acid that was developed by Société Azote et Produits Chimique, Toulouse, France, approximately 5 years ago is now being marketed by the Luwa Corp., Charlotte, N.C. The Phorex process is a solvent extraction system that uses isobutanol.

In the United States, reductions in the amount of phosphorus in detergents and attempts to find satisfactory alternatives to phosphorus detergent builders have been well publicized during this year. Several States and some cities have banned phosphates from detergents used in domestic laundry products. The level of phosphates in the Great Lakes, according to the Environmental Protection Agency (EPA), could be significantly reduced if phosphate detergents were banned from States around the Great Lakes. An amendment to the Clean Water Bill that would ban phosphates from detergents sold in these States is before the Congress. FMC Corp., a manufacturer of elemental phosphorus in Idaho, estimates that, of the total phosphorus entering the Great Lakes, 10% is from detergents, 60% is from fertilizer runoff, 15% is from atmospheric sources, and the balance is from sewage; a reduction in phosphate detergents would not, therefore, significantly improve the quality of water in the Lakes. The National Resource Commission of Michigan banned phosphate detergents, and a law suit was filed by the Soap and Detergent Association contesting the legality of the ban. It has been suggested that it would be more feasible to treat waste water to remove phosphates rather than attempt to use alternative, but less efficient, detergents with the risk of higher costs to the consumer. The amendment, if passed by Congress, will also require EPA to investigate the feasibility of introducing a national ban on phosphate detergents. EPA has included phosphates on a list of chemicals scheduled for investigation under the Toxic Substances Controls Act. Over the past decade, world production of sodium tripolyphosphate has declined about 40%. Proctor and Gamble, the largest producer of sodium tripolyphosphate, has developed a synthetic zeolite builder and plans to reduce the phosphorus content in detergents to 2% or 3%. In the Netherlands, Akzo-Zout Chimie plans large-scale tests for NAS, a synthetic zeolite produced from sand, soda ash, caustic soda, and alumina.

At the Bureau of Mines Albany Metallurgy Research Center, characterization and beneficiation tests were conducted on a wide variety of phosphatic materials from Idaho, Montana, Utah, and Wyoming. A sample of Gay mine phosphatic shale was tested in a 27-kilogram-per-hour flotation unit to study the applicability of a combination carbonate-silica flotation process to a mixed altered-unaltered ore. Samples of Utah phosphate ore containing pyrite were successfully beneficiated using a sulfide-carbonate-silica flotation system. Flotation tests were conducted to study the selectivity of sulfosuccinate reagents (Aerosol 18 and Aero promoter 845) as collectors for magnesium-bearing minerals. The indications were that these reagents were selective for floating magnesium-calcium carbonate minerals from a relatively coarse and well-deslimed pulp, but were nonselective for flotation of finely ground material. To determine if the weathering of unaltered phosphate ores could be accelerated, 30-day heap leaching tests were conducted using dilute solutions of acid, salts, and bases. Only minor effects were observed. To further attempt liberation of phosphate pellets from unaltered ores, ores were attrition-milled and ground in dilute acid. Neither liberation nor flotation test results were improved by the acid pretreatment.

Testing a phosphoric acid acidulation-defluorination method continued with emphasis on making large monocalcium phosphate crystals. Operating temperatures between 160° and 170° C and separation of the crystals from the mother liquor within an hour after discharge from the reactor gave crystal recoveries of 55% with recycled acid. A series of tests was conducted, using reagent grade phosphoric acid as the acidulant. Although foaming was a problem, crystal recoveries of 83% to 96% were obtained.

Vanadium was recovered from Western phosphate slime tailings by sulfuric acid leaching followed by liquid-liquid extraction of the leach solution. A single-stage leach to dissolve both phosphate and vanadium gave good solubilization of both values. Two-stage leaching to selectively remove phosphate prior to vanadium solubilization was found to be unnecessary. Salt (NaCl) roasting was tried but not continued because it solubilizes silicon, which interferes with extraction of vanadium from the leach solution. Vanadium was extracted with equivalent efficiency from phosphoric, sulfuric, and mixed acid solutions with a 6% mixture of LIX63 in Napoleum 470. Chromium and uranium were not extracted to any significant extent. Stripping of vanadium from the extract was accomplished with either sodium hydroxide or ammoniacal sodium carbonate solutions.

An improved fluorspar substitute was made when limestone ($CaCo_3$) was used instead of hydrated lime ($Ca(OH)_2$) for precipitating calcium fluoride (CaF_2) from fluosilicic acid. These precipitates generally showed fluorine losses between 5% and 10% when heated to 1,000°C; materials made at the lower pH values showed lower fluorine losses. Limestone reduced silica content in the product to around 1% rather than the 10% to 15% found when lime was the neutralizing agent. The silica suspension left in the filtrate, following separation of the CaF_2 product, was precipitated with ammonia, leaving a final filtrate containing Ca, F, and SiO_2 at 0.04, 0.08, and 0.01 grams per liter, respectively.

Bench-scale continuous-circuit studies were made on the conversion of fluosilicic acid to CaF_2. Greater reactor retention times gave slightly better fluorine recovery. Lower pH, down to 3.0, and smaller limestone particle sizes increased fluorine content of the CaF_2 product and improved fluorine retention when the product was heated to 1,000°C.

Removal of fluorine from freshly mixed triple superphosphate was investigated in batch and continuous rotary kiln operations.

Studies to determine the feasibility of direct acidulation of Florida land pebble matrix with sulfuric acid were continued to attempt to improve phosphate recovery and reduce the problem of slime disposal associated with conventional Florida washing and flotation processes. During 1977, digestion results and filtration rates were obtained on four central Florida matrices ranging in grade from about 12% to 18% P_2O_5. Large gypsum crystals were grown from all matrices tested, and all filter cakes had a sandy, nonthixotropic texture.

A technique of dry-attritioning a phosphate matrix was followed by air classifying to remove a part of the clay and other fine gangue. The air-classified coarse product, when digested, yielded filtration rates about double that of the unclassified material for each matrix tested. The treatment resulted in an overall loss in phosphate recovery from the matrix of 12% to 14%.

A sample of calcined Fort Hall mill shale from Idaho (21.4% P_2O_5), treated by the same direct sulfuric acid (H_2SO_4) digestion technique that had been applied to Florida matrix, yielded approximately 95% recovery of P_2O_5 in the product acid with a filtration rate of 3,662 kilograms per square meter per day.

In acid purification studies oriented primarily toward lowering levels of iron and aluminum in matrix-derived acid, liquid-liquid extraction using octyl-phenyl phosphoric acid was found to be the method of choice after evaluating several other phosphoric esters and extractants of other classifications. Bench-scale tests carried out in separatory funnels showed that the octyl-phenyl ester (OPPA) in kerosine extracted about two-thirds of the aluminum, most of the iron, and one-third of the magnesium. Reagent regeneration was accomplished with a two-step treatment with hydrochloric acid (HCl); stripping with other reagents has been ineffective to date.

The Bureau of Mines Tuscaloosa Metallurgy Research Center conducted programs to develop or improve beneficiation procedures to recover phosphate from low-grade phosphate-bearing ore from Hardee and DeSoto counties in Florida. Drill core samples of the Hawthorn Formation containing more than 5% P_2O_5 were processed by grinding, desliming, thickening the pulp, and conditioning. Rougher and cleaner flotation circuits produced concentrates that ranged from 22.5% to 32.1% P_2O_5 and MgO levels from 2.6% to 0.89%, respectively.

Investigations continued on the effectiveness of organic and inorganic reagents on the settling and dewatering characteristics of Florida phosphate slimes. Polyethylene oxide (PEO) was found to be unusually effective. Various types of equipment were used to develop a continuous method to dewater phosphate slimes. These were a rotating trommel screen, a vibrating screen, a screw classifier, and curved static screens. When slime and reagent were mixed in a propellar-agitator conditioner and fed to a rotating trommel screen, the percent solids in the slime was increased from 5% to the range of from 25% to 30% using 1.1 kilograms PEO per metric ton of dry slime solids. Lesser concentrations of PEO were found effective with higher retention times in the trommel. Investigative work continued on the physical characteristics of flocs obtained by flocculating Florida phosphate slimes. Because of concern about the effect of recycled waters on flotation systems, particularly if they are waters containing flocculants, programs were initiated to develop procedures to purify waters for reuse. Preliminary evaluation of plant return water used in fatty acid flotation feed indicated it was less effective than supernatant water recovered from slime samples. Tolerance levels of PEO in flotation circuits appear to be higher in the return water than supernatant water recovered from slime. Further testing is planned to understand the effects of PEO on flotation.

The Florida Bureau of Geology supplied core samples obtained from reclaimed phosphate land. The samples were characterized for their size consist and P_2O_5 content by the Tuscaloosa Metallurgy Research Center, and head samples were submitted to the EPA, Montgomery, Ala., for radiometric analysis. The results of these analyses of core samples will be used to assist in identifying potentially hazardous environmental conditions in the Florida phosphate area.

Studies to determine the feasibility of recovering phosphate values from slimes were initiated. Selective flocculation studies using monanionic, cationic, and anionic polymers, gums, and starches did not show any significant concentration of the phosphate values in the slimes. Flotation tests on the total amount of slime did not successfully concentrate phosphate values. Flotation tests on the plus 5-micron fraction produced a high-grade concentrate. Studies will continue in order to learn how to concentrate phosphate values from the plus 5-micron slime fraction and dewater the minus 5 micron fraction.

---

[1]Physical scientist, Division of Nonmetallic Minerals.
[2]Federal Register. V. 42, No. 9, Jan. 13, 1977, p. 2706.
[3]Wilson, W. E. Simulated Changes in Ground-Water Levels Resulting From Proposed Phosphate Mining, West Central Florida—Preliminary Results. U.S. Geol. Survey Open File Rept. 77-882, 1978.
[4]Value, if sold, net selling price f.o.b. plant, or, if used, estimated value from comparable selling prices or a developed price; that is, cost plus overhead and profit.
[5]European Chemical News. Aug. 12, 1977, p. 8.
[6]Industrial Minerals. August 1977, p. 55.
[7]Industrial Minerals. September 1977, p. 9.
[8]Mining Journal. Nov. 18, 1977, pp. 411, 413.
[9]Industrial Minerals. August 1977, p. 57.
[10]U.S. Embassy, Cairo, Egypt. State Department Airgram A-120, June 14, 1977, p. 3.
[11]Work cited in footnote 6.
[12]European Chemical News. Mar. 25, 1977, p. 37.
[13]Industrial Minerals. August 1977, p. 9.
[14]U.S. Embassy, Helsinki, Finland. State Department Airgram A-28, Mar. 11, 1977, p. 5.
[15]Journal of Commerce. Aug. 15, 1977, p. 9.
[16]de la Pena p., L. General Description of Project for Exploitation and Beneficiation of Phosphate Rock of San Juan de la Costa, State of South Baja California, Mexico. Roca Fosforica Mexicana, S.A.
[17]Industrial Minerals. September 1977, p. 70.
[18]Mining Journal. Oct. 28, 1977, p. 351.
[19]Industrial Minerals. July 1977, p. 15.
[20]U.S. Embassy, Dakar, Senegal. State Department Airgram A-86, Nov. 14, 1977, p. 1.
[21]European Chemical News. Mar. 18, 1977, p. 12.
[22]U.S. Embassy, Damascus, Syria. State Department Airgram A-74, Nov. 15, 1977, p. 7.
[23]U.S. Embassy, Lome, Togo. State Department Airgram A-20, Aug. 4, 1977, pp. 6 and 7.
[24]Phosphorus & Potassium. No. 90, July-August 1977, pp. 21-24.
[25]Industrial Minerals. September 1977, p. 13.
[26]Bureau of Mines. Mineral Industries of the U.S.S.R. MP-2, July 1977, p. 17.
[27]Phosphorus & Potassium. No. 89, May-June 1977, pp. 52, 53.

Platinum-Group Metals

By James H. Jolly[1]

World mine production of the platinum-group metals increased 7% to an estimated 6.4 million troy ounces in 1977. The Republic of South Africa and the U.S.S.R. both had production increases, and together accounted for 92% of world production. Canada accounted for about 7% of world production, and the United States and six other countries for less than 1%.

World consumption of platinum-group metals was at about the same level as in 1976. A decline in platinum consumption by the Japanese jewelry industry, which consumes about 25% of the world platinum output, was offset in part by increased usage of platinum in automobile emission control catalysts. Despite increased U.S. automobile production in 1977, producers' sales of both platinum and palladium to the industry declined, owing mainly to consumption of stocks accumulated in 1976. Low prices and weak demand for platinum prompted the world's largest producer of platinum, Rustenburg Platinum Mines Ltd., to begin in November a program to trim production in an effort to bring world supply and demand into closer balance. Producers' prices for the platinum-group metals were relatively steady in 1977, although late in the year the price for platinum increased owing mainly to improved demand and reduced supply from the U.S.S.R.

U.S. mine production, all derived as a byproduct of copper refining, dropped 9% compared with that of 1976, to 5,545 troy ounces, owing to reductions in copper production. Refinery output, produced almost entirely from secondary materials and including both toll and nontoll metal, was up slightly to 1.2 million troy ounces. Imports and exports of platinum-group metals were also slightly lower than in 1976. Reported sales were 1.6 million ounces, just slightly lower than in 1976.

Table 1.—Salient platinum-group metals[1] statistics

(Troy ounces)

	1973	1974	1975	1976	1977
United States:					
Mine production[2]	19,980	12,657	18,920	6,116	5,545
Value	$2,103,704	$1,932,203	$2,280,200	$464,527	$396,649
Refinery production:					
New metal	19,916	13,234	16,571	7,101	5,199
Secondary metal	265,901	325,216	270,101	215,355	195,219
Toll-refined metal	1,039,189	1,088,022	r1,175,468	869,664	1,005,023
Total refined metal	1,325,006	1,426,472	r1,462,140	1,092,120	1,205,441
Exports (except manufactured goods)	627,526	835,754	659,885	512,407	426,631
Imports for consumption	2,504,181	3,251,311	1,820,284	2,667,059	2,510,374
Stocks Dec. 31: Refiner, importer, dealer	1,033,124	1,121,806	849,210	1,085,703	1,012,812
Consumption (sales)	1,833,901	1,981,010	1,308,717	1,603,077	1,592,277
World: Production	5,232,149	5,769,239	5,713,660	r5,978,541	6,385,902

rRevised.
[1]The platinum group comprises six metals: Platinum, palladium, iridium, osmium, rhodium, and ruthenium.
[2]Recovered from platinum placers and as byproducts of copper refining.

Legislation and Government Programs.—U.S. Government inventories of platinum, palladium, and iridium remained unchanged in 1977. The quantities, in troy ounces, held in the Federal stockpile and the goals (objectives) at yearend were as follows:

	Goal	Inventory
Platinum	1,314,000	452,645
Palladium	2,450,000	1,254,994
Iridium	97,761	17,002

Congress amended the Clean Air Act establishing emission standards for 1978 and subsequent automobile model years. The legislation kept the 1978 and 1979 standards at the 1977 model year level but set more stringent standards for 1980 and 1981. The new emission standards for hydrocarbons (HC), carbon monoxide (CO), and nitrogen oxides (NO_x), in grams per mile, were as follows:

Model year	HC	CO	NO_x
1978 and 1979	1.5	15	2
1980	.41	7	2
1981 and subsequent years	.41	3.4	1

The Environmental Protection Agency can grant a 2-year waiver on the final CO standard.

DOMESTIC PRODUCTION

Domestic mine production of platinum-group metals in 1977 was 5,545 troy ounces, 9% less than in 1976. All of the output was recovered from anode slimes produced in the electrolytic refining of copper from Western States. U.S. refinery production, including toll-refined metal, was 1.2 million troy ounces. Of this, 99% was secondary metal. Secondary metal refined on a nontoll basis fell 9% to 195,219 troy ounces in 1977, whereas toll-refined secondary metal increased 17%, reaching 1,003,940 troy ounces. Refined primary metal production totaled 6,282 troy ounces, most of which was of domestic origin.

The Johns-Manville Corp. continued exploration and development of its platinum-palladium claims in the Stillwater Complex, Montana, but at yearend had not announced plans to mine the deposit. Evaluation of drilling done in the 1977 field season indicated significantly higher platinum-group mineralization along an 18,000-foot strike length west of the West Fork Adit area. The new zone averaged 0.65 troy ounce of platinum-palladium per ton across a 7-foot width. Minor values of nickel and copper were also present. Previous work in other areas along the 24-mile-long mineralized horizon had indicated an average platinum-palladium content of 0.43 troy ounce per ton. The platinum-to-palladium ratio in most samples investigated remained about 1 to 3.5.

Amax Explorations Inc. continued exploration at its Minnamax copper-nickel-platinum-group metal project near Babbitt, Minn. Mine evaluation was expected to continue through 1981, and if the evaluation is favorable, production could result by 1985. The Bureau of Mines and other research groups were testing bulk ore samples and developing processes for the recovery of platinum-group metals, copper, and nickel.

A map and list of reported occurrences of platinum-group metals in the conterminous United States was published by the U.S. Geological Survey in 1977.[2]

Table 2.—Platinum-group metals refined in the United States

(Troy ounces)

Year	Platinum	Palladium	Iridium	Osmium	Rhodium	Ruthenium	Total
PRIMARY METAL							
Nontoll-refined:							
1973	5,560	13,121	957	176	88	14	19,916
1974	4,103	8,634	381	72	38	6	13,234
1975	5,292	10,968	236	44	28	3	16,571
1976	2,748	4,025	244	45	35	4	7,101
1977	831	4,300	52	9	6	1	5,199
Toll-refined:							
1973	32,883	3,972	1,158	102	381	70	38,566
1974	16,293	2,784	742	96	185	7	20,107
1975	14,619	2,002	373	15	164	1	17,174
1976	8,676	1,063	355	39	95	4	10,232
1977	466	610	4	--	3	--	1,083
SECONDARY METAL							
Nontoll-refined:							
1973	94,884	150,019	6,785	20	11,561	2,632	265,901
1974	95,999	213,416	3,494	6	11,127	1,174	325,216
1975	103,623	149,552	2,300	44	13,683	899	270,101
1976	64,901	134,747	3,921	10	8,058	3,718	215,355
1977	50,838	134,086	1,442	12	5,011	3,830	195,219
Toll-refined:							
1973	581,005	373,396	3,395	1,292	36,865	4,670	1,000,623
1974	654,156	365,779	3,465	1,447	36,196	6,872	1,067,915
1975[r]	635,148	437,809	9,793	1,514	49,063	24,967	1,158,294
1976	494,069	311,000	6,507	1,429	34,035	12,392	859,432
1977	620,848	327,450	4,970	1,955	42,178	6,539	1,003,940
1977 TOTALS							
Total primary refined	1,297	4,910	56	9	9	1	6,282
Total secondary refined	671,686	461,536	6,412	1,967	47,189	10,369	1,199,159
Grand total refined	672,983	466,446	6,468	1,976	47,198	10,370	1,205,441

[r]Revised.

CONSUMPTION AND USES

Reported sales of the platinum-group metals to U.S. industry totaled 1.6 million troy ounces in 1977. The automotive industry was the largest purchaser, accounting for 30% of total purchases, followed by the electrical industry (22%), the chemical industry (17%), the dental-medical industry (9%), the petroleum industry (6%), the glass industry (5%), and other industries (11%). Compared with 1976 levels, sales of the whole group in 1977 were down slightly. As shown in table 3, platinum accounted for almost 50% of sales, followed by palladium (44%), rhodium (3%), ruthenium (2%), iridium (1%), and osmium (less than 1%). In addition to the above sales, more than 1 million troy ounces was recycled on a toll basis for reuse by the various industries, mainly the chemical and petroleum industries.

The principal domestic uses of platinum-group metals in 1977 were as catalysts to control automobile exhaust emissions, reforming catalysts to upgrade the octane rating of gasolines, catalysts to produce acids and organic chemicals, electrical contacts and relays primarily for use in telephone systems, bushings for glass fiber manufacture, and dental alloys for orthodontic and prosthodontic devices.

Table 3.—Platinum-group metals[1] sold to consuming industries in the United States

(Troy ounces)

Year and industry	Platinum	Palladium	Iridium	Osmium	Rhodium	Ruthenium	Total
1973	658,533	1,012,484	30,676	1,629	73,515	57,064	1,833,901
1974	943,689	886,063	22,778	1,723	61,602	65,155	1,981,010
1975	698,553	541,548	9,143	1,084	36,848	21,541	1,308,717
1976:							
Automotive	480,965	194,496	--	--	391	--	675,852
Chemical	83,560	128,229	1,351	66	19,225	5,834	238,265
Dental and medical	26,858	139,279	233	729	75	140	167,314
Electrical	89,319	152,312	6,368	--	9,062	29,728	286,789
Glass	41,683	2,989	288	--	3,828	93	48,881
Jewelry and decorative	23,371	5,700	1,024	--	5,170	2,942	38,207
Petroleum	59,103	7,291	395	--	1	--	66,790
Miscellaneous	46,246	26,766	458	2	3,123	4,384	80,979
Total	851,105	657,062	10,117	797	40,875	43,121	1,603,077
1977:							
Automotive	354,338	125,010	--	--	871	--	480,219
Chemical	84,414	161,234	2,901	182	20,245	12,033	281,009
Dental and medical	27,083	112,473	264	728	275	188	141,011
Electrical	90,217	223,748	3,764	--	10,758	16,258	344,745
Glass	59,995	907	144	--	13,986	162	75,194
Jewelry and decorative	34,650	15,567	1,138	--	5,011	398	56,764
Petroleum	74,772	8,507	5,103	--	--	--	88,382
Miscellaneous	64,350	53,023	142	1	4,070	3,367	124,953
Total	789,819	700,469	13,456	911	55,216	32,406	1,592,277

[1]Comprises primary and nontoll-refined secondary metals.

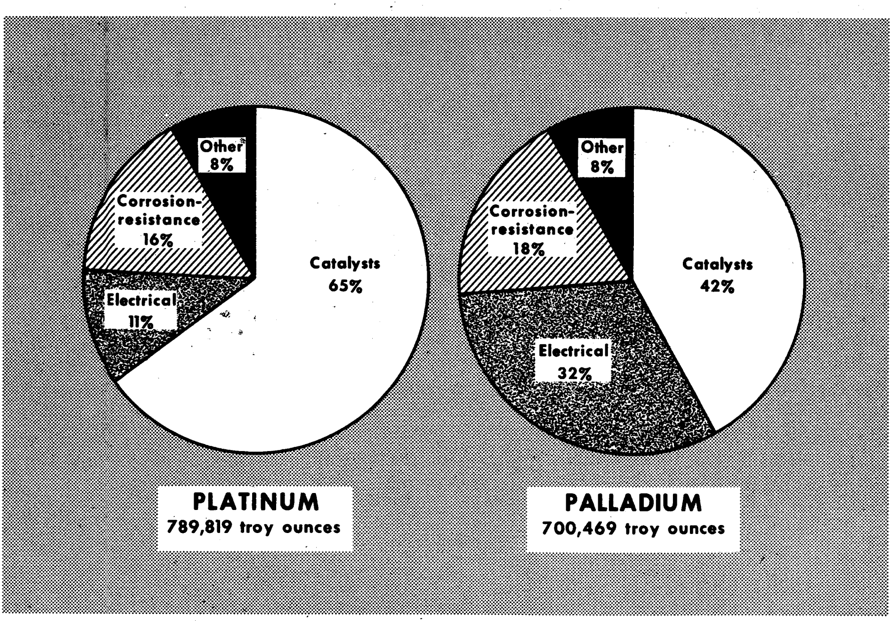


Figure 1.—Uses of platinum and palladium in 1977.

STOCKS

Stocks of platinum-group metals held by refiners, importers and dealers decreased about 7% in 1977 compared with those of 1976. Ruthenium stocks rose 65%, palladium stocks 3%, and rhodium 1%. Stocks of the other three metals decreased as follows: Platinum, 18%; iridium, 23%; and osmium, 4%. It should be noted that these are partial industry stocks, since the Bureau of Mines does not collect inventory data from end users of the platinum-group metals, some of whom may hold sizable inventories. In addition, there were Government stockpiles of platinum, palladium, and iridium.

Table 4.—Refiner, importer, and dealer stocks of platinum-group metals in the United States, December 31[1]

(Troy ounces)

Year	Platinum	Palladium	Iridium	Osmium	Rhodium	Ruthenium	Total
1973	446,522	493,078	14,813	327	51,504	26,880	1,033,124
1974	532,675	478,210	18,159	869	55,791	36,102	1,121,806
1975	420,770	335,621	18,276	627	53,847	20,069	849,210
1976	536,318	459,765	20,318	439	47,769	21,094	1,085,703
1977	438,045	475,358	15,689	420	48,392	34,908	1,012,812

[1]Includes metal in depositories of the New York Mercantile Exchange; on Dec. 30, 1977, this comprised 141,800 troy ounces of platinum and 68,300 troy ounces of palladium.

PRICES

The producers' price for platinum was $162 per troy ounce for most of the year. It was increased to $180 in the last few days of December. The producers' palladium price began the year at $55 per troy ounce, was raised to $60 late in January, and remained at that level for the rest of the year. The rhodium price was $400 at the beginning of the year, and was increased to $450 in March owing to improved industrial demand and increased speculation regarding the use of rhodium in automobile emission catalysts. The iridium price started the year at $300, was lowered to $250 on June 30 for a few weeks, and then returned to $300 for the rest of the year. The price for osmium was $200 per troy ounce for the first 6 months, but was lowered to $150 in the last 6 months of the year because of continued weak demand. Ruthenium was unchanged throughout the year at $60 per troy ounce.

Dealers' prices for platinum remained below the producers' price, except for a brief period in March and for November and December when dealers' prices were significantly higher. Dealers' prices for the other five metals were lower than producers' prices thoughout the year. Average prices for the year, per troy ounce, calculated at the low ends of the ranges of weekly averages published by Metals Week follow:

	Producer	Dealer
Platinum	$162.00	$157.22
Palladium	59.62	49.35
Iridium	298.08	258.08
Osmium	175.00	130.00
Rhodium	440.38	409.33
Ruthenium	60.00	34.73

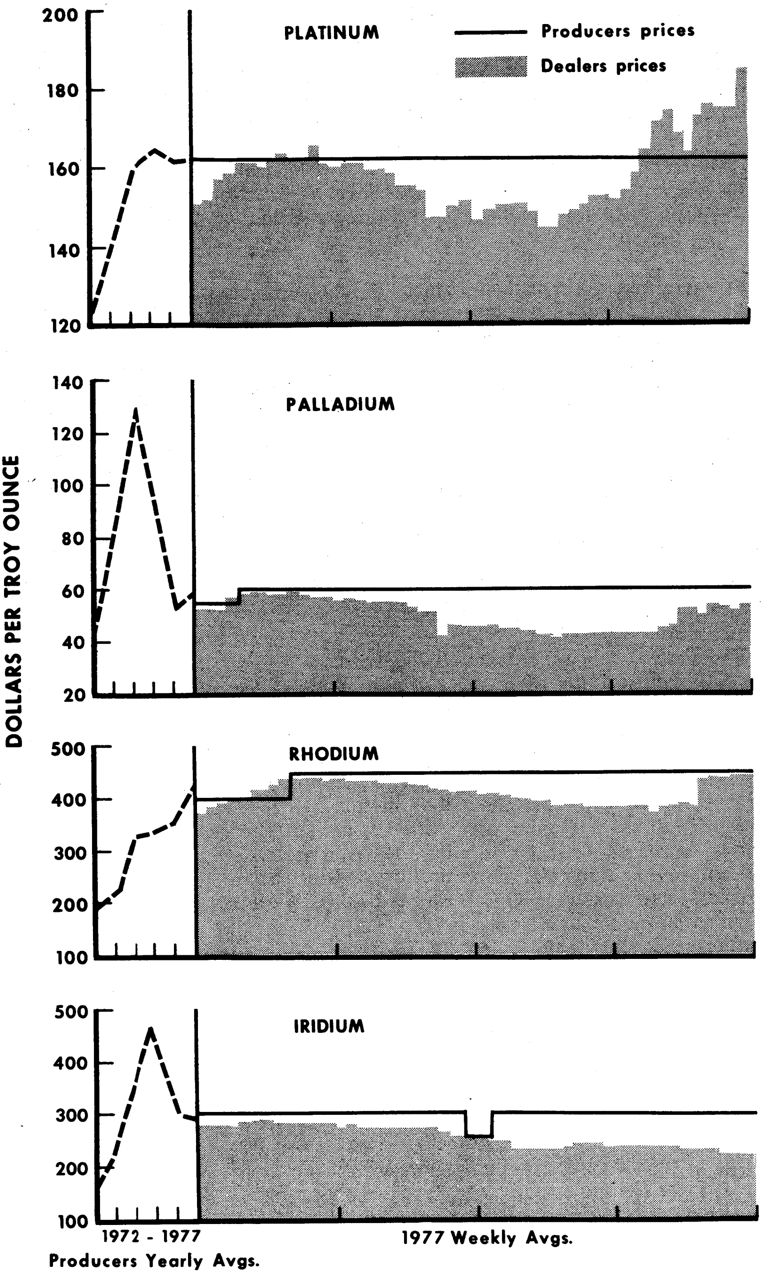


Figure 2.—Prices of four platinum-group metals.

FOREIGN TRADE

Exports of unwrought and semimanufactured platinum-group metals decreased 17% in 1977 to 426,631 troy ounces; about 214,000 troy ounces of this, or 50%, was platinum. Exports valued at $47 million went mainly to Japan (32% of total value), the Federal Republic of Germany (15%), Switzerland (13%), and the United Kingdom (12%).

In 1977 imports (2.5 million troy ounces) and their value ($273 million), both decreased 6% from the 1976 level. Of total imports, including estimates of metals in scrap and composite import classes, 40% was platinum and 53% was palladium. Compared with 1976 levels, platinum imports decreased 15% and palladium imports increased 3%. The principal source of platinum-group metal imports was the Republic of South Africa, which supplied 50% of the imports directly and was the origin of a substantial part of the 9% of imports from the United Kingdom. The U.S.S.R. supplied 25% of imports directly and an unknown additional quantity from European countries and Japan. Imports of each metal were estimated as follows:

	Thousand troy ounces
Platinum	1,008
Palladium	1,327
Indium	22
Osmium	7
Rhodium	87
Ruthenium	59
Total	2,510

Table 5.—U.S. exports of platinum-group metals, by country

Year and destination	Platinum-group metals				Platinum, unworked or partly worked				Platinum-group metals, except platinum, unworked or partly worked				Total	
	Ores and concentrates		Waste, scrap, and sweepings		Not rolled		Rolled		Not rolled		Rolled			
	Quantity (troy ounces)	Value (thousands)	Quantity (troy ounces)	Value (thousands)	Quantity (troy ounces)	Value (thousands)	Quantity (troy ounces)	Value (thousands)	Quantity (troy ounces)	Value (thousands)	Quantity (troy ounces)	Value (thousands)	Quantity (troy ounces)	Value (thousands)
1976:														
Australia	--	--	--	--	1,903	$254	--	--	1,586	$76	--	--	3,489	$330
Belgium-Luxembourg	--	--	48,910	$2,579	4,040	780	--	--	392	8	--	--	53,342	3,367
Canada	287	$54	383	27	12,604	2,162	14	$5	33,946	2,613	620	$30	47,854	4,891
France	--	--	1,028	116	2,657	445	8	3	6,155	416	178	5	10,026	985
Germany, Federal Republic of	3,167	290	14,288	1,599	11,550	1,930	441	80	43,013	3,349	2,257	351	74,716	7,599
Italy	--	--	--	--	--	--	--	--	4,280	176	2,727	59	7,007	235
Japan	186	4	--	--	66,095	10,263	8,827	1,333	38,715	3,917	5,034	371	118,857	15,888
Mexico	--	--	--	--	199	40	--	--	2,432	202	--	--	2,631	242
Netherlands	--	--	451	84	52	12	19	6	2,475	291	100	35	3,097	428
South Africa, Republic of	--	--	5,964	916	--	--			5,226	872	--	--	11,190	1,788
Switzerland	296	41	6,258	394	24,703	3,957	--	--	1,518	93	10	1	32,785	4,486
Taiwan	--	--	--	--	8	5	--	--	5,697	313	280	9	5,985	327
United Kingdom	1,772	148	103,710	9,364	3,857	589	551	76	21,131	881	1,230	50	132,251	11,108
U.S.S.R	--	--	--	--	--	--	--	--	1,603	358	--	--	1,603	358
Venezuela	--	--	--	--	4	1	--	--	1,306	23	160	7	1,470	31
Other	--	--	154	7	1,369	294	50	10	3,786	287	745	92	6,104	690
Total	5,708	537	181,146	15,086	129,041	20,732	9,910	1,513	173,261	13,875	13,341	1,010	512,407	52,753
1977:														
Australia	--	--	--	--	952	151	--	--	1,303	57	--	--	2,255	208
Belgium-Luxembourg	8,810	448	44,104	3,198	630	126	852	171	8	1	102	9	54,506	3,953
Brazil	700	17	--	--	17	4	64	7	104	11	291	17	1,176	56
Canada	1,438	152	281	20	13,330	2,393	--	--	18,061	2,182	153	22	33,263	4,769
France	--	--	30	2	2,407	496	47	8	3,639	392	156	15	6,279	913
Germany, Federal Republic of	5,072	171	14,463	1,825	8,079	1,586	213	88	38,469	3,253	525	133	66,821	7,056
Ireland	--	--	--	--	--	--	--	--	2,100	30	--	--	2,100	30
Italy	--	--	--	--	1,500	221	--	--	218	64	--	--	1,718	285
Japan	--	--	4,739	83	58,572	9,305	6,946	1,131	37,882	4,387	2,408	174	110,547	15,080
Korea, Republic of	--	--	--	--	1,332	324	--	--	531	107	23	1	1,886	432
Mexico	--	--	--	--	349	76	--	--	3,082	291	--	--	3,431	367

Netherlands	--	--	--	--	34	17	16	1	2,889	450	372	17	3,311	485
Peru	--	--	--	--	31	6	--	--	1,231	69	--	--	1,262	75
South Africa, Republic of	--	--	1,053	31	--	--	--	--	--	--	--	--	1,053	31
Switzerland	--	--	4,140	271	31,386	5,289	3,331	650	14	2	4	1	38,875	6,213
Taiwan	--	--	--	--	57	12	--	--	1,922	187	--	--	1,979	199
United Kingdom	1,148	75	54,006	4,139	17,347	316	431	99	15,434	1,122	1,937	78	90,303	5,829
Other	--	--	300	13	1,100	154	--	--	4,218	318	248	24	5,866	509
Total	17,168	863	123,116	9,582	137,123	20,476	11,900	2,155	131,105	12,923	6,219	491	426,631	46,490

Table 6.—U.S. imports for consumption of platinum-group metals, by country

Year and country	Unwrought (troy ounces): Platinum grains and nuggets	Platinum sponge	Palladium	Iridium	Osmium	Osmiridium	Rhodium	Ruthenium	Unspecified combinations[1]	Platinum-group metals from precious metal ores	Sweepings, waste and scrap
1976	596	904,048	994,360	18,179	1,259	6,685	62,260	75,673	216,616	--	146,773
1977:											
Australia	--	--	--	--	--	--	--	--	--	--	1,600
Belgium-Luxembourg	--	--	--	--	--	--	--	--	--	--	19,657
Canada	955	531	21,840	84	--	--	2,191	--	22	830	58,144
Colombia	--	--	--	--	--	--	--	--	3,068	3,995	926
France	--	2,770	1,000	145	--	--	2,946	--	--	--	213
Germany, Federal Republic of	--	5,186	6,229	--	150	--	947	1,004	170	--	1,644
Italy	--	--	--	--	--	--	--	--	--	--	2,800
Japan	--	2,498	15,730	--	--	--	353	--	--	--	--
Mexico	--	2,313	--	--	--	--	--	--	--	--	150,089
Netherlands	70	3,239	3,387	50	--	--	342	1,050	1,314	--	1,150
Norway	--	2,566	7,704	--	--	--	132	113	1,486	--	1,716
Romania	--	2,680	--	--	--	--	--	--	--	--	--
South Africa, Republic of	4,267	653,826	484,640	6,350	200	1,400	33,690	46,115	8,807	--	1,533
Sweden	--	--	--	--	--	--	--	--	--	--	3,567
Switzerland	10	7,080	1,480	--	25	--	1,288	--	8,697	--	--
U.S.S.R	--	5,607	490,535	--	--	4,341	19,743	--	68,450	--	--
United Kingdom	1,330	80,270	66,864	1,659	--	7,773	17,658	4,859	15,515	--	1,112
Yugoslavia	--	--	3,198	--	--	--	--	--	678	--	--
Other	--	3,277	--	--	--	--	--	600	--	--	3,714
Total	6,632	771,843	1,102,607	8,288	375	13,514	79,290	53,741	108,207	4,825	247,865

	Semimanufactured (troy ounces)								Platinum-group metals in materials not elsewhere specified (troy ounces)	Total	
	Platinum	Palladium	Iridium	Osmium	Osmiridium	Rhodium	Ruthenium	Unspecified combinations[1]		Quantity (troy ounces)	Value (thousands)
1976	95,653	128,951	2,883	--	--	1,864	1,000	556	9,703	2,667,059	$291,536
1977:											
Australia	--	--	--	--	--	--	--	--	--	1,600	372
Belgium-Luxembourg	--	6,592	--	--	--	--	--	--	--	26,249	4,739
Canada	1,976	--	--	--	--	--	--	--	1,937	88,510	11,111
Colombia	--	--	--	--	--	--	--	--	--	7,989	1,126
France	--	--	--	--	--	--	--	--	--	7,074	1,717
Germany, Federal Republic of	3,087	105	--	--	--	--	--	--	6,848	25,370	3,223
Italy	--	--	--	--	--	--	--	--	--	2,800	454
Japan	--	--	--	--	--	--	--	--	--	18,581	2,091
Mexico	--	--	--	--	--	--	--	--	--	152,402	2,145
Netherlands	--	--	--	--	--	--	--	--	--	10,602	1,354
Norway	2,235	1,258	--	--	--	--	--	--	2,270	19,480	2,354
Romania	--	--	--	--	--	--	--	--	--	2,680	429
South Africa, Republic of	16,917	1,999	--	--	--	--	--	--	7,447	1,267,191	158,437
Sweden	--	--	500	--	--	--	--	--	--	4,067	830
Switzerland	1,010	850	--	--	--	--	--	--	--	20,440	3,257
U.S.S.R	4,825	23,714	--	--	--	--	--	--	--	617,215	45,635
United Kingdom	14,355	14,552	1	--	--	650	--	59	--	226,657	32,378
Yugoslavia	--	--	--	--	--	--	--	--	--	3,876	255
Other	--	--	--	--	--	--	--	--	--	7,591	1,137
Total	44,405	49,070	501	--	--	650	--	59	18,502	2,510,374	273,044

[1]Contains not less than 90% platinum by weight.

Table 7.—Imports of platinum-group metals, in 1977, by source

(Percent of total imports)

Source	Platinum	Palladium	Iridium	Osmium	Rhodium	Ruthenium	Total
South Africa, Republic of	68	37	33	13	40	79	50
U.S.S.R	7	39	13	30	23	(1)	25
United Kingdom	11	6	26	53	21	9	9
Other	14	18	28	4	16	11	16

[1]Less than 1/2 unit.

WORLD REVIEW

World mine production of the platinum-group metals was estimated to be about 6.4 million ounces in 1977. The Republic of South Africa, the U.S.S.R., and Canada produced about 99% of the world total. Placer mining in Colombia yielded an estimated 26,000 troy ounces. All dredging was done by Compania Mineros Colombianos S.A.; however, small quantities of platinum metals were also produced by hand methods. Copper and nickel ores were production sources for small quantities of platinum-group metals in Japan, Finland, the Philippines, and Australia. Ethiopian production was derived from placers worked by hand methods.

Canada.—Production of platinum-group metals in Canada increased 9% to 469,000 troy ounces despite reduced copper-nickel production in the latter half of 1977. The value of platinum-group metal production was estimated at $62 million, up from $50 million in 1976.[3]

Platinum-group metals were recovered as byproducts of nickel-copper mining in the Sudbury, Shebandowan, and Pickle Lake districts of Ontario and the Thompson area of Manitoba. Inco Ltd. and Falconbridge Nickel Mines, Ltd., were major producers of platinum-group metals, mainly from Ontario ores; Inco Ltd. was by far the leader. None of the platinum-group metals from these operations was refined to metal in Canada; refining was done in England, the Republic of South Africa via Norway, and the United States.

The Langmuir mine near Timmins, Ontario, a joint venture of Inco and Noranda Mines Ltd., was a small byproduct producer of platinum-group metals in 1977. The copper-nickel concentrates from the mine were processed in Inco's plant at Sudbury. This mine was scheduled to close in March 1978 owing to poor results and increased costs.

The Thierry copper-nickel deposit of Union Minière Explorations and Mining Corp. Ltd. (UMEX) shipped concentrate containing precious metals to the Noranda smelter in Quebec for recovery of the metals. Adverse economic conditions forced UMEX to reduce its anticipated output by half in 1977.

South Africa, Republic of.—South African mine output of platinum-group metals in 1977 was estimated at 2.95 million troy ounces, 9% higher than in 1976. South Africa was the world's largest producer of platinum (65%), rhodium (55%), and ruthenium (52%), and may have been the largest producer of osmium as well. Virtually all of the country's platinum-group production was mined from the Merensky Reef in the Bushveld Complex in Transvaal Province; small but significant quantities of osmiridium were also recovered as a byproduct of gold mining.

South African platinum-group resources, which occur essentially in three horizons of the Bushveld Complex, were estimated at 2 billion troy ounces, based on a mining depth of about 4,000 feet.[4] The potential resources of the Bushveld horizons were Merensky Reef, 580 million troy ounces; Upper Group Chrome Seams, 1,000 million troy ounces; and the Platreef, 400 million ounces. Together they represented 70% of the world's resources of platinum-group metals.

Rustenburg Platinum Mines, Ltd. (RPM), operators of three mining sections (Rustenburg, Union, and Amandelbult), produced an estimated 1.6 million troy ounces of platinum-group metals in 1977, up slightly from the 1976 output. The increase occurred despite production cutbacks in November and December which resulted from low prices and weak markets for platinum. To reduce labor costs and increase efficiency, RPM continued mechanization of the Rustenburg section where about 60% of the

Table 8.—Platinum-group metals: World production by country[1]

(Troy ounces)

Country	1975	1976	1977[p]
Australia:			
Palladium, metal content, from nickel ores[e]	1,400	[r]1,550	1,590
Platinum, metal content, from nickel ores[e]	430	470	480
Canada: Platinum-group metals from nickel ore	399,218	416,820	469,014
Colombia: Placer platinum	22,114	26,000	[e]26,000
Ethiopia: Placer platinum	162	[r e]150	[e]100
Finland: Platinum-group metals from copper ores[e]	600	640	720
Japan:[2]			
Palladium from nickel and copper ores	13,915	18,089	22,716
Platinum from nickel and copper ores	5,486	8,706	9,737
Philippines:			
Palladium from nickel/cobalt ores	836	--	--
Platinum from nickel/cobalt ores	579	--	--
South Africa, Republic of: Platinum group metals from platinum ores[e 3]	2,600,000	2,700,000	2,950,000
U.S.S.R.: Placer platinum and platinum-group metals recovered from nickel/copper ores[e]	2,650,000	2,800,000	2,900,000
United States: Placer platinum and platinum-group metals from gold and copper ores	18,920	6,116	5,545
Total	5,713,660	5,978,541	6,385,902

[e]Estimate. [p]Preliminary. [r]Revised.

[1]Excludes metal refined in Norway and the United Kingdom derived from Canadian and South African ores. Also excluded is metal refined in the Federal Republic of Germany, which is believed to be derived from imported ores. Production is as follows in troy ounces: 1975—3,601; 1976—2,283; 1977—4,820 (estimate).

[2]Japanese figures exclude metal recovered from Philippine ores.

[3]Includes osmiridium from gold ores estimated at 2,500 troy ounces annually.

area being mined was mechanized and about 18% was mined by longwall systems. Longwall stopes were also being developed in the Union section. The first of three milling circuits at the Amandelbult section began operating at full capacity (60,000 troy ounces of platinum per year) in May. Installation of the other two circuits reportedly can be made on short notice when required.

In October, Rustenburg Platinum Holdings Ltd. (RPH), RPM's parent company, acquired Atok Platinum Mines Ltd., a relatively small platinum-group metal producer (40,000 troy ounces per year) on the eastern limb of the Merensky Reef. The acquisition will allow RPH to economically develop properties it holds adjacent to those of Atok.

Impala Platinum Ltd. (IPL), the world's second largest producer of platinum, produced an estimated 1.2 million troy ounces of platinum-group metals in 1977. In December, the territory of Bophuthatswana in which IPL's existing mines, concentrator and smelter are situated, became an independent country. This, together with about 25% of RPM's mining operations, constituted the most important industrial enterprise in the new country. Platinum mining activities for the two companies involved were not expected to be affected significantly because of the change in sovereignty.

IPL continued mine development by increasing stope mechanization and shaft sinking. The No. 7A shaft, sunk to a depth of 1,180 feet, was equipped and commissioned late in the year. The No. 7 vertical shaft at the Bafokeng North mine, the 21st shaft to be sunk by IPL since mining began in 1968, was started in July and was expected to be commissioned in mid-1978. The new shaft, which will have an ultimate depth of 2,200 feet, will allow establishment of seven mining levels to exploit the Merensky Reef.[5]

South Africa's Bantu Mining Corp. (BMC) was trying to interest local and foreign companies in developing the chromite-rich (30%) Upper Group No. 2 Reef in the Lebowa homeland.[6] BMC envisioned an operation producing chromite and 100,000 troy ounces of platinum-group metals annually for 35 years. The high rhodium content (two to three times that found in the Merensky Reef) was of special interest because of anticipated large usage of rhodium in automobile emission control catalysts.

U.S.S.R.—The U.S.S.R. produced about 2.9 million troy ounces of platinum-group metals in 1977, accounting for an estimated 27% of the world's platinum production, 65% of the palladium, 36% of the rhodium, and 38% of the ruthenium. A small production of metal came from the gold-platinum placers in the central Urals, but most was a byproduct of nickel-copper mining in the Norilsk-Talnakh region of northwestern Siberia and the Pechenga-Monchegorsk region of the Kola Peninsula.

Production of platinum-group metals was expected to increase rapidly in the next few years, owing to expansion of the copper-nickel mines at Talnakh and the Nadeznda smelter-refinery complex near Norilsk. The Oktyabrskiy mine at Talnakh, reportedly the largest underground mine in the U.S.S.R. nonferrous industry and the source for much of the U.S.S.R.'s platinum-group metal production, was undergoing rapid expansion and was scheduled to produce 50% of the total ore in the Norilsk area by 1980.[7] A fourth underground mine in the Talnakh area was planned for completion in 1984. Sinking of a 1,650-foot production shaft began in April. A new nickel-copper smelter complex to treat the increased tonnage was under construction; the first phase was scheduled for completion in 1978. Part of the concentrate shipments to the new complex were to arrive via a 22-mile pipeline, scheduled for completion in 1980. Platinum-group metal-rich residues from the new complex were expected to be refined to metal at the Krasnoyarsk refinery, 900 miles south of Norilsk.

TECHNOLOGY

Research on automotive emission control catalysts continued at a high level in 1977 in an effort to meet the more stringent standards set by Congress for 1981 and thereafter. The three-way converter, which employs a platinum-rhodium catalyst to act simultaneously on carbon monoxide, unburned hydrocarbons, and nitrogen oxides, appeared to be the best device to attain the standards. The major domestic and foreign automobile producers tested various three-way converter models on some production cars in California. Because of possible shortages in the supply of rhodium, research was directed toward reducing the rhodium content per catalytic unit.[8] Unless the rhodium-platinum ratio in the catalyst could be brought down to near that found in South African ores, it would be difficult to obtain enough rhodium to equip all U.S. cars with three-way converters. One company reported the development of a successful three-way catalyst which reduced the use of rhodium by 50% to 0.01 troy ounce.[9] Catalysts containing even lower rhodium quantities were undergoing tests. A German company announced the development of a nonprecious-metal catalyst that can attain the 1981 standards; additional testing was being carried out to determine the catalyst's durability.[10]

Platinum-group metal catalysts supported on metallic substrates were reported to be superior to the conventional ceramic substrate catalysts used for automobile emission control.[11] Metal substrate catalysts were more compact and more efficient than ceramic monoliths, and were found to have greater resistance to thermal shock and mechanical failure.

The use of platinum to cathodically protect ships and marine structures, such as offshore oil and gas platforms, was reviewed.[12] Tests of a new cathodic protection system on a petroleum production platform in the North Sea reportedly showed many advantages over conventional anode systems. The test system, which used a buoyant platinized-columbium anode moored about 10 feet above the seabed at a position 330 feet from the platform, provided full and uniform protection to the structure.

A new rhodium electroplating process useful in finishing contacts, printed circuits, reed switches, connectors, and vacuum tube grids was reported.[13] The process was designed to produce thick (500-microinch) deposits which are hard, low-stress, and crack-free. Bureau of Mines researchers successfully electroplated thick coatings of platinum and platinum-group alloys on base metals, molybdenum, and tungsten.[14] Objectives of the Bureau program were to provide substitutes for solid platinum shapes both as a means to conserve expensive scarce metals and to produce stronger finished pieces.

Certain organic rhodium complexes were under investigation as a means of catalytically splitting water to generate hydrogen and oxygen using sunlight.[15] The investigation was of considerable interest because it has the potential to produce hydrogen fuel.

Hydrogen in steels adversely affects their ductility due to hydrogen embrittlement and may lead to cracking and fracture if the steel is in a state of tensile stess. Studies carried out on the effect of alloying additions of palladium on flake formation in steels indicated that hydrogen embrittlement can be eliminated by adding 0.3 to 0.5 weight-percent palladium.[16]

A new alloy, zirconia-grain-stabilized platinum with 10% rhodium, was developed that is more creep and deformation resistant at elevated temperatures than conventional platinum-10% rhodium alloy.[17] The new material reportedly should find application in the glass industry, particularly for components subject to high stress whose service life has previously been short, and in resistance heating applications, such as furnace windings, heater tapes, and ignition coils.

A mechanism of the action of platinum compounds as antitumor agents was proposed.[18] A wide range of studies led to the conclusion that platinum antitumor compounds exert their potency by stopping the replication of DNA, thereby preventing cell division. Formation of a complex between the bases of the DNA and platinum compounds was likely, but the exact nature of the binding was not yet understood.

A comprehensive report on the medical and biological effects of platinum-group metals in the environment was published.[19] The report concluded that most metals and nonvolatile compounds were of little danger to man or the environment; however, some compounds were identified as physiologically active or dangerous. Platinum and palladium emitted from automobile exhaust catalysts were thought to be innocuous in the environment.

---

[1]Physical scientist, Division of Nonferrous Metals.

[2]Blair, W. N., N. J. Page and M. G. K. Johnson. Map and List of Reported Occurrences of Platinum-Group Metals in the Conterminous United States. U.S. Geol. Survey, Misc. Field Studies, Map MF-861, 1977.

[3]Hogan, J. J. Platinum. Canadian Mining J., v. 99, No. 2, February 1978, pp. 49-51.

[4]Von Gruenwaldt, G. The Mineral Resources of the Bushveld Complex. Miner. Sci. and Eng., v. 9, No. 2, April 1977, pp.83-95.

[5]Coal Gold and Base Metals. Impala Platinum Sinks 21st Shaft. V. 25, No. 9, September 1977, pp. 79-83.

[6]Metals Week. Bantu Mining Seeking Partners for UG2 Reef Platinum Mine; Site Has High Rhodium Content. V. 48, No. 17, Apr. 25, 1977, p. 6.

[7]Mohide, T. P., C. L. Warden and J. D. Mason. Towards a Nickel Policy for the Province of Ontario. Ontario Ministry of Natural Resources, Div. of Mines, Mineral Policy Background Paper No. 4, December 1977, 247 pp.

[8]American Metal Market. Test 3-Way Catalyst To Reduce Rhodium Used in Exhaust Systems. V. 85, No. 55, Mar. 21, 1977, p. 25.

[9]———. GM Catalytic Converters Cut Rhodium. V. 85, No. 165, Aug. 25, 1977. p. 2.

[10]———. Germans Develop Exhaust Control for Autos Without Precious Metals. V. 85, No. 182, Sept.20, 1977, p. 5.

[11]Pratt, A.S., and J. A. Cairns. Noble Metal Catalysts on Metallic Substrates. Platinum Metals Rev., v. 21, No. 3, July 1977, pp.74-83.

[12]Sheir, L. L. Platinum Provides Protection for Steel Structures. Platinum Metals Rev., v. 21, No. 4, October 1977, pp. 110-121.

[13]Materials Engineering. Rhodium Electroplate. V. 86, No. 3, September 1977, p. 85.

[14]American Metal Market. Platinum Conservation Studied. V. 85, No. 242, Dec. 26, 1977, p. 2.

Schlain, D., F. X. McCawley, and G. R. Smith. Electrodeposition of Platinum Metals From Molten Cyanides. Platinum Metals Rev., v. 21, No. 2, April 1977, pp. 38-42.

[15]Chemical and Engineering News. Rhodium Complex Splits Water Using Sunlight. V. 55, No. 31, Aug. 1, 1977, pp. 15-16.

[16]Platinum Metals Review. The Effect of Palladium Additions on the Flaking of Steels. V. 21, No. 1, January 1977, pp. 16-17.

[17]Materials Engineering. New Pt-Rh Alloy Is Stronger, Resists Creep. V. 86, No. 5, November 1977, p. 49.

[18]Thompson, A. J. The Mechanism of Action of Anti-Tumor Platinum Compounds. Platinum Metals Rev., v. 21, No. 1, January 1977, pp. 2-15.

[19]Committee on Medical and Biological Effects of Environmental Pollutants. Platinum-Group Metals. National Research Council ISBN-0309026407, 1977, 342 pp.

Potash

By Richard H. Singleton[1]

Apparent consumption of potash in the United States increased 8% in 1977 to 6.6 million tons of K_2O equivalent. Increased demand was met primarily by a 10% increase in imports, to 5.1 million tons of K_2O, 95% of which came from Canada. Domestic production increased 2% in 1977 to 2.5 million tons of K_2O. Producers' inventories remained at 515,000 tons of K_2O. Sales by domestic producers decreased 2% in volume, to 2.46 million tons of K_2O, and 2% in value, to $207 million. Exports decreased 1% to 932,079 tons of K_2O. Compared with 1976, sales by domestic producers increased 9%, to 1.43 million tons of K_2O, during the first half of the year, but were down 12%, to 1.03 million tons of K_2O, in the second half. The average selling price, f.o.b. mine, for domestic potash remained at $84 per ton of K_2O.

Standard, coarse, and granular grades of muriate comprised 78% of domestic potash production. Muriate comprised 99% of imports, 85% of exports, and 95% of apparent consumption.

Duval Corp., one of five domestic producers of sulfate of potash, terminated production of sulfate during the fourth quarter of 1977. Duval also announced suspension of muriate production by mid-1978 and expansion of its potassium-magnesium-sulfate production capability.

Federal criminal and civil suits against five U.S. potash producers were settled during the first half of 1977 by acquittal or dismissal. A settlement agreement was reached on class-action suits seeking damages from seven U.S. potash producers.

Potash production in Canada increased 22% to 6.7 million tons of K_2O equivalent.

Table 1.—Salient statistics on potash[1]

(Thousand short tons and thousand dollars)

Item	1973	1974	1975	1976	1977
United States					
Production	4,684	4,716	r4,576	r4,427	4,675
K_2O equivalent	2,603	2,552	2,501	2,400	2,457
Sales by producers	5,174	4,708	3,819	r4,612	4,675
K_2O equivalent	2,865	2,545	2,094	2,500	2,461
Value at plant[2]	$123,738	$158,607	$187,857	r$210,759	$206,872
Average value per ton	$23.92	$33.69	$49.19	r$45.70	$44.25
Exports[3]	1,579	1,415	1,419	1,670	1,650
K_2O equivalent	889	787	779	945	932
Value[4]	$57,997	$66,175	$92,701	$91,887	$90,186
Imports for consumption[3]	6,046	7,245	6,271	7,578	8,386
K_2O equivalent	3,587	4,326	3,797	r4,595	5,076
Customs value	$145,693	$236,747	$267,248	$344,229	$374,202
Apparent consumption[5]	9,641	10,538	8,671	r10,520	11,411
K_2O equivalent	5,563	6,084	5,112	6,149	6,605
Yearend producers' stocks, K_2O equivalent	206	212	619	519	515
World production, marketable K_2O equivalent	20,841	23,310	r27,269	r26,741	28,356

rRevised.
[1]Includes muriate and sulfate of potash, potassium magnesium sulfate, and some parent salts. Excludes other chemical compounds containing potassium.
[2]F.o.b. mine.
[3]Excludes potassium chemicals and mixed fertilizers.
[4]F.a.s. U.S. port.
[5]Measured by sales plus imports minus exports.

Overseas exports from Canada increased 38% to 1.36 million tons of K_2O. Producers' stocks increased by 423,000 tons of K_2O to 1.3 million tons of K_2O. Potash Corp. of America announced plans to construct, by 198[illegible], a potash mine-mill unit in New Brunswick. The Government of the Province of Saskatchewan acquired, by purchase, two more potash mines, one Canadian-owned and the other European-owned. Firm agreements were made at yearend for two other similar acquisitions, both owned by U.S. firms. These acquisitions would give the Provincial Government direct control of about 40% of the Province's potash industry.

World production of potash increased 6% to 28.4 million tons of K_2O equivalent, with the major portion of the increase occurring in North America. The apportionment of world production was Eastern Europe, 45%; North America, 32%; Western Europe, including Israel and the People's Republic of the Congo, 22%; and others, 1%. The U.S.S.R. and Canada continued as the first and second largest producers, with 32% and 24%, respectively, of world production. Serious flooding of the only potash mine in the People's Republic of the Congo in June 1977 terminated potash production in that country. The Arab Potash Co., a Jordanian firm, announced plans to construct, by 1982, a facility for extracting potash from Dead Sea brine.

Total world demand continued to increase, rising 6% in 1977 to 27.2 million tons of K_2O equivalent.

DOMESTIC PRODUCTION

Production of potash increased 2% to 2.5 million tons of K_2O equivalent. Production of sulfate of potash, including purchased muriate that was converted to sulfate, remained at 10% of total production. Production of standard-grade muriate decreased 10% to 868,000 tons of K_2O, but output of coarse-grade muriate increased 11% to 549,000 tons. Production of the granular grade remained constant.

New Mexico was the source of 85% of U.S. production in 1977: Eight underground mines were operated near Carlsbad; two mines were operated by Duval Corp., and one each by AMAX Chemical Corp., International Minerals & Chemical Corp., Kerr-McGee Chemical Corp., Mississippi Chemical Corp., National Potash Co., and Potash Co. of America.

The average K_2O content of ores mined in New Mexico declined to 14.2% in 1977 from 14.8% in 1976. These ores had contained an average of 18.2% K_2O in 1967.

Three companies produced potash in Utah: Texasgulf, Inc., working an old room-and-pillar mine near Moab by solution mining; Great Salt Lake Minerals and Chemicals Corp., producing potassium sulfate from brines from the Great Salt Lake; and Kaiser Aluminum and Chemical Corp., treating near-surface brines near Wendover. In California, potash continued to be produced from Searles Lake brines by the Kerr-McGee Chemical Corp.

AMAX Chemical Corp. estimated its total Carlsbad potash ore reserves at 7.8 million tons of K_2O equivalent of muriate, averaging 15% K_2O. Included in these reserves were main ore-body reserves of 3.2 million tons of K_2O in ore averaging 19% K_2O, and low bed-height reserves, primarily at another mine depth, of 4.6 million tons of K_2O in ore averaging 13% K_2O.

Duval Corp. stopped producing sulfate of potash at Carlsbad, N. Mex., in October. Near yearend 1977, Duval announced its planned closure (by mid-1978 or sooner) of its North mine, mainly because of lower-than-anticipated sylvinite ore grades. Duval reported that it would continue to produce only one potash product, a potassium magnesium sulfate fertilizer ingredient made from langbeinite ore taken from its Nash-Draw mine near Carlsbad. Duval announced that construction would begin immediately to expand potash production capacity to 110,000 tons per year of K_2O equivalent.

Completion of Mississippi Chemical Corp.'s modernization and expansion of its flotation circuit near Carlsbad, N. Mex., allowed muriate production to be reestablished during the first half of 1977.

The potash reserve in Potash Co. of America's New Mexico mine was revised downward to about 3.6 million tons of K_2O equivalent, adequate for approximately 10 more years of mining. An exploratory-drilling program was completed by Potash Co. of America on a langbeinite property in the Carlsbad area; however, in view of the marginal nature of the project, mining will not be undertaken at this time.

Texasgulf, Inc., was reportedly drilling an exploration well about 20 miles northwest of its Cane Creek potash mine near Moab,

Table 2.—Domestic production, sales, and stocks of potash

(Thousand short tons and thousand dollars)

Item	Production				Sold or used						Stocks, end of 6-month period			
	Gross weight		K_2O equivalent		Gross weight		K_2O equivalent		Value[1]		Gross weight		K_2O equivalent	
	1976	1977	1976	1977	1976	1977	1976	1977	1976	1977	1976	1977	1976	1977
January-June:														
Muriate of potash, 60% K_2O minimum														
Standard	863	685	524	416	898	961	547	583	37,912	33,580	544	245	329	149
Coarse	358	444	219	272	398	500	242	305	17,123	21,840	107	60	65	37
Granular	375	401	228	242	421	408	256	247	19,057	18,237	78	67	47	40
Chemical	42	47	26	30	45	48	28	30	W	W	2	(2)	1	(2)
Potassium sulfate	233	257	120	133	238	238	122	123	21,594	21,257	84	100	44	52
Other potassium salts[3]	378	487	101	124	443	557	119	142	W	W	142	103	36	27
Total	2,249	2,321	1,218	1,217	2,443	2,712	1,314	1,430	113,748	117,923	957	576	522	306
July-December:														
Muriate of potash, 60% K_2O minimum														
Standard	723	746	441	452	745	679	454	412	25,247	23,789	522	313	316	190
Coarse	451	453	276	277	443	284	271	174	16,999	12,664	115	229	70	140
Granular	385	409	233	247	390	334	236	202	15,201	14,224	74	142	45	85
Chemical	44	48	28	30	45	41	28	26	W	W	1	7	1	4
Potassium sulfate	219	215	113	111	222	235	114	121	25,538	21,109	81	80	42	42
Other potassium salts[3]	356	483	91	123	324	390	83	96	W	W	174	196	45	54
Total	2,178	2,354	1,182	1,240	2,169	1,963	1,186	1,031	97,011	88,949	967	967	519	515
Grand Total	4,427	4,675	2,400	2,457	4,612	4,675	2,500	2,461	210,759	206,872	XX	XX	XX	XX

XX Not applicable. W Withheld to avoid disclosing company proprietary data; included in "Total."
[1]F.o.b. mine.
[2]Less than 1/2 unit.
[3]Includes soluble muriate, manure salts, and potassium magnesium sulfate.

Table 3.—Producton and sales of potash in New Mexico

(Thousand short tons and thousand dollars)

Period	Crude salts[1] (mine production)		Marketable potassium salts				
			Production		Sold or used		
	Gross weight	K_2O equivalent	Gross weight	K_2O equivalent	Gross weight	K_2O equivalent	Value[2]
1976:							
January-June	8,583	1,289	1,876	1,005	2,069	1,098	92,744
July-December	8,725	1,271	1,834	984	1,820	985	72,610
Total	17,308	2,560	3,710	1,989	3,889	2,083	165,354
1977:							
January-June	9,305	1,329	1,985	1,027	2,316	1,202	96,991
July-December	9,680	1,374	2,046	1,066	1,696	883	72,625
Total	18,985	2,703	4,031	2,093	4,012	2,085	169,616

[1]Sylvinite and langbeinite.
[2]F.o.b. mine.

Table 4.—Salient statistics on sulfate of potash[1]

(Thousand short tons of K_2O equivalent and thousand dollars)

Item	1973	1974	1975	1976	1977
United States					
Production	232	227	240	233	244
Sales by producers	254	237	207	236	244
Value[2]	$19,199	$26,257	$35,481	$47,132	$42,366
Exports[3]	127	77	86	93	93
Imports	27	29	38	23	38
Value[4]	NA	$4,138	$8,086	$4,507	$6,791
Apparent consumption[5]	154	189	159	167	189
Yearend producers' stocks	23	13	46	42	42

NA Not available.
[1]Excluding potassium magnesium sulfate.
[2]F.o.b. mine.
[3]Export data supplied by Potash/Phosphate Institute.
[4]C.i.f. to U.S. port.
[5]Sales plus imports minus exports.

Utah. The area may have potential for development of potash solution mining.

Drilling by St. Joe Minerals Corp. partially outlined a potentially commercial potash property in northeastern Arizona.

In January 1977, criminal trial began in U.S. District Court in Chicago, Ill., of five U.S. potash producers charged with production and price fixing and export coordination during the 1970-74 potash prorationing period in Saskatchewan, Canada. Potash Co. of America and National Potash Co. were acquitted of the charge in February. In March, a hung jury resulted in a mistrial for the remaining three indictees (International Minerals & Chemical Corp., AMAX Chemical Corp., and Duval Corp.); however they were acquitted by the Federal judge in May. A companion civil suit that had been filed by the Federal Government against the same five producers was dismissed in June.

The States of Illinois, Connecticut, and Minnesota and 30 other potash users had, meanwhile, filed class-action civil suits, mostly in the same Illinois court, seeking damages for the high prices paid for potash during prorationing. The parties being sued were Texasgulf, Inc., and Kerr-McGee Chemical Corp. in addition to the five producers that had been acquitted in the Federal suits. A settlement agreement was reached in August, with preliminary Court approval, between the defendants and those plaintiffs (five including the States of Illinois and Minnesota) that had purchased potash directly from the producers. Scheduled final settlement was June 1978. The agreed-upon settlement was approximately $3 million.

In November, a Federal antitrust suit was filed in U.S. District Court in Alburquerque, N. Mex., by Montreal Trading, Ltd. (a Canadian potash buyer) charging AMAX Chemical Corp., International Minerals and Chemical Corp., Potash Co. of America, and Potash Co. of Canada, Ltd. (a Canadian trading firm) with conspiring, since 1969, to monopolize the potash market in possible violation of antitrust laws. The suit asks that Montreal Trading be awarded treble damages.

Two companies continued engineering-economic analyses to determine the feasibility of deep solution mining of potash in a Montana-North Dakota area near the Canadian border. A third company, a U.S. producer, had also leased property in the same area. It was reported that contamination from a Canadian 300-megawatt coal-fired powerplant under construction 8 miles north of the Canadian border may prohibit potash beneficiation on the U.S. side of the border by lifting air-pollution levels to above the limits of U.S. quality standards. Construction of the powerplant was scheduled for completion in 1978. Negotiations were underway between the United States and Canada in an attempt to resolve the problem.

The Federal Bureau of Mines completed an engineering-economic study in November, defining the potash reserve that would be lost by the proposed nuclear Waste Isolation Pilot Plant (WIPP) area east of Carlsbad, N. Mex. The study, completed for the U.S. Department of Energy, concluded that a reserve of langbeinite containing 4.4 million tons of K_2O is within the WIPP site. Prevention of its recovery by WIPP represented a value loss of about $50 million in terms of 1977 dollars for acquisition costs, taxes payable on estimated revenues, and royalties payable to the owner of the potash.

Table 5.—Sales of North American potash, by State of destination

(Short tons of K_2O equivalent)

Destination	Agricultural potash		Nonagricultural potash	
	1976	1977	1976	1977
Alabama	108,470	115,873	44,227	53,114
Arizona	2,100	4,048	28	372
Arkansas	53,398	62,974	255	380
California	64,015	62,010	5,133	6,344
Colorado	14,362	19,060	529	668
Connecticut	3,806	4,277	229	132
Delaware	27,617	32,162	24,004	29,577
Florida	191,196	134,462	598	569
Georgia	262,812	237,556	1,160	963
Hawaii	26,309	17,044	--	--
Idaho	15,946	15,615	--	80
Illinois	818,259	730,053	41,903	32,435
Indiana	497,021	479,940	4,895	5,219
Iowa	526,327	515,603	749	489
Kansas	52,280	40,765	1,822	3,050
Kentucky	133,198	160,688	16,550	16,630
Louisiana	50,298	55,330	779	3,977
Maine	15,262	12,717	156	64
Maryland	63,776	52,223	1,739	1,427
Massachusetts	2,925	2,714	809	854
Michigan	191,906	182,683	2,513	2,565
Minnesota	405,016	483,440	70	109
Mississippi	191,105	231,693	2,256	4,080
Missouri	238,555	225,169	3,142	3,834
Montana	9,082	8,431	666	1,514
Nebraska	58,695	51,489	322	828
Nevada	117	--	540	760
New Hampshire	276	238	--	--
New Jersey	15,060	15,420	1,833	676
New Mexico	2,372	3,863	468	4,541
New York	70,550	69,333	52,013	53,760
North Carolina	153,593	150,196	1,489	688
North Dakota	16,652	21,718	41	223
Ohio	401,923	403,548	39,450	52,080
Oklahoma	22,894	22,151	618	3,727
Oregon	19,824	23,225	1,162	826
Pennsylvania	74,006	80,074	4,049	4,279
Rhode Island	2,447	2,375	523	277
South Carolina	107,707	107,978	550	276
South Dakota	10,527	13,196	--	--
Tennessee	130,908	143,444	546	168
Texas	213,248	207,665	16,113	30,491
Utah	772	1,313	154	1,129
Vermont	6,668	7,925	--	--
Virginia	76,041	84,364	1,307	1,238
Washington	36,003	37,536	3,436	3,891
West Virginia	4,813	4,980	50	11
Wisconsin	336,114	352,139	195	402
Wyoming	1,780	2,835	1,008	938
Total	5,728,031	5,693,535	280,079	329,655

Source: Potash/Phosphate Institute, Atlanta, Ga.

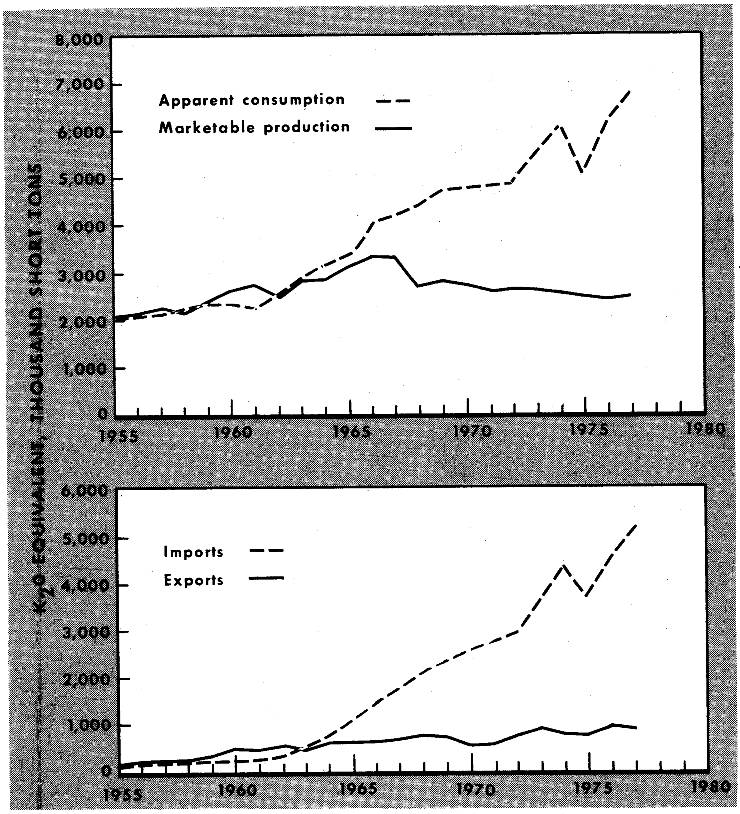


Figure 1.—Marketable production, apparent consumption, exports, and imports of potash measured in K_2O equivalent.

CONSUMPTION AND USES

Apparent domestic consumption of potash increased 8% to 6.6 million tons of K_2O equivalent; approximately 95% of this was used in the fertilizer industry and the balance in chemicals manufacture, mainly in production of caustic potash. Domestic sales by North American producers for nonagricultural purposes increased 18% to 329,655 tons according to the Potash/Phosphate Institute.

The north-central States of Illinois, Indiana, Iowa, Minnesota, Ohio, and Wisconsin purchased 52% of all agricultural potash, the same as in 1976. Total domestic sales by North American producers for agricultural purposes of granular-grade muriate of potash increased 10% to 1.81 million tons of K_2O; sales of standard and coarse grades decreased 2% and 4% to 1.15 and 2.18 million tons of K_2O, respectively, according to the Potash/Phosphate Institute. Apparent consumption of potassium sulfate continued to increase, rising 13% to 189,000 tons of K_2O.

Table 6.—Sales of North American muriate of potash to U.S. customers, by grade

(Thousand short tons of K_2O equivalent)

	1976	1977
Agricultural:		
Standard	1,174	1,149
Coarse	2,271	2,180
Granular	1,642	1,809
Soluble	397	419
Total	5,484	5,557
Nonagricultural:		
Soluble	90	112
Other	187	213
Total	277	325
Grand total	5,761	5,882

Source: Potash/Phosphate Institute, Atlanta, Ga.

STOCKS

Domestic producers' inventories did not change significantly, remaining at about 515,000 tons of K_2O equivalent at yearend. Producers' stocks of standard-grade muriate decreased while stocks of granular grades (particularly coarse grade) increased.

PRICES

Domestic prices for muriate of potash, particularly standard grade, remained depressed during the year and discount selling prevailed. Average muriate prices were near those of 1976. Sulfate prices remained near early 1976 levels after having peaked during the second half of 1976.

Table 7.—Bulk prices of U.S. potash, by type and grade [1]

(U.S. cents per unit K_2O)

	1975		1976[r]		1977	
	January-June	July-December	January-June	July-December	January-June	July-December
Muriate, 60% K_2O minimum:						
Standard	76.23	76.97	69.32	55.64	57.55	57.80
Coarse	75.05	76.19	70.58	62.81	71.51	72.89
Granular	72.98	74.92	74.49	64.37	73.85	70.44
All muriate[2]	75.19	[r]76.22	70.88	59.81	64.85	64.37
Sulfate, 50% K_2O minimum	163.39	181.63	176.63	223.41	173.18	174.02

[r]Revised.
[1]Average prices based on sales, f.o.b. mine
[2]Excluding soluble and chemical muriates.

FOREIGN TRADE

Total U.S. exports of potash decreased 1% to 932,079 tons of K_2O equivalent. Areas receiving these exports were Latin America (59%), Oceania (16%), Asia (15%), Canada (5%), and Western Europe (5%). Exports of sulfate of potash remained at 93,000 tons of K_2O. Exports to Brazil, the main recipient country, increased 1% to about 380,000 tons of K_2O. Although exports of muriate to Mexico decreased, total exports of muriate to Latin America remained fairly close to that of 1976 because of increased shipments to Colombia and Costa Rica. New Zealand remained the second largest importer of U.S. potash, although exports to that country decreased 26% to about 110,000 tons of K_2O. Increased tonnage of potash exported to Taiwan was counteracted by decreased shipments to Japan, the Philippines, and Malaysia; therefore total shipments to the Orient remained nearly the same as during 1976. Japan remained the largest importer of U.S. sulfate of potash.

Potash imports, 95% from Canada, increased 10% to 5.1 million tons of K_2O equivalent. Muriate of potash comprised 99% of these imports on a K_2O basis. Imports from Israel, the second largest supplier, nearly doubled, to about 140,000 tons of K_2O equivalent, all as standard muriate. Imports from Spain more than doubled, reaching about 30,000 tons of K_2O equivalent.

Potash imports, all muriate, from Comecon countries decreased from 27,000 to 20,000 tons on a K_2O basis. However, imports from the U.S.S.R. resumed with three shipments made into Eastern U.S. ports. A similar-sized shipment, 6,000 tons of muriate, came from Latvia.

Table 8.—U.S.exports of potash materials, by use

Materials	Approximate average K_2O content (percent)	1976 Quantity (short tons)	1976 Approximate equivalent as potash (K_2O): Short tons	1976 Approximate equivalent as potash (K_2O): Percent of total	1976 Value[1] (thousands)	1977 Quantity (short tons)	1977 Approximate equivalent as potash (K_2O): Short tons	1977 Approximate equivalent as potash (K_2O): Percent of total	1977 Value[1] (thousands)
Used chiefly as fertilizers:									
Potassium chloride all grades	61	1,329,399	810,933	83.7	$68,763	1,302,471	794,507	83.3	$66,967
Potassic chemical fertilizer, n.e.c	40	329,706	131,882	13.6	22,977	340,129	136,052	14.2	22,835
Natural potassic salt fertilizer, crude	20	10,586	2,117	.2	147	7,600	1,520	.2	384
Total	XX	1,669,691	944,932	97.5	91,887	1,650,200	932,079	97.7	90,186
Used chiefly in chemical industries:									
Potassium hydroxide	80	11,057	8,845	.9	2,811	19,292	15,434	1.6	3,559
Potassium peroxide	83	--	--	--	--	24	20	(2)	20
Potassium compounds, n.e.c	31	48,968	15,180	1.6	16,611	20,697	6,416	.7	15,226
Total	XX	60,025	24,025	2.5	19,422	40,013	21,870	2.3	18,805
Grand total	XX	1,729,716	968,957	100.0	111,309	1,690,213	953,949	100.0	108,991

XX Not applicable.
[1]F.a.s., U.S. port.
[2]Less than 1/2 unit.

Table 9.—U.S. exports of potash materials, by country

Destination	Fertilizer: Chloride, Quantity (short tons) 1976	Fertilizer: Chloride, Quantity (short tons) 1977	Fertilizer: Chemical fertilizer n.e.c., Quantity (short tons) 1976	Fertilizer: Chemical fertilizer n.e.c., Quantity (short tons) 1977	Fertilizer: Total, Quantity (short tons) 1976	Fertilizer: Total, Quantity (short tons) 1977	Fertilizer: Total, Value[1] (thousands) 1976	Fertilizer: Total, Value[1] (thousands) 1977	Chemical: Hydroxide (caustic), Quantity (short tons) 1976	Chemical: Hydroxide (caustic), Quantity (short tons) 1977	Chemical: Other n.e.c., Quantity (short tons) 1976	Chemical: Other n.e.c., Quantity (short tons) 1977	Chemical: Total, Quantity (short tons) 1976	Chemical: Total, Quantity (short tons) 1977	Chemical: Total, Value[1] (thousands) 1976	Chemical: Total, Value[1] (thousands) 1977
Argentina	2,037	3,085	4,488	2,976	6,525	6,061	$404	$315	--	2	392	255	392	257	$314	$272
Australia	45,906	59,845	13,561	13,120	[2]61,141	[2]73,007	[2]4,229	[2]4,682	24	8,175	148	246	172	[3]8,427	192	[3]597
Belgium-Luxembourg	4,998	3,912	--	--	4,998	3,912	247	208	--	15	5,442	178	5,442	193	513	165
Brazil	596,636	597,110	50,497	39,426	[2]654,962	636,536	[2]33,357	34,168	2,720	1,246	8,828	2,020	11,548	3,266	2,374	940
Canada	5,605	23,566	63,145	63,248	[2]69,826	[2]88,373	[2]4,166	[2]5,946	6,086	6,619	7,485	7,532	13,571	[3]14,159	4,606	[3]4,601
Chile	886	--	1,156	4,850	2,042	4,850	112	453	11	8	78	116	89	[3]125	56	[3]116
Colombia	4,409	46,077	3,347	24,578	7,756	[2]76,166	553	[2]4,406	165	101	200	188	365	289	167	182
Costa Rica	19,091	37,585	8,321	13,996	27,412	51,581	1,496	2,927	--	--	33	18	33	18	14	23
Denmark	8,835	14,054	--	3,472	8,835	17,526	428	746	--	--	--	--	--	--	--	--
Dominican Republic	32,539	23,638	--	1,998	32,539	25,636	2,070	1,463	18	16	96	23	114	39	67	29
Ecuador	--	7,164	--	5	--	7,169	--	332	--	--	23	21	23	21	17	20
El Salvador	1,400	3,743	--	2,223	1,400	5,966	74	287	--	5	--	9	--	14	--	9
Finland	--	--	--	--	--	--	--	--	--	--	--	81	--	81	--	44
France	--	--	--	--	--	--	--	--	11	--	24	705	35	705	30	442
Germany, Federal Republic of	--	--	--	385	--	385	--	14	20	--	3,764	2,885	3,784	2,885	2,094	2,015
Guatemala	--	7,352	308	2,756	308	10,108	11	537	5	21	65	10	70	31	34	21
Guyana	565	--	479	--	1,044	--	125	--	--	--	2	4	2	4	6	16
Honduras	1,176	1,181	196	1,516	[2]1,417	[2]2,712	[2]140	[2]327	--	--	4	2	4	2	9	7
India	--	--	--	--	--	--	--	--	326	44	63	118	389	162	169	72
Indonesia	--	--	--	--	--	--	--	--	--	--	280	1	280	1	107	3
Ireland	7,306	10,305	--	--	7,306	10,305	354	572	--	--	--	(4)	--	(4)	--	1
Israel	17	--	--	50	17	50	1	9	--	3	1	40	1	[3]51	4	[3]141
Italy	--	--	--	--	[2]24	[2]67	[2]1	[2]4	--	--	21	9	21	9	14	18
Jamaica	6,500	9,552	--	--	6,500	9,552	504	806	7	13	5	4	12	17	15	19
Japan	97,042	59,110	96,345	98,034	193,387	157,144	12,113	8,634	46	118	212	188	258	306	3,227	4,045
Korea, Republic of	--	50	27,832	16,975	27,832	17,025	2,299	1,568	6	167	316	44	322	211	148	93
Malaysia	17,495	--	5,518	2,169	23,013	2,169	869	110	--	--	16,804	22	16,804	22	1,212	130
Mexico	154,903	67,854	37,455	17,794	[2]192,508	[2]85,890	[2]10,021	[2]4,356	1,149	628	2,010	2,004	3,159	2,632	1,316	1,145
Netherlands	39	4	--	--	[2]72	4	[2]2	1	82	185	185	177	267	362	223	159
Netherlands Antilles	--	--	--	--	--	--	--	--	48	200	(4)	7	48	207	16	74
New Zealand	241,907	180,225	--	286	241,907	180,511	12,574	8,930	6	11	59	85	65	96	62	73

See footnotes at end of table.

Table 9.—U.S. exports of potash materials, by country —Continued

Destination	Fertilizer								Chemical							
	Chloride		Chemical fertilizer n.e.c.		Total				Hydroxide (caustic)		Other n.e.c.		Total			
	Quantity (short tons)		Quantity (short tons)		Quantity (short tons)		Value[1] (thousands)		Quantity (short tons)		Quantity (short tons)		Quantity (short tons)		Value[1] (thousands)	
	1976	1977	1976	1977	1976	1977	1976	1977	1976	1977	1976	1977	1976	1977	1976	1977
Nicaragua	2,040	2,752	1,157	3,306	3,197	[2]6,097	$261	$353	--	--	22	1,678	22	1,678	$33	$143
Panama	--	1,134	31	89	31	1,223	5	50	--	--	69	18	69	18	54	23
Peru	51	162	9,920	210	9,971	372	834	15	6	15	125	67	131	[3]83	120	[3]127
Philippines	28,028	186	--	--	28,028	186	1,506	6	7	75	101	71	108	146	116	122
Singapore	--	--	5,180	23,240	5,180	23,240	479	1,020	--	--	38	16	38	16	160	838
South Africa, Republic of	4,503	2,800	--	--	4,503	2,800	231	161	38	156	112	131	150	287	141	185
Spain	--	--	--	--	[2]35	--	[2]1	--	115	370	13	3	128	373	53	149
Sweden	20,338	31,812	--	--	20,338	31,812	1,070	1,519	--	2	11	35	11	37	10	24
Taiwan	3,942	84,809	--	--	3,942	84,809	183	3,668	--	631	236	219	236	850	134	490
Thailand	--	55	--	--	--	[2]123	--	6	--	44	3	16	3	60	4	40
Trinidad and Tobago	--	25	--	--	--	[2]35	--	[2]3	--	5	--	445	--	450	--	48
U.S.S.R	--	--	--	--	--	--	--	--	--	--	331	--	331	--	156	--
United Kingdom	19,982	19,841	--	--	[2]20,186	[2]19,878	[2]926	926	--	--	224	153	224	153	220	220
Uruguay	--	2,745	386	1,074	386	3,819	25	205	--	--	30	15	30	15	16	9
Venezuela	26	120	25	2,327	51	2,447	8	364	29	114	387	480	416	594	218	335
Other	1,197	618	359	26	[2]1,572	[2]654	[2]208	[2]89	132	303	726	358	858	661	981	580
Total	1,329,399	1,302,471	329,706	340,129	[2]1,669,691	[2]1,650,200	[r] [2]91,887	90,186	11,057	19,292	48,968	20,697	60,025	[3]40,013	19,422	[3]18,805

[r]Revised.
[1]F.a.s., U.S. port.
[2]Includes crude natural potassic salt fertilizer—1976: Australia, 1,674 tons ($93,940); Brazil, 7,829 tons ($6,526); Canada, 576 tons ($22,376); Honduras, 45 tons ($6,623); Hong Kong, 16 tons ($540); Italy, 24 tons ($1,183); Mexico, 150 tons ($7,105); Netherlands, 33 tons ($1,106); Spain, 35 tons ($1,167); the United Kingdom, 204 tons ($6,846). 1977: Australia, 42 tons ($1,407); Canada, 1,559 tons ($65,089); Colombia, 5,511 tons ($277,750); Honduras, 15 tons ($2,009); Italy, 67 tons ($4,094); Mexico, 242 tons ($23,433); Nicaragua, 39 tons ($1,316); Territory of Pacific Islands, 10 tons ($1,110); Thailand, 68 tons ($3,346); Trinidad and Tobago, 10 tons ($1,730); the United Kingdom, 37 tons ($1,254).
[3]Includes potassium peroxide—1976: No exports of potassium peroxide. 1977: Australia, 6 tons ($4,866); Canada, 8 tons ($2,850); Chile, 1 ton ($1,074); Israel, 8 tons ($6,336); Peru, 1 ton ($4,714).
[4]Less than 1/2 unit.

Table 10.—U.S. imports for consumption of potash materials, by use

Materials	Approximate average K_2O content (percent)	1976 Quantity (short tons)	1976 Approximate equivalent as potash (K_2O) Short tons	1976 Approximate equivalent as potash (K_2O) Percent of total	1976 Value (thousands) Customs	1976 Value (thousands) C.i.f.	1977 Quantity (short tons)	1977 Approximate equivalent as potash (K_2O) Short tons	1977 Approximate equivalent as potash (K_2O) Percent of total	1977 Value (thousands) Customs	1977 Value (thousands) C.i.f.
Used chiefly as fertilizers:											
Muriate (chloride)	61	7,474,534	4,559,465	99.1	$332,301	$422,396	8,229,253	5,019,844	98.8	$359,392	$464,373
Potassium nitrate, crude	r45	13,623	r6,130	.1	2,297	2,695	21,975	9,889	.2	3,247	3,589
Potassium sodium nitrate mixtures, crude	14	40,020	5,603	.1	5,345	5,517	54,023	7,563	.1	5,101	5,852
Potassium sulfate, crude	50	46,848	23,424	.5	4,106	4,507	76,039	38,020	.7	6,097	6,791
Other potash fertilizer material	6	3,301	198	(1)	180	186	4,351	261	(1)	365	408
Total	XX	7,578,326	r4,594,820	99.8	344,229	435,301	8,385,641	5,075,577	99.8	374,202	481,013
Used chiefly in chemical industries:											
Bicarbonate	46	916	421		241	314	2,787	1,282		742	974
Bitartrate: Cream of tartar	25	728	182		646	714	627	157		479	536
Carbonate	61	2,281	1,391		590	732	2,076	1,266		559	699
Caustic	80	721	578		288	358	737	590		371	442
Chlorate and perchlorate	36	1,271	458		434	589	2,562	922		1,140	1,395
Cyanide	70	1,151	806	.2	1,069	1,188	696	487	.2	671	745
Ferricyanide	42	504	212		755	804	694	291		1,271	1,357
Ferrocyanide	44	766	337		706	753	504	222		509	543
Nitrate	50	129	64		38	42	672	336		154	181
Rochelle salts	22	357	79		312	345	254	56		167	190
Sorbate	26	2,422	630		6,621	7,211	2,529	658		7,280	7,970
All other	31	5,674	1,759		4,827	5,373	5,559	1,723		4,690	5,265
Total	XX	16,920	6,917	.2	16,527	18,423	19,697	7,990	.2	18,033	20,297
Grand total	XX	7,595,246	4,601,737	100.0	360,756	453,724	8,405,338	5,083,567	100.0	392,235	501,310

r Revised. XX Not applicable.
[1] Less than 1/2 unit.

Table 11.—U.S. imports for consumption of potash materials, by country

(Short tons)

Year and country	Bitartrate, cream of tartar	Caustic (hydroxide)	Chlorate and perchlorate	Cyanide	Muriate (chloride)	Potassium nitrate, crude	Potassium sodium nitrate mixtures, crude	Potassium nitrate (saltpeter), refined	Potassium sulfate	All others	Total: Quantity	Total: Value (thousands): Customs	Total: Value (thousands): C.i.f.
1976:													
Belgium-Luxembourg	--	13	--	--	--	--	--	--	13,007	424	13,444	$1,262	$1,401
Canada	--	[1]	--	[1]	7,279,590	300	331	39	1,190	3,493	7,284,943	324,001	412,018
Chile	--	--	--	--	6,344	--	27,420	--	--	--	33,764	3,728	3,750
China, People's Republic of	--	--	--	--	--	--	--	--	--	34	34	18	23
Congo	--	--	--	--	17,361	--	--	--	--	--	17,361	820	976
France	--	20	--	--	--	--	--	--	16,000	838	16,858	1,883	1,963
German Democratic Republic	--	--	--	--	44,345	--	--	--	--	94	44,439	2,188	2,705
Germany, Federal Republic of	--	492	--	477	10,025	2	--	40	16,651	5,082	32,769	5,793	7,026
Israel	--	--	--	--	94,492	13,319	12,269	--	--	83	120,163	8,952	10,207
Italy	465	--	--	63	--	--	--	--	--	119	647	632	698
Japan	--	14	--	176	--	2	--	--	--	2,858	3,050	7,820	8,522
Netherlands	--	--	--	--	--	--	--	--	--	656	656	314	374
Spain	263	--	948	--	22,376	--	--	--	--	247	23,834	1,589	1,988
Sweden	--	182	315	--	--	--	--	--	--	80	577	263	323
Switzerland	--	--	8	--	--	--	--	--	--	13	21	72	78
U.S.S.R	--	--	--	--	--	--	--	--	--	3	3	6	7
United Kingdom	--	--	--	435	1	--	--	--	--	870	1,306	1,219	1,388
Other	--	--	--	--	--	--	--	49	--	1,328	1,377	196	277
Total	728	721	1,271	1,151	7,474,534	13,623	40,020	128	46,848	16,222	7,595,246	360,756	453,724
1977:													
Belgium-Luxembourg	--	--	--	--	--	--	--	--	9,261	117	9,378	690	816
Canada	--	1	--	--	7,917,816	152	842	59	1,582	489	7,920,941	348,050	450,540
Chile	--	--	--	--	--	2,358	42,760	--	--	4,000	49,118	4,406	5,070
China, People's Republic of	--	--	55	--	--	--	--	--	--	33	88	47	69
Cuba	--	--	--	--	2,420	--	--	--	--	--	2,420	102	133
France	--	39	57	44	--	--	--	--	18,860	1,379	20,379	2,074	2,329
German Democratic Republic	--	--	--	--	[2]16,687	--	--	--	--	72	[2]16,759	[2]811	[2]972
Germany, Federal Republic of	3	358	--	486	[1]	--	4	40	28,755	6,406	[2]36,052	[2]6,520	[2]7,364
Israel	--	--	--	--	213,336	19,465	2,485	275	--	37	235,598	11,573	13,590
Italy	443	--	--	[1]	--	--	--	--	11,574	108	12,125	1,357	1,545

Japan	--	15	--	20	--	--	34	--	(1)	2,757	2,826	7,695	8,423
Latvia	--	--	--	--	6,063	--	--	--	--	--	6,063	181	281
Mexico	--	(1)	--	--	190	--	--	--	--	48	238	27	30
Netherlands	--	--	--	--	--	--	--	--	--	1,000	1,000	320	387
Norway	--	--	--	--	--	--	7,898	--	--	--	7,898	766	868
Spain	181	--	1,965	--	55,628	--	--	--	6,007	159	63,940	4,079	4,727
Sweden	--	324	478	--	--	--	--	--	--	2	804	542	625
Switzerland	--	--	7	--	--	--	--	--	--	12	19	69	74
U.S.S.R.	--	--	--	--	17,113	--	--	--	--	20	17,133	849	1,077
United Kingdom	--	--	--	146	--	--	--	--	--	1,481	1,627	1,808	2,050
Other	--	--	--	--	--	--	--	298	--	634	932	269	340
Total	627	737	2,562	696	8,229,253	21,975	54,023	672	76,039	18,754	8,405,338	392,235	501,310

[1]Less than 1/2 unit.
[2]Adjusted by the Bureau of Mines.

WORLD REVIEW

Potash production in North America increased 16% to 9.2 million tons of K_2O equivalent. Total overseas exports increased 19% to 2.29 million tons of K_2O. Areas receiving these imports were Asia, mainly Japan (49%); Latin America, mainly Brazil (36%); Oceania (9%); Western Europe (5%); and Africa (1%). Exports to Latin America increased 31% compared with those of 1976.

Potash production in Eastern Europe increased 1% to 12.8 million tons of K_2O equivalent. Total exports from the two East European producing countries, the U.S.S.R. and the German Democratic Republic, increased 5% to 5.6 million tons of K_2O. Areas receiving these exports were other East European countries (61%); Western Europe (21%); Asia (10%); Latin America (6%); and others (2%).

Potash production in Western Europe, including Israel and the People's Republic of the Congo, increased 4% to 6.0 million tons of K_2O equivalent. Total exports from West European primary producing countries, including Israel and the People's Republic of the Congo, increased 35% to 2.8 million tons of K_2O. Areas receiving these exports were Western Europe, 53%; Asia, 18%; Africa, 11%; Latin America, 8%; North America, 7%; Eastern Europe, 2%; and Oceania, 1%.

Total world shipments to nonproducing countries including Italy and the United Kingdom increased 15% to 10.1 million tons of K_2O equivalent; receiving areas were Eastern Europe, mainly Poland, (34%); Western Europe, (24%); Asia, mainly Japan and India, (21%); Latin America, mainly Brazil, (14%); Africa, mainly the Republic of South Africa, (4%); and Oceania, 3%. Imports into Brazil, the market economy world's largest nonproducing importer, increased 25% to 1.03 million tons of K_2O. Imports into Japan, the second largest nonproducing importer in the market economy world, increased 16% to about 80,000 tons of K_2O.

Total 1977 exports of potassium sulfates from Europe decreased 9% to about 610,000 tons of K_2O; of this, 39% was shipped to nonproducing West European countries and 16% went to Asia.

Brazil.—The French firm, Entreprise Minière et Chimique, signed an agreement in November with Petróleo Brasileiro S.A. (Petrobras), the Brazilian national oil company, under which Mines de Potasse d'Alsace will give technical assistance in the exploitation of potash deposits in Sergipe in northeastern Brazil. In 1976, Petrobras had acquired full control of this long-delayed project through its new subsidiary Petrobras Mineração S.A., and had sought participation with and conducted negotiations with several world firms including three U.S. potash producers. Brazil's domestic demand for potash and negative trade balance suggested development of a domestic potash industry, despite technical difficulties expected because of the nature of the potash deposits. Three types of deposits have been identified. The extensive carnallitic deposit may require solution-mining techniques and unusual beneficiation methods. Two rich sylvinite deposits of more limited extent have been discovered, but one is irregular and the other is underlain with hygroscopic and mechanically weak tachyhydrite. Plans were made to begin geological studies immediately, including rock mechanics of the deposits and pilot mining and processing studies.

Canada.—Potash production in Canada, all muriate, increased 22% to 6.7 million tons of K_2O equivalent, according to the Potash/Phosphate Institute. Exports to the United States increased 5% to 4.7 million tons of K_2O. Overseas exports increased 38% to 1.36 million tons of K_2O. Areas receiving these exports were Asia (70%), Latin America (20%), and other (10%). Yearend producers' stocks increased by 423,000 tons to 1.3 million tons of K_2O. Estimated domestic consumption in Canada increased about 11% to approximately 320,000 tons of K_2O.

Table 12.—Salient statistics on Canadian potash

(Thousand short tons of K_2O equivalent)

	1976	1977
Production	5,507	6,712
Sales to North American customers	4,716	4,902
Exports		
United States	r4,471	4,690
Overseas	987	1,358
Imports for consumption[e]	22	34
Domestic consumption[1]	r267	286
Yearend producers' stocks	881	1,304

[e]Estimate. [r]Revised.
[1]Canadian potash only.

Source: Potash/Phosphate Institute, Atlanta, Ga.

The Saskatchewan Provincial Government continued acquisition of that Province's potash industry by purchase of two more mines owned by Alwinsal Potash of Canada, Ltd., and Sylvite of Canada, Ltd., respectively. A firm agreement was established by yearend to acquire Amax Potash Ltd.'s reserves and its service contract with International Minerals & Chemical Corp. (Canada) Ltd. to mine and beneficiate potash. A firm agreement was established at yearend to acquire 60% of the mine and plant owned by A.P.M. Operators Ltd.; 40% would continue to be owned by Texasgulf, Inc. These acquisitions would give the Province control of five separate operations, and with capacity expansions of the Government's units totaling about 300,000 tons (scheduled for 1979) the acquisitions would give the Government direct control of about 40% of the Province's potash industry.

The Supreme Court of Canada reserved judgment in December on the constitutionality of the prorationing legislation enacted by the Saskatchewan Government in 1969. An appeal had been filed by Central Canada Potash Ltd. and the Canadian Federal Government in January, immediately following a ruling by the Saskatchewan Court of Queen's Bench that prorationing was constitutional.

A suit against the Saskatchewan Government challenging the constitutionality of the heavy reserves tax remained stalled during the year. The suit had been filed in Saskatchewan Court of Queen's Bench in July 1975 by nine Saskatchewan potash producers. The acquisition of three producers and the pending acquisition of two others left only four independent producers at yearend in this case. A somewhat similar suit filed in the same court in June 1976 by the nine producers challenged the constitutionality of the reserves tax and the prorationing tax on the basis that they were royalty payments and, therefore, represented breaches of the original contracts made between the producers and the Saskatchewan Government when the individual companies first began to produce potash in Saskatchewan. The suit also remained stalled pending the outcome of the other two suits described.

In November, Canada's Supreme Court ruled that Saskatchewan's oil royalties were unconstitutional because the Province was attempting to regulate the price of an export commodity, an exercise constitutionally under the jurisdiction of the Federal Government. This case had clear implications in the litigation affecting the Saskatchewan potash industry. At yearend, the Saskatchewan Provincial Government indicated its intention to enact retroactive legislation to protect itself against the Supreme Court decision.

After 4 years of exploration, Potash Co. of America announced in October plans to construct a muriate of potash mine-mill unit in New Brunswick, Canada, at an estimated cost of $106 million. The unit would produce about 600,000 tons per year of K_2O. A mining lease was granted by the Provincial Government of New Brunswick under which the Province would collect a royalty of 6-1/4% of the value of the product loaded on cars. The agreement, which would be in effect for 21 years, would be thrice renewable and could be incrementally extended to a total period of 84 years. The agreement also would allow the Government to take up to 25% equity in the venture at some future date. The plant, the first North American unit since the Sylvite operation began in 1970 in Saskatchewan, was scheduled to go onstream in late 1981 at about 70% capacity. Construction was scheduled to begin in early 1978 about 15 miles east of Frederickton. Approximately one-third of the product would go by rail to the Eastern United States and Canada; the remainder would be shipped to world markets. The bulk of the high-grade sylvinite deposit was reported to be in one bed 15 to 70 feet thick and approximately 5 miles long. Reserves were estimated to be sufficient for a mine life of at least 20 years.

International Minerals & Chemical Corp. indicated in a preliminary development plan submitted to the Provincial Government of New Brunswick that another year or two of exploration was required to establish production feasibility of mining in New Brunswick. The deposit, in the same area of New Brunswick as the planned Potash Co. of America mine, has an unusual configuration with variations in grade and thickness and, therefore, may require unusual mining techniques. It must be determined whether the salt covering the sylvinite bed is of sufficient thickness for mine safety. Solution mining was considered and abandoned because of its high energy intensity and low extraction efficiency. Estimated reserves were reported to be 12 to 32 million tons of K_2O equivalent.

Chile.—In March, the Government-owned Corporación de Fomento de la Producción signed an agreement to produce

Table 13.—World

(Thousand short tons

Importing areas	Exporting									
	Canada		France[2]		German Democratic Republic		Germany, Federal Republic of		Israel	
	1976	1977	1976	1977	1976	1977	1976	1977	1976	1977
Africa:										
South Africa, Republic of	20	24	65	50	--	--	48	44	24	48
Other	--	(4)	56	66	3	17	4	7	11	21
Total Africa	20	24	121	116	3	17	52	51	35	69
Asia:										
China, People's Republic of	--	33	--	--	21	--	--	--	--	--
India	93	150	--	--	135	205	97	166	--	--
Japan	315	425	31	29	23	15	52	54	34	49
Korea, Republic of South	103	148	--	3	--	--	--	3	--	--
Malaysia	50	84	--	--	--	21	--	--	44	83
Philippines	27	34	--	--	--	3	1	1	1	2
Taiwan	100	33	--	(4)	--	--	--	--	--	--
Other	28	38	22	52	44	53	21	19	--	2
Total Asia	716	945	53	84	223	297	171	243	79	136
Latin America:										
Brazil	142	265	31	33	137	160	67	60	19	47
Cuba	--	--	--	--	68	85	7	--	--	--
Mexico	(4)	--	--	--	--	--	--	--	--	--
Other	21	7	2	12	16	36	12	21	2	--
Total Latin America	163	272	33	45	221	281	86	81	21	47
North America:										
Canada	XX	XX	--	--	--	--	--	--	--	--
United States	4,442	4,627	--	21	--	--	22	6	53	142
Total North America	4,442	4,627	--	21	--	--	22	6	53	142
Oceania:										
Australia	59	52	--	--	--	--	1	1	--	--
New Zealand	--	13	--	(4)	--	--	2	1	--	--
Other	--	--	--	--	--	--	--	2	--	--
Total Oceania	59	65	--	(4)	--	--	3	4	--	--
Western Europe:										
Austria	--	--	5	9	66	82	45	52	--	--
Belgium	--	--	60	67	7	14	46	87	11	3
France	--	--	XX	XX	25	36	13	33	--	99
Ireland	--	--	38	45	47	53	46	39	18	25
Italy	21	22	62	54	38	77	6	32	70	75
Netherlands	--	--	29	62	35	47	42	68	20	17
Scandinavia	--	--	5	55	93	78	199	107	24	30
United Kingdom	8	1	38	43	169	167	83	60	46	63
Other	--	30	75	101	79	141	14	76	--	21
Total Western Europe	29	53	312	436	559	695	494	554	189	333
Eastern Europe:										
Czechoslovakia	--	--	--	3	532	510	--	3	--	--
Hungary	--	--	--	--	295	312	8	3	--	--
Poland	--	--	--	6	506	506	14	12	--	--
Yugoslavia	--	--	--	--	123	139	6	9	--	--
Other	--	--	5	8	74	113	3	6	--	--
Total Eastern Europe	--	--	5	17	1,530	1,580	31	33	--	--
World total	5,429	5,986	524	719	2,536	2,870	859	972	377	727

XX Not applicable. [e]Estimate. [r]Revised.

[1]Data supplied by the International Phosphate Industry Association (ISMA, Ltd.), Paris, France.

[2]Includes Congolese exports.

[3]Excludes 1977 exports of potassium magnesium sulfate from the United States.

[4]Less than 1/2 unit.

[5]Scandinavian imports from France, the Federal Republic of Germany, and Israel taken from Phosphorus and Potassium, No. 85, October/November 1976, published by the British Sulphur Corp., Ltd.

trade in potash[1]

of K_2O equivalent)

countries											
Italy		Spain		United States[3]		U.S.S.R.		Total[3]			
1976	1977	1976	1977	1976	1977	1976	1977	1974	1975	1976	1977
--	--	13	10	3	--	--	--	201	202	173	176
29	30	27	41	--	2	--	--	140	130	130	184
29	30	40	51	3	2	--	--	341	332	303	360
--	--	--	7	--	--	--	--	160	106	21	40
--	--	--	--	--	--	3	46	463	231	328	567
--	--	2	3	106	65	133	159	948	986	696	799
3	--	--	--	15	12	--	--	206	322	121	166
--	--	--	5	19	3	--	28	67	83	113	224
--	--	--	--	18	1	--	7	68	51	47	48
--	--	--	--	1	50	--	--	118	99	101	83
5	9	--	13	2	--	37	31	155	155	159	217
8	9	2	28	161	131	173	271	2,185	2,033	1,586	2,144
--	--	12	26	377	380	43	57	702	569	828	1,028
--	--	--	--	--	--	68	19	128	132	143	104
--	--	11	--	70	48	--	--	56	70	81	48
5	12	17	23	73	102	--	--	235	134	148	213
5	12	40	49	520	530	111	76	1,121	905	1,200	1,393
--	--	--	--	r22	34	--	--	28	20	r22	34
6	--	16	34	XX	XX	--	14	4,367	3,702	4,539	4,844
6	--	16	34	r22	34	--	14	4,395	3,722	r4,561	4,878
--	--	--	--	37	44	--	--	138	109	97	97
--	--	--	--	156	99	17	36	175	123	175	149
--	15	--	--	--	--	--	--	--	--	--	17
--	15	--	--	193	143	17	36	313	232	272	263
--	--	--	--	--	--	36	55	230	166	152	198
--	--	15	16	6	7	108	134	768	324	253	328
--	--	--	4	--	--	20	24	204	147	58	196
--	--	9	4	3	3	--	5	114	119	161	174
XX	XX	8	6	--	--	35	60	228	247	240	326
--	--	7	8	--	--	40	36	210	160	173	238
--	--	42	43	18	19	118	96	513	[5]585	499	428
--	--	43	39	14	12	79	74	442	415	480	459
12	8	41	39	--	9	--	2	186	212	221	427
12	8	165	159	41	50	436	486	2,895	2,375	2,237	2,774
--	--	--	--	--	--	169	166	521	762	701	682
--	--	--	--	--	--	242	237	397	597	545	552
--	--	--	3	--	--	1,214	1,244	1,481	1,751	1,734	1,771
--	--	--	--	--	--	73	87	314	158	202	235
--	3	--	--	--	--	105	89	91	157	187	219
--	3	--	3	--	--	1,803	1,823	2,804	3,425	3,369	3,459
60	77	263	324	r940	890	2,540	2,706	14,054	13,024	r13,528	15,271

Table 14.—World trade in sulfates of potash[1 2]

(Thousand short tons of K_2O equivalent)

Importing areas	Exporting countries: France[3] 1976	France[3] 1977	German Democratic Republic 1976	German Democratic Republic 1977	Germany, Federal Republic of 1976	Germany, Federal Republic of 1977	Italy 1976	Italy 1977	Spain 1976	Spain 1977	United States[4] 1976	United States[4] 1977	Total[4] 1974	Total[4] 1975	Total[4] 1976	Total[4] 1977
Africa:																
Algeria	--	--	--	--	--	--	17	24	11	23	--	--	30	38	28	47
Morocco	8	6	--	3	--	--	5	2	10	6	--	--	21	28	23	17
South Africa, Republic of	4	6	--	--	19	18	--	--	--	--	--	--	30	33	23	24
Other	8	9	--	--	--	2	7	4	--	1	--	--	2	1	15	16
Total Africa	20	21	--	3	19	20	29	30	21	30	--	--	83	100	89	104
Asia:																
Japan	27	29	--	--	17	25	--	--	--	--	40	38	115	122	84	92
Korea, Republic of	--	3	--	--	--	3	3	--	--	--	15	12	5	24	18	18
Other	3	9	--	3	12	9	5	9	--	7	2	4	9	15	22	41
Total Asia	30	41	--	3	29	37	8	9	--	7	57	54	129	161	124	151
Latin America:																
Brazil	5	--	1	2	3	3	--	--	2	--	16	6	21	19	27	11
Colombia	--	--	--	--	--	--	--	--	--	2	2	6	6	14	2	8
Cuba	3	--	7	14	6	--	--	--	--	--	--	--	16	15	16	14
Mexico	--	--	--	--	--	--	--	--	2	--	15	9	6	9	17	9
Other	--	12	--	--	--	7	5	12	--	--	11	10	25	9	16	41
Total Latin America	8	12	8	16	9	10	5	12	4	2	44	31	74	66	78	83
North America:																
Canada[e]	--	--	--	--	--	--	--	--	--	--	[r]19	20	28	15	[r]19	20
United States	13	10	--	--	22	6	6	--	--	--	XX	XX	27	39	41	16
Total North America	13	10	--	--	22	6	6	--	--	--	[r]19	20	55	54	[r]60	36
Oceania	--	(5)	--	--	--	2	--	--	--	--	7	8	8	9	7	10
Western Europe:																
Austria	--	--	6	10	14	12	--	--	--	--	--	--	21	19	20	22
Belgium	NA	18	--	--	21	9	--	--	--	--	--	--	9	16	21	27
Denmark	--	--	--	--	--	1	--	--	--	--	--	--	1	1	--	1
France	[e]68	XX	--	--	5	6	--	--	--	--	--	--	71	50	73	6

Greece	10	10	--	--	7	14	12	8	10	4	--	--	21	16	39	36
Netherlands	29	22	1	2	22	34	--	--	--	--	--	--	59	43	52	58
Norway	43	44	--	--	--	--	--	--	--	--	--	--	53	45	43	44
Sweden	--	--	2	--	13	15	--	--	--	--	--	--	24	16	15	15
Other	30	15	4	2	18	40	--	--	--	--	--	--	52	37	52	57
Total Western Europe	180	109	13	14	100	131	12	8	10	4	--	--	311	243	315	266
Eastern Europe:																
Czechoslovakia	--	--	37	13	--	--	--	--	--	--	--	--	18	13	37	13
Hungary	--	--	26	14	8	3	--	--	--	--	--	--	13	19	34	17
Poland	7	6	10	11	14	12	--	--	--	3	--	--	31	16	31	32
U.S.S.R	--	--	--	--	--	--	--	--	--	--	--	--	--	20	--	--
Yugoslavia	--	--	r4	4	3	2	--	--	--	--	--	--	5	12	7	6
Other	--	--	6	5	--	--	--	3	--	--	--	--	8	7	6	8
Total Eastern Europe	7	6	83	47	25	17	--	3	--	3	--	--	75	87	115	76
World total	258	199	104	83	204	223	60	62	35	46	r127	113	735	720	r788	726

[e]Estimate. [r]Revised. NA Not available. XX Not applicable.
[1]Data spplied by ISMA, Ltd., Paris, France.
[2]Includes potassium sulfate and potassium magnesium sulfate.
[3]Exports from France also include the exports of potassium sulfate produced in Belgium by the conversion of muriate, essentially of French origin.
[4]Excludes exports of potassium magnesium sulfate from the United States.
[5]Less than 1/2 unit.
[6]Shipment from Belgium to France (see footnote 3).

muriate of potash from brine in the Salar de Atacama, a dry lake bed rich in mineral deposits. The agreement was joint with Foote Mineral Co., which was to invest up to $20 million in plant and facilities to produce coproduct lithium carbonate.

In early 1977, the Government set up a joint venture with Garret Research and Development Co., Inc., to develop an improved commercial process to convert muriate of potash from Salar de Atacama into high-grade potassium nitrate. In addition, the venture was to comprise a study to improve efficiency of recovery of potassium nitrate and other chemicals in existing plants, followed by a design of new plants.

Congo, People's Republic of the.—Serious flooding of the only potash mine in the People's Republic of the Congo in June 1977 terminated potash production in that country. While excavating headings from the existing sylvinite mine into adjacent extensive carnallite beds, a fault was encountered that exposed a dolomite aquifer that overlay the potash deposits. The future of the operation, at Hollé-St. Paul, had already been in doubt; production had been at nearly half capacity for the past few years, and the operation had been economically marginal. The sylvinite lens was more folded than expected and varied in thickness. Consequently, Compagnie Potasses du Congo had decided to begin, with French aid, exploitation of the vast carnallitic deposits adjacent to the sylvinite lens using the existing mine shaft. Deliveries of muriate continued after the flooding using the approximately 100,000 tons of accumulated producers' stocks.

France.—Production of potash decreased only 1% to 1.74 million tons of K_2O, after large reductions in the previous 2 years from a high of 2.51 million tons of K_2O in 1974. Yearend producers' inventories decreased about 90,000 tons of K_2O to about 80,000 tons. Combined exports from France, Belgium, and the People's Republic of the Congo, 61% of which went to Western Europe, increased 37% to about 720,000 tons of K_2O. The French potash industry reportedly was economically marginal. Plans were being made to modernize the industry and thereby increase productivity.

The French Government drew up a plan to dispose of part of the highly saline waste brines from its potash industry by pumping it underground to a depth of approximately 6,000 feet at a location southwest of Mulhouse. Construction of the disposal unit began in 1977 and initial operation, with an estimated capacity of 20 kilograms of chloride ion per second, was expected in 1979. At a December 1976 meeting in Bonn on the Rhine River pollution problem, attended by representatives from France, the Federal Republic of Germany, Luxembourg, the Netherlands, and Switzerland, France agreed to reduce its salt effluent into the Rhine by two-thirds to about 50 kilograms of chloride ion per second.

German Democratic Republic.—Production increased 2% to about 3.6 million tons of K_2O equivalent. Exports increased 13% to about 2.9 million tons of K_2O. Export distribution was 55% to Eastern Europe, mostly to Czechoslovakia and Poland, 24% to Western Europe, 10% to Asia, 10% to Latin America, and 1% to Africa.

Germany, Federal Republic of.—Production increased 15% to 2.58 million tons of K_2O equivalent but remained below the 1974 production peak of 2.89 million tons of K_2O. Potash producers' stocks continued to be controlled and held at a near normal level. Domestic consumption increased approximately 6% to about 1.6 million tons of K_2O. Exports, 23% of which was sulfates, increased 13% to 970,000 tons of K_2O; the export breakdown, by world area, was 56% to Western Europe, 26% to Asia, 9% to Latin America, 6% to Africa, and 3% to others.

Israel.—Installation of compactors for converting standard-grade muriate into granular grade began in an attempt to improve Israel's lagging export market. Contracts were reportedly signed with several U.S. firms allowing average yearly exports to the United States of approximately 300,000 tons of K_2O equivalent of muriate during the next 10 years. The first experimental batches of granular-grade muriate were expected to be shipped to the United States in early 1979. Exports of potash nearly doubled to about 730,000 tons of K_2O. Production of muriate increased 4% to about 790,000 tons of K_2O. Producers' stocks of muriate remained high, approximately 400,000 tons of K_2O.

Jordan.—A $425 million contract was signed November 7, 1977, requiring Jacobs Engineering Group, Inc., to design and construct, for Arab Potash Co., a complex for extracting 0.8 million tons (K_2O equivalent) per year of muriate of potash from Dead Sea brines. The complex, scheduled to become operational in 1982, was to consist of about 40 square miles of solar evaporation ponds, a beneficiation plant, and infrastructure including a 6-mile-long canal from the lake to the ponds, a slurry pipeline from the ponds to the plant, a town, roads from the complex to the port of Aqaba (120 miles), and to the capital city of Amman (50 miles), and storage and shiploading facilities at Aqaba. Construction of the pond system was scheduled to begin in early 1978 east of the south end of the lake. Financing had not been detailed at yearend, but 51% of the Arab Potash Co. was to be owned by the Jordanian Government and 25% by the Arab Mining Co. The complex was to be operated by the Arab Potash Co., a Jordanian firm formed in 1956 to exploit the potash resource of the Dead Sea.

Mexico.—The Mexican Federal Government revealed its interest in developing a domestic potash industry to relieve its dependence on foreign imports, about 50,000 tons per year of K_2O, mostly muriate from the United States. Potash resources, sylvinite and carnallite, in sufficient quantity for commercialization have been identified in the Tancamichapa Salt Dome, south of Coatzocoalcos in Veracruz State. Exploratory drilling was underway in 1977 in the Cuchillo Parado salt structure in northeastern Chihuahua State about 150 miles from Carlsbad, N. Mex. A study was also underway to produce muriate from geothermal waters at the geothermal powerplant in Cerro Prieto, Baja, California Norte, south of Mexicali.

Spain.—Spanish potash production continued to increase in 1977, rising 5% to about 620,000 tons of K_2O equivalent. Mine modernization proceeded in Catalonia. In Pamplona, the State-owned Potasas de Navarre determined that recovery of potash from carnallite was uneconomical. Exports, 49% to Western Europe, increased 23% to about 320,000 tons of K_2O equivalent.

Thailand.—The Thailand Department of Mineral Resources (DMR) completed a 63-hole potash exploration program in the two evaporite basins of eastern Thailand. Most of the holes showed carnallite and many showed sylvinite. The drillings indicated two relatively shallow high-grade sylvinite deposits that may have commercial possibilities if they prove sufficiently extensive. In October, the DMR invited a limited number of private western-nation companies to submit proposals for further exploration and eventual development of Thailand's potash resources.

U.S.S.R.—Estimated production remained at about 9.2 million tons of K_2O equivalent. Construction of three large potash plants, Soligorsk 4, Berezniki 4, and Novosolikamsk, continued. A French firm won a contract to build, at Soligorsk, a dissolution-recrystallization plant for beneficiating sylvinite ore for production of muriate of potash at a rate of about 100 tons per hour of K_2O equivalent. Japanese and French firms bid on construction, at Berezniki, of a 1.3-million-ton-per-year K_2O equivalent plant at an estimated cost of about $200 million. Rail transportation problems continued. Assignment of rail cars for potash transport had low priority compared with grain shipment.

Reported exports for 1977 increased 7% to 2.7 million tons of K_2O equivalent. Export distribution was 67% to Eastern Europe, mostly Poland, 18% to Western Europe, 10% to Asia, and 5% to other areas. Trial shipments of granular-grade muriate, manufactured in the U.S.S.R. by compaction of fine material in recently purchased roll-type compacters, were made to the United States in 1977. The particles were broken and dusty upon arrival and the material was sold as standard grade. The common uncompacted Soviet muriate shipped to the United States in 1977 was finer and dustier than the standard North American grade. Attempts to improve material quality and transportation continued in the U.S.S.R. Port facilities at Ventspils and Odessa were being improved.

Negotiations were underway in late 1977 between Occidental Petroleum Co. and the U.S.S.R. to finalize an agreement, reached preliminarily in 1974, to exchange U.S. superphosphoric acid for U.S.S.R. potash, urea, and ammonia over a 20-year period. U.S. agriculture would absorb most of the potash, which could reach 1 million tons per year. A similar 10-year agreement involving an annual exchange of 1 million tons of U.S.S.R. muriate for U.S. triple superphosphate, supplied by Agrico Chemical Co., was under consideration during 1977.

Construction of solar evaporation ponds began in the Gulf of Karabogaz on the Caspian Sea to produce a crystalline evaporite that would be refined to produce potassium sulfate. Recovery was to be increased by introduction of muriate of potash into plant streams. Annual production of potassium sulfate was expected to reach approximately 70,000 tons of K_2O equivalent by about 1980. Karabogaz already had an established capability for production of commercial quantities of sodium and magnesium salts.

United Kingdom.—Operating difficulties continued in Cleveland Potash Ltd.'s Boulby mine in northern Yorkshire. These included irregularities in bed geometry and ore quality, methane pockets, and a mine temperature of near 100°F. Many of the problems were alleviated in 1977 by development of a novel horizontal drilling technique that allowed definition of seam configuration and quality 1,000 yards ahead of the mining operation. Methane pockets occurring in shale horizons within the potash seam were detected, in a separate development, by drilling 100 yards ahead of the mining. Operation of continuous miners aided in nearly doubling the 1977 output to 90,000 tons of K_2O equivalent. The production rate, which reached 160,000 tons per year by yearend, was estimated to reach about 300,000 tons per year of K_2O, approximately 50% of rated capacity, by mid-1978. The parent companies, Charter Consolidated Ltd. and its partners, mainly Imperial Chemicals Ltd., announced a further capital investment of about $35 million for a total of about $180 million in the Boulby mine. A second mine shaft was installed by February to complete mine construction. It was announced that a major priority in 1978 would be to develop more working areas underground. A thick sylvinite bed containing 5 million tons of 30%-K_2O ore was delineated. Cooling of the working areas was undertaken by installation of 13 water-spray units.

Domestic consumption increased slightly in 1977 to about 510,000 tons of K_2O. Most of British potash supply was imported from the German Democratic Republic, the Federal Republic of Germany, Spain, and the U.S.S.R., in order of volume.

Whitby Potash Ltd., after its acquisition in early 1977 by Consolidated Gold Fields Ltd., appealed again in 1977 for a second planning permit for potash mining in the North York Moors National Park. Whitby had explored for potash and built a pilot solution-mining unit in the area during the early 1970's. However, the previous planning permit had expired in 1976, and an application for renewal had been denied in early 1977 on environmental grounds. The latest application was for further exploration with the ultimate goal of building a 300,000-ton K_2O-equivalent muriate solution mining complex. A rich, 26-foot-thick sylvinite bed had been partially outlined at a depth of about 4,500 feet. Based on 20 exploratory holes drilled previously, a mine life of 50 years had been estimated. A public hearing on the permit application was scheduled for February 1978.

Table 15.—Marketable potash: World production by country

(Thousand short tons of K_2O equivalent)

Country[1]	1975	1976	1977[p]
Canada	5,992	5,507	6,712
Chile	13	16	[e]18
China, People's Republic of[e 2]	[r]330	[r]330	330
Congo	[r]315	280	89
France	2,116	1,764	[e]1,740
German Democratic Republic	3,328	3,484	3,559
Germany, Federal Republic of	2,450	2,244	2,581
Israel	[r]789	761	793
Italy	[r]155	154	166
Spain	506	590	621
U.S.S.R	8,757	9,161	9,201
United Kingdom	17	50	89
United States	2,501	2,400	2,457
Total	[r]27,269	26,741	28,356

[e]Estimate. [p]Preliminary. [r]Revised.

[1]In addition to the countries listed, Australia apparently produced small quantities of marketable potash during 1975-77, but output was not reported quantitatively, and general information was inadequate for the formulation of reliable estimates of output levels.

[2]Data for year ending June 30 as reported in the British Sulphur Corp., Ltd., Statistical Supplement No. 16, November-December, 1977, London, pp. 18-19.

TECHNOLOGY

A continuous 100-pound-per-hour potash process investigation unit was designed and built by the Bureau of Mines in 1977 to evaluate selected flocculation techniques for removing insoluble slimes from potash ore. Shakedown testing using a high-insoluble-content potash ore containing 14% K_2O and 5.5% insolubles indicated that four flotation stages were required for insolubles flotation. One cell was sufficient for subsequent flotation of sylvinite from halite. Tests showed that the system was capable of removing 87% of the insoluble slimes and that 74% of the K_2O could be recovered as 61%-K_2O muriate in the subsequent sylvinite flotation operation. Most of the potash loss was due to nonflotation of coarse particles of sylvite.

The Alumet Co. operated a pilot plant in Utah for production of alumina, sulfate of potassium, and sulfuric acid by roasting alunite. An environmental impact statement for a proposed commercial plant in Beaver county, Utah, was approved by the Bureau of Land Management. The $500 million facility would be tied in with phosphate fertilizer production whereby the byproduct acid would be reacted with phosphate rock mined in Idaho. Estimated annual yield would be 500,000 tons alumina, 200,000 tons of K_2O equivalent as sulfate of potash, up to 1.7 million tons of phosphate fertilizer, and up to 20,000 tons of aluminum fluoride. The Alumet group, consisting of Earth Sciences, Inc., National Steel Corp., and Southwire Co. was seeking funding for the project at yearend.

[1]Physical scientist, Division of Nonmetallic Minerals.

Pumice and Volcanic Cinder

By A. C. Meisinger[1]

Although U.S. output of pumiceous materials declined in quantity by 3% in 1977, value of production rose 14% to a record high of $12 million compared with that of 1976. The combined quantity from 197 operations in four States (Arizona, California, Nevada, and Oregon) was equal to 3 million tons, or 75% of total domestic output sold or used by producers. The quantity of volcanic cinder and scoria produced in 1977 was 12% less than that in 1976, but the output of pumice and pumicite sold or used established record levels of 1.18 million tons and $4.6 million.

Combined use of pumiceous materials for road construction and maintenance and concrete admixtures and aggregate continued as the principal end uses and comprised 84% of total domestic consumption (excluding imports) compared with 79% in 1976.

Average values for all end-use categories increased over those of 1976, and the weighted average of domestic pumiceous materials output was $2.98 per ton, compared with $2.53 per ton the previous year.

Both imports and exports of pumice and pumicite increased significantly in tonnage and value. Canada, Israel, and France were the principal export destinations, and Greece continued to be the major source for imported pumice and pumicite.

DOMESTIC PRODUCTION

Domestic production of pumiceous materials in 1977 totaled 4.0 million tons valued at a record $12 million (previous record high was $11.2 million in 1975). Compared with 1976 output, the quantity of pumiceous materials produced in 1977 decreased 3% but the value increased 14%.

Domestic output came from 92 individuals, firms, and governmental agencies producing from 253 operations in 12 States, compared with 93 producers and 259 operations in 11 States in 1976. California led all producing States in number of active operations with 101, followed by Oregon with 67, and Arizona with 22. The combined output of pumiceous materials from four States (Arizona, California, Nevada, and Oregon) was nearly 3 million tons, or 75% of the national total. Other States with significant output levels in 1977 were Hawaii and New Mexico.

Although volcanic cinder, including scoria, was produced in 10 of the 12 States and in American Samoa, and comprised 71% of the total domestic output of pumiceous materials in 1977, the quantity sold or used (2.8 million tons) was under 3 million tons for the first time since 1971. The 12% decline in the quantity of volcanic cinder mined in 1977 was attributed primarily to a 23% and 34% decrease in output from Arizona and Hawaii operations, respectively. Domestic output of pumice and pumicite in 1977, however, increased significantly for the second straight year (table 1) and established record levels in quantity (1.18 million tons) and value ($4.6 million). The previous record highs were 1.16 million tons in 1964 and $4.2 million in 1961. The 30% increase in domestic output of pumice and pumicite over that in 1976 (49% over that of 1975) mainly reflected the response of domestic producers to the increased demand for pumice and pumicite in abrasive applications, building block, and construction aggregate, and the smallest quantities of competitive grades imported in recent years.

CONSUMPTION AND USES

Total consumption (quantity sold or used) of domestically produced pumiceous materials declined only 3% from that of 1976. The combined quantity of pumice, pumicite, volcanic cinder, and scoria used for road construction and concrete admixtures and aggregate in 1977 increased from 3.27 million tons in 1976 to 3.38 million tons, and accounted for 84% of total U.S. consumption. End uses for the remaining 16% were landscaping (8%), other uses including abrasives (about 6%), and railroad ballast, (2%). Pumiceous materials used as roofing granules accounted for 54% of the total quantity and 55% of the total value of "Other uses" shown in table 3.

The quantity of pumiceous materials used in concrete admixtures and aggregate and in landscaping increased 28% and 6%, respectively, over that of 1976, but the quantity used for abrasive applications decreased 10%; that used in road construction and maintenance, 13%; in railroad ballast, 70%; and for "Other uses", 15%. The very significant decrease in railroad ballast use in 1977 was attributed primarily to the closing of the Atchison, Topeka, and Santa Fe Railway Co. volcanic cinder pit in Arizona during the year.

Table 1.—Pumice, pumicite, and volcanic cinder sold or used in the United States[1]

(Thousand short tons and thousand dollars)

Year	Pumice and pumicite		Volcanic cinder		Total	
	Quantity	Value	Quantity	Value	Quantity	Value
1973	824	3,612	3,113	5,269	3,937	8,881
1974	873	3,669	3,064	5,452	3,937	9,121
1975	790	3,493	3,102	7,710	3,892	11,203
1976	906	3,830	3,228	6,636	4,134	10,466
1977	1,178	4,625	2,831	7,340	4,009	11,965

[1]Values f.o.b. mine or mill.

Table 2.—Pumice, pumicite, and volcanic cinder sold or used by producers in the United States, by State

(Thousand short tons and thousand dollars)

State	1976		1977	
	Quantity	Value	Quantity	Value
Arizona	802	1,240	621	1,226
California	705	3,245	636	3,838
Hawaii	330	636	260	574
Montana	5	8	5	7
Nevada	388	763	656	1,154
New Mexico	486	1,560	457	1,835
Oklahoma	1	W	1	W
Oregon	1,125	2,311	1,083	2,429
Utah	164	264	W	W
Washington	--	--	W	W
Other States[1]	128	439	290	902
Total	4,134	10,466	4,009	11,965
American Samoa	47	30	1	10

W Withheld to avoid disclosing individual company confidential data. Included with "Other States."
[1]Colorado, Idaho, Oklahoma (value only), Utah (1977), and Washington (1977).

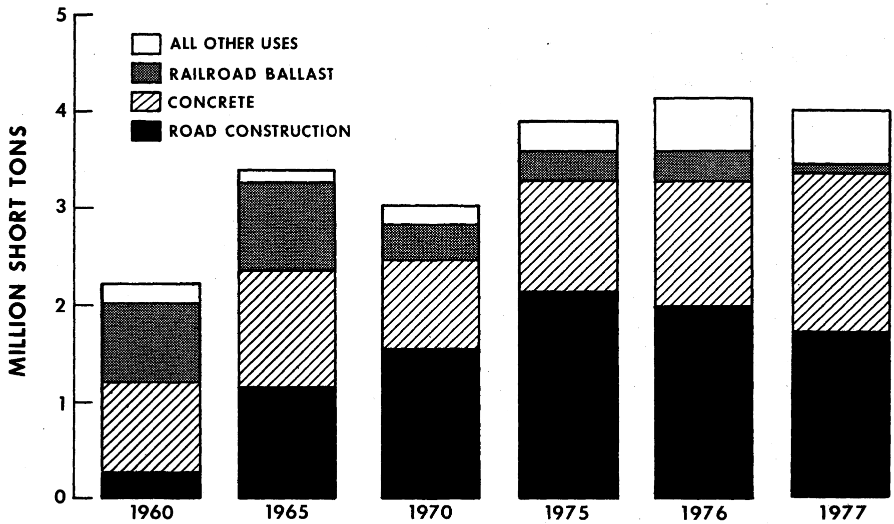


Figure 1.—Pumice and volcanic cinder sold or used by producers in the United States, by use.

Table 3.—Pumice, pumicite, and volcanic cinder sold and used by producers in the United States, by use

(Thousand short tons and thousand dollars)

Use	1976 Quantity	1976 Value	1977 Quantity	1977 Value
Abrasives (includes cleaning and scouring compounds)	29	706	26	749
Concrete admixture and concrete aggregate	1,293	3,397	1,659	4,487
Landscaping	302	1,340	320	1,853
Railroad ballast	310	422	94	192
Road construction (includes ice control and maintenance)	1,980	3,119	1,722	2,990
Other uses[1]	220	1,482	188	1,694
Total	4,134	10,466	4,009	11,965

[1]Includes absorbents, heat-or-cold insulating medium, roofing granules, soil conditioners, and miscellaneous uses.

PRICES

The weighted average value of pumiceous materials produced domestically in 1977 was $2.98 per ton, an 18% increase compared with that of 1976. The average value for crude material increased from $1.20 per ton to $1.43 per ton, and that for prepared material increased from $4.15 per ton to $4.38 per ton.

Average prices per ton for pumiceous materials in all major uses were higher in 1977 compared with those of 1976. The average price of pumiceous materials used for abrasives (including cleaning and scouring compounds) was $28.81 per ton, a $4.47 increase; for concrete admixtures and aggregate, $2.70, a $0.07 increase; for landscaping, $5.79, a $1.35 increase; for railroad ballast, $2.04, a $0.68 increase; for road construction material, $1.74, a $0.16 increase; and for all other reported uses, $9.01, a $2.27 increase.

Quoted prices for pumice and pumicite in trade publications in 1977 were as follows: Quoted prices at yearend in the American Paint and Coatings Journal, per pound, bagged, f.o.b. New York or Chicago, were $0.0445 to $0.02 ($0.0445 to $0.08 at yearend 1976) for powdered pumice, and $0.0665 to $0.09 for lump pumice (unchanged from 1976). Quoted prices at yearend in Chemical

Marketing Reporter for domestic grades, bagged in 1-ton lots were for fine, $0.0765 to $0.1140 per pound; medium, $0.1160 per pound; and coarse, $0.094 per pound. Prices for imported (Italian) silk-screened pumice, bagged in 1-ton lots were for fine, $138 per ton; medium, $150 per ton; and coarse, $140 per ton. The price of imported small-lump and large-lump pumice was quoted at $275 per ton.

FOREIGN TRADE

The 3-year decline in exports of pumice and pumicite ended in 1977. Producers shipped nearly 1,800 tons to foreign countries during the year, or 78% more than the quantity exported in 1976. Average value of 1977 exports were $287 per ton compared with $268 per ton the previous year, Canada received most of the exported material (1,428 tons), followed by Israel (116 tons), and France (91 tons).

A substantial increase in imports of pumice and pumicite during the year reversed the rapid 2-year decline that had resulted in 1976 in the lowest quantity imported since 1962. Compared with that in 1976, imports increased over 200% to 253,463 tons. Of the total quantity of pumice imported, Greece supplied 85% and Italy contributed 15%. The bulk of the pumice imported (97%) was used in the manufacture of concrete masonry products, and the quantity was 220% greater than that of 1976.

Table 4.—U.S. exports of pumice

Year	Quantity (short tons)	Value (thousands)
1974	2,911	$1,211
1975	1,252	1,027
1976	1,011	271
1977	1,797	516

Table 5.—U.S. imports for consumption of pumice, by class and country

Country	Crude or unmanufactured		Wholly or partly manufactured		Used in the manufacture of concrete masonry products		Manufactured, n.s.p.f. value (thousands)
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	
1976:							
Austria	--	--	--	--	--	--	$7
Canada	229	$46	--	--	--	--	10
China, People's Republic of	--	--	--	--	--	--	10
Greece	--	--	1	(1)	25,794	$46	1
Italy	3,115	102	1,108	$86	51,154	217	19
Netherlands	--	--	--	--	--	--	9
Other[2]	--	--	(1)	(1)	--	--	14
Total	3,344	148	1,109	86	76,948	263	70
1977:							
Austria	--	--	--	--	--	--	11
Canada	--	--	--	--	--	--	10
Germany, Federal Republic of	1	(1)	(1)	2	--	--	18
Greece	938	8	--	--	215,453	783	1
Italy	5,352	197	964	79	30,755	129	80
Other[3]	--	--	--	--	--	--	13
Total	6,291	205	964	81	246,208	912	133

[1]Less than 1/2 unit.
[2]The Federal Republic of Germany, Japan, Mexico, the United Kingdom, Taiwan.
[3]Japan, Mexico, Switzerland, the United Kingdom.

WORLD REVIEW

Portugal.—Development of pumice deposits on the Island of São Miguel in the Azores was reported to be underway in early 1977.[2] Mining and processing operations were being handled through a joint venture of Francis Concrete, Ltd., of the United Kingdom and PEPON-Sociedade Industrial de Pedra-Pones Dos Açores Lda. Processing installations were completed in January at Ponta Delgada, about 12 miles from the deposit area. Initial washing and screening operations at the plant are rated at 150 tons per hour. Plans to increase capacity to 250 tons per hour by mid-1978 were reportedly being considered.

---

[1]Industry economist, Division of Nonmetallic Minerals.
[2]Industrial Minerals (London). Pumice—a Dual Role in Industry. No. 120, September 1977, p. 20.

Table 6.—Pumice and related volcanic materials: World production by country

(Thousand short tons)

Country[1]	1975	1976	1977[p]
Argentina[2]	75	63	70
Austria: Pozzolan	14	13	10
Cape Verde Islands: Pozzolan[e]	17	17	17
Chile: Pozzolan	[e]165	109	110
Costa Rica[e]	2	1	1
Dominica: Pumice and volcanic ash	117	[e]120	[e]120
Egypt	([3])	[e]([3])	[e]([3])
France: pozzolan and volcanic ash	[r]765	790	[e]780
Germany, West:			
Pumice (marketable)	2,111	2,551	[e]1,875
Pozzolan	144	110	[e]120
Greece:			
Pumice	580	441	626
Pozzolan	[r]938	1,081	1,385
Guadeloupe: Pozzolan	220	[e]220	[e]220
Guatemala: Volcanic ash (for cement)	17	26	[e]27
Iceland	[4]4	[4]2	8
Italy:			
Pumice and pumiceous lapilli	744	[r] [e]750	[e]770
Pozzolan	6,128	[e]6,600	[e]6,600
Martinique: Pumice	86	[e]90	[e]90
New Zealand	42	55	[e]55
Spain[5]	153	[r] [e]155	[e]165
United States (sold or used by producers):			
Pumice and pumicite	790	906	1,178
Volcanic cinder[6]	3,117	3,275	2,833
Total	[r]16,229	17,375	17,060

[e]Estimate. [p]Preliminary. [r]Revised.
[1]Pumice is also produced in a number of other countries, including (but not limited to) Iran, Japan, Mexico, Turkey, and the U.S.S.R. (sizable quantity), but output is not reported quantitatively and available general information is inadequate for the formulation of reliable estimates of output levels.
[2]Unspecified volcanic materials produced mainly for use in construction products.
[3]Less than 1/2 unit.
[4]Exports.
[5]Includes Canary Islands.
[6]Includes American Samoa.

Rare-Earth Minerals and Metals

By Christine M. Moore[1]

Domestic production of rare-earth oxide (REO) contained in bastnäsite and monazite concentrates increased 17% in 1977. Molycorp, Inc., and the Davison Chemical Div. of W. R. Grace & Co., the principal processors of rare earths in 1977, expanded their facilities. Consumption of rare earths increased during the year. Petroleum catalysts remained the major end use, but production and consumption of rare earths for metallurgical uses increased dramatically. The ceramic and glass industries were also major consumers.

Exports of rare earths increased fourfold during the year and imports of monazite nearly doubled. Mischmetal imports also increased.

Legislation and Government Programs.—The General Services Administration (GSA) shipped 2,541 tons REO equivalent, contained in monazite, and 9 and 24 tons REO, respectively, contained in sodium sulfate and rare-earth chloride. Stocks of rare-earth materials held by the Government totaled 4,600 tons REO equivalent at yearend. Government stocks of yttrium oxide (Y_2O_3) remained at 237 pounds during the year.

DOMESTIC PRODUCTION

Concentrate.—Domestic production of REO in bastnäsite and monazite in 1977 increased 17% over the 1976 level. Bastnäsite continued to be the major domestic source of rare earths; the remainder, less than 10%, was produced from monazite.

Molycorp, Inc., the sole domestic producer of bastnäsite concentrate, was acquired by Union Oil Co. of California during the year. According to the company's annual report, production of rare-earth concentrates at Molycorp's Mountain Pass, Calif., operation increased 18% to 16,930 short tons of REO contained in bastnäsite concentrate; production in 1976 was 14,372 tons.

Titanium Enterprises, jointly owned by American Cyanamid Co. and Union Camp Corp., continued to recover monazite as a byproduct of mining a beach sand deposit near Green Cove Springs, Fla., for titanium minerals and zircon. Monazite production during 1977 was more than double the 1976 level.

Humphreys Mining Co. also recovered monazite from heavy-mineral beach sand operations. Humphreys' dredging operation was located near Hilliard, Fla., and the wet, heavy concentrates were trucked to the company's drying plant at Folkston, Ga., for processing. Monazite production by Humphreys decreased significantly during the year due to the mining of titanium sands of lower monazite content.

The U.S. Geological Survey announced the discovery of heavy-mineral sand deposits of potential economic grades in Charleston County, S.C.[2]

Compounds and Metals.—During 1977, Molycorp and the Davison Chemical Div. of W. R. Grace at Chattanooga, Tenn., were the major producers and processors of rare-earth compounds. Molycorp, the principal domestic processor, operated plants at Louviers, Colo., and York, Pa. Production of mixed rare-earth compounds increased during the year.

Producers of high-purity oxides and compounds during the year were Molycorp; W. R. Grace; Nucor Corp., Research Chemicals Div., Phoenix, Ariz.; Reactive Metals and Alloys Corp. (REMACOR), West Pittsburgh, Pa.; and Transelco Div. of Ferro Corp., Penn Yan, N.Y.

Mischmetal production more than doubled in 1977 and shipments of mischmetal increased threefold over the 1976 level. During the year REMACOR and Ronson Metals Corp., Newark, N.J., produced mischmetal. The Rare Earth Metals Co. of America (REMCOA) plant at Arnold, Pa., continued bench-scale studies of mischmetal production during the year, and at yearend the company reportedly decided to postpone plans for full-scale production.

REMACOR announced plans to expand its mischmetal production capacity from 1.2 to 4.0 million pounds per year at a cost of $2 million. Bastnäsite supplied by Molycorp was to be the primary raw material.

Production of rare-earth ferrosilicon alloys by Foote Mineral Co., Exton, Pa., Molycorp, and REMACOR more than doubled during the year.

Molycorp and Research Chemicals were the major processors of yttrium oxide. Research Chemicals also produced other high-purity metals during the year.

Hitachi Magnetics Corp. expanded production capacity for rare-earth-cobalt magnets during 1977 at its Edmore, Mich. plant.

CONSUMPTION AND USES

Domestic rare-earth processors consumed an estimated 15,300 tons of REO contained in raw materials in 1977, an 8% increase from the previous year. Bastnäsite consumption increased 3% and monazite consumption increased 37%. Shipments of rare-earth and yttrium products from primary processing plants to domestic end-use consumers were about 11,000 tons contained REO. High-purity rare-earth and yttrium oxides and metals were about 8% of total shipments, but comprised about 30% of the total value of shipments.

The approximate distribution of rare-earths and yttrium by end use, based on information supplied by primary processors and certain consumers, was as follows: Petroleum cracking catalysts, 41%; metallurgical, including nodular iron and steel, other alloys, and mischmetal, 37%; ceramics and glass, 18%; and miscellaneous, including electrical, arc carbons, and research, 4%.

The use of rare-earth zeolites in cracking catalysts to increase the yield of gasoline from petroleum feedstocks continued to be the single largest use of rare earths. However, a significant increase in the use of rare earths as additives to ductile iron and steel occurred. Production and consumption of mischmetal and rare-earth silicides increased during the year and continued growth of this end use was expected.

The production of lighter and striker flints continued to be a major consumer of mischmetal. Other rare-earth alloys and metals were used in the production of high-temperature alloys and superalloys.

The glass industry continued to be a major consumer of rare-earth compounds, particularly cerium oxide. The established uses of cerium oxide are as an abrasive for polishing glass; as an additive in eyeglasses, television tubes, and camera lenses; and as a decolorizing agent in refining clear glass. Rare-earth oxides of praseodymium, erbium, holmium, and neodymium were used as colorants in glass. Lanthanum oxide was used to improve the refractive quality of camera lenses.

During 1977, an estimated 140 tons of Y_2O_3 contained in raw materials was consumed, a 17% increase over the 1976 level of 120 tons. During the year, production of phosphors for color televisions and fluorescent lights, a major use of Y_2O_3, increased.

Synthetic garnets composed of yttrium-aluminum (YAG), yttrium-iron (YIG), gadolinium-aluminum (GAG), and gadolinium-iron (GIG) were used as microwave filters and control devices, as simulated diamonds, and, when doped with neodymium or erbium, in lasers. Minor quantities of gadolinium-gallium garnets (GGG) in thin-film, magnetic-bubble memory systems were used in communication and computer systems.

Significant quantities of rare-earth oxides and fluorides were used in carbon-arc lamps, which emit a high-intensity white-light used in searchlights and the motion picture industry.

Rare-earth cobalt alloys were estimated to account for 2.5% of the permanent magnet market in 1977. Samarium remained the principal rare earth used in magnets. Samarium-cobalt permanent magnets were used in traveling wave tubes, alternators and generators, line printers, and various missile applications. Research during the year was directed toward the use of mischmetal, which was more readily available at a lower cost, as a substitute for samarium in the magnets.

STOCKS

Stocks of rare earths in all forms, held by 14 rare-earth producing, processing, or consuming companies decreased 18% during 1977.

At yearend 1977, bastnäsite concentrate stocks held by the principal producer and four other processors had decreased slightly from the level at the beginning of the year. Monazite stocks decreased about 35% during the year; stocks of compounds and mixtures of rare earths decreased 23%, and stocks of mischmetal and high-purity metals decreased 50%.

PRICES

The average declared value of imported monazite from Malaysia and Australia decreased from $205 per short ton in 1976 to $164 per short ton in 1977. The average price per short ton of Australian monazite (minimum 60% REO including ThO_2) as quoted in Metal Bulletin (London) was $171 to $186 (A$154 to A$168) until June 1977 when it decreased to $166 to $176 (A$150 to A$159). Quoted prices for Malaysian xenotime, a yttrium-rich rare-earth mineral, remained at the 1976 level of $2 to $3 per pound c.i.f.

Prices for unleached, leached, and calcined bastnäsite containing 55% to 60%, 68% to 72%, and 85% to 90% REO, were increased from 50, 58, and 68 cents per pound REO, respectively, to 65, 70, and 80 cents per pound REO, respectively, at yearend. Yearend prices quoted in the American Metal Market for cerium and lanthanum concentrates were $0.85 and $1.05 per pound, respectively. Mischmetal prices, as quoted in the American Metal Market, were increased from $3.45 per pound at the beginning of the year to $3.95 per pound at yearend.

Rhodia, Inc. of Monmouth Junction, N.J., a subsidiary of Rhône-Poulenc S.A., quoted rare-earth oxide prices per kilogram (2.2046 pounds) f.o.b., New Brunswick, N.J. as follows:

Product	Percent purity	Quantity (kilograms)	Price
Erbium	96	50	$134.00
Europium	99.99	25	1,370.00
Gadolinium	99.99	500	84.75
Lanthanum	99.995	500	12.45
Neodymium	95	1,000	5.15
Praseodymium	96	1,000	30.75
Samarium	96	3,000	[1]18.40
Terbium	99.9	5	895.00
Thulium	99.9	1	3,300.00
Yttrium	99.99	500	73.00

[1]Price increases of 25% each were scheduled effective Sept. 1, 1978 and Jan. 1, 1979.

Nominal prices for various rare-earth materials also were quoted by Research Chemicals in dollars per pound as follows:

Element	Oxide[1]	Salts[2]	Metal[3]
Cerium	$7.50	$12.00	$50.00
Dysprosium	40.00	27.00	130.00
Erbium	45.00	27.00	160.00
Europium	700.00	325.00	3,000.00
Gadolinium	55.00	36.00	220.00
Holmium	120.00	80.00	300.00
Lanthanum	7.25	12.00	50.00
Lutetium	2,000.00	1,000.00	6,000.00
Neodymium	18.00	12.00	110.00
Praseodymium	32.00	16.00	170.00
Samarium	32.00	16.00	155.00
Terbium	350.00	175.00	845.00
Thulium	1,000.00	550.00	2,600.00
Ytterbium	85.00	70.00	240.00
Yttrium	30.00	18.00	150.00

[1]Minimum 99.9% purity, more than 1 pound.
[2]Minimum 99.9% purity, more than 1 pound; includes chlorides, nitrates, sulfates, oxalates, and acetates.
[3]Minimum 1 pound, ingot form.

FOREIGN TRADE

Exports of ferrocerium and other pyrophoric alloys during 1977 totaled 520,955 pounds valued at $1,042,669, compared with 119,792 pounds valued at $334,973 in 1976. During 1977, a threefold increase in exports of rare-earth and yttrium compounds went primarily to the Netherlands (31%), Japan (30%), the United Kingdom (9%), and Norway (7%). Total shipments of rare-earth and yttrium compounds were 1,931,245 pounds valued at $6,038,111.

Imports of monazite during 1977 totaled 5,480 tons, more than double the 2,103 tons received in 1976. Shipments from Australia totaled 3,149 tons.

Imports of cerium oxide tripled during the year to 2,441 pounds from 814 pounds in 1976. Receipts of other cerium compounds decreased 8% from 13,055 pounds in 1976 to 12,021 pounds in 1977. Imports of cerium ore from Australia during the year totaled 15,537 pounds valued at $28,629. Imports of ferrocerium and other pyrophoric alloys increased 14% to 45,876 pounds in 1977, compared with 40,259 pounds in 1976. The average unit value increased from $4.15 per pound in 1976 to $5.72 in 1977. There were no imports of cerium chloride during the year.

Receipts of mischmetal increased dramatically in 1977 to 498,653 pounds, with 44% of the shipments from Austria and 30% from Brazil. The average unit value of mischmetal receipts increased from $1.62 per pound in 1976 to $2.90 per pound in 1977. Receipts of other rare-earth metal alloys from the Federal Republic of Germany increased 10% during the year to 1,147 pounds valued at $23,508. Imports of rare-earth metals, including scandium and yttrium from the U.S.S.R. and the United Kingdom, increased 23% to 91 pounds in 1977, compared with 74 pounds in 1976.

During 1977, the tariff on cerium oxide, cerium chloride, and other cerium compounds was 15% ad valorem. The tariff on mischmetal was 50 cents per pound. There was a tariff of 5% ad valorem on rare-earth and yttrium metal. A tariff of 50 cents per pound plus 6% ad valorem was imposed on ferrocerium and other alloys. Imports of monazite and cerium concentrate remained duty free.

Table 1.—U.S. imports for consumption of monazite

Country	1973		1974		1975		1976		1977	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Australia	--	--	--	--	--	--	--	--	3,149	$491
Malaysia	1,991	$244	984	$154	2,462	$508	2,103	$431	2,331	409
Thailand	110	10	336	47	103	24	--	--	--	--
Total	2,101	254	1,320	201	2,565	532	2,103	431	5,480	900
REO content[e]	1,156	XX	726	XX	1,411	XX	1,157	XX	3,014	XX

[e]Estimate. XX Not applicable.

Table 2.—U.S. imports for consumption of rare-earth metals[1]

Country	1975		1976		1977	
	Pounds	Value	Pounds	Value	Pounds	Value
Germany, Federal Republic of	491	$22,592	--	--	--	--
U.S.S.R	2,659	58,336	--	--	55	$1,875
United Kingdom	57	6,890	74	$9,131	36	9,933
Total	3,207	87,818	74	9,131	91	11,808

[1]Including scandium and yttrium.

WORLD REVIEW

World production of monazite increased 39% over the 1976 level to 17,287 tons in 1977. The largest increase occurred in Australia where production nearly doubled; other countries with increased production included Malaysia and Brazil. Bastnäsite production also increased during the year. France, Japan, the U.S.S.R., the United Kingdom, and the United States remained the only countries to produce a full range of rare-earth compounds and metals during the year.

Australia.—According to the Mineral Sands Producers' Association Ltd., monazite production in short tons was as follows:

State	1975	1976	1977
New South Wales	1,207	1,089	327
Queensland	685	227	683
Western Australia	3,252	3,698	8,636
Total	5,144	5,014	9,646

E. I. du Pont de Nemours & Co., Inc., increased its equity share in Allied Eneabba Pty., Ltd., from 25% to 40%. Allied Minerals N.L. decreased its share in the company from 75% to 60%. Allied Eneabba mined beach sands for monazite at Eneabba, in Western Australia.

Westralian Sands Ltd. merged with Western Mineral Sands Pty., Ltd. and Ilmenite Pty., both owned by Tioxide Australia Pty., Ltd. Tioxide owned 40% of Westralian with the option to increase its share to 51% when Westralian completed a $25 million ilmenite beneficiation plant near Bunbury.

The Wickham separation plant of Rutile and Zircon Mines (New Castle) Ltd. was reportedly inactive during most of the year. A 2-year modernization program at the

Table 3.—Monazite concentrates: World production, by country

(Short tons)

Country[1]	1975	1976	1977[p]
Australia	4,968	5,016	9,646
Brazil	[e]1,600	1,775	[e]2,000
India[e]	3,300	3,300	3,300
Korea, Republic of[e]	10	10	10
Malaysia[2]	3,621	2,071	[e]2,200
Nigeria[e]	20	20	20
Sri Lanka	[e]5	1	[e]5
Thailand	405		
United States	W	W	W
Zaire	328	265	106
Total	14,257	12,458	17,287

[e]Estimate. [p]Preliminary. W Withheld to avoid disclosing individual company confidential data.
[1]In addition to the countries listed, Indonesia and North Korea may produce monazite, but output, if any, is not reported quantitatively, and available general information is inadequate for formulation of reliable estimates of output levels.
[2]Exports.

Cable Sands Pty. Ltd. concentrator at Bunbury was underway.

France.—Rhône-Poulence S.A. announced plans to increase the polishing compounds production capacity at its La Rochelle rare-earth facility to 2,200 tons per year. Total rare earths production capacity at the plant in 1977 was 11,000 tons per year.

Senegal.—NL Industries, Inc. and the Government of Senegal agreed to undertake a feasibility study for the mining of titanium beach sands containing monazite along the Senegal coast. Completion of the study was scheduled for 1979.

United Kingdom.—Johnson Matthey Chemicals Ltd. acquired the remaining 50% equity in Rare Earth Products Ltd. from Rio-Tinto Zinc, Ltd. The plant, located at Widnes, produces rare-earth metals, oxides, and salts.

TECHNOLOGY

Photochemical separation of lanthanides by ultraviolet light from argon fluoride and krypton fluoride lasers was reported.[3] Europium, samarium, and ytterbium as well as elements of the actinide series may be recovered by the process at lower cost than the current separation methods. The new photochemical method also was expected to aid in the reprocessing of nuclear wastes.

Yttria-stabilized zirconium oxide was found to be suitable for use in electrolytic cells for the dissociation of water vapor into hydrogen and oxygen. Ytterbium oxide was found to result in more highly conductive materials for electrolytic cells, but the high cost of the oxide prohibited its use.[4]

The substitution of rare-earth cobalt magnets for Alnico permanent magnets reportedly resulted in lower magnet weight for the same flux density.[5] Response time in line actuators decreased as a result.

Research was conducted on rare-earth oxides as alloying agents for titanium.[6] Lutetium, neodymium, and dysprosium oxides were found to be acceptable for dispersion strengthening of titanium alloys. The addition of yttrium oxide was found to ease metallization of high-alumina bodies with tungsten.

A group of compounds including any one of several rare earths, rhodium, and boron in the general formula $RERh_4B_4$ were found to be superconductors which operate at higher temperatures and magnetic fields than superconducting materials currently in use.[7] Technological improvements and applications of the compounds were discussed.

Cerium was found to provide rust prevention control in steel.[8] The best rust prevention was achieved by fixing all sulfur in the steel as cerium manganese oxysulfide.

High optical sensitivity was observed in cerium-doped strontium barium niobate crystals.[9] Introduction of cerium increased the recording sensitivity and saturation efficiency of the crystals. Use of the crystals in high-speed, rewritable optical memory applications was expected.

The neodymium-doped glass laser at the Lawrence Livermore Laboratory in Livermore, Calif., began operation and proved to be the world's most powerful laser. Room temperature operation of a solid state laser in the blue spectral region was described.[10] The laser used a 0.2% praseodymium-doped $LiYF$ crystal.

Palladium-yttrium alloys were shown to be more permeable to hydrogen than palladium-silver alloys. The alloy was also found to be less susceptible to poisoning by oxidation. More effective utilization of palladium-yttrium alloys in hydrogen diffusion alloys was planned.[11]

Because of their predictable geochemical properties, rare-earth elements were used as tracers of water-rock interactions in hydrothermal systems.[12] The lanthanides reflect changes in their distribution pattern within the deposits depending on the sequence of reactions in the systems.

The Bureau of Mines continued research on rare-earth alloy catalysts, rare-earth oxides additives in refractories, and mischmetal as a replacement for samarium in samarium-cobalt permanent magnets.

A patent was issued for obtaining fluorine-free cerium from bastnäsite ore that had been leached with nitric acid.[13] A patent was issued for an improved reagent for use in the solvent extraction separation of rare earths and yttrium which would permit higher feed solution concentration.[14]

The 13th Rare Earth Research Conference was held at Oglesbay Park, W.Va., in October. The program reviewed all phases of rare-earth research and development and included sessions on solid-state science, spectroscopy, and bioinorganic chemistry. Publication of the proceedings at the October meeting was planned by the Rare Earth Information Center of Ames, Iowa.

[1]Mineral specialist, Division of Nonferrous Metals.

[2]U.S. Department of the Interior, Geol. Survey, News Release. Oct. 13, 1977, 2 pp.

[3]Chemical & Engineering News. V. 55, No. 10, Mar. 7, 1977, p. 16.

[4]Browall, K. W., and R. H. Doremus. Synthesis and Evaluation of Doped Y_2O_3-Stabilized ZrO_2 for the Production of Hydrogen. J. Am. Ceram. Soc., v. 60, No. 5-6, May-June 1977, pp. 262-267.

[5]Rashidi, A. S. Rare Earth Magnets Improve Response in Linear Actuators. Control Eng., v. 24, No. 11, November 1977, pp. 56-58.

[6]Waugh, R. C. Suitable Oxides for Dispersion Strengthening of Titanium Alloys. Internat. J. Powder Met. & Powder Technol., v. 12, No. 2, April 1976, pp. 85-89.

[7]Robinson, A. L. Ternary Compounds: A Promising Way to Make Superconductors. Science, v. 196, No. 4293, May 27, 1977, pp. 966-968.

[8]Shimada, H., Y. Sakakibara, and H. Okada. Rust Prevention Control by Changing Sulfide Type. Corrosion, v. 33, No. 6, June 1977, pp. 196-199.

[9]Yamaji, A., Y. Enomoto, K. Kinoshita, and T. Murakami. Preparation, Characterization, and Properties of Dy-Doped Small-Grained $BaTiO_3$Ceramics. J. Am. Ceram. Soc., v. 60, No. 3-4, March-April 1977, pp. 97-101.

[10]Esterowitz, L., R. Allen, M. Kruer, F. Bartoli, L. S. Goldberg, H. P. Jensen, A. Linz, and V. O. Nicolai. Blue Light Emission by a Pr:$LiYF_4$ Laser Operated at Room Temperature. J. Appl. Phys., v. 48, No. 2, February 1977, pp. 650-652.

[11]Platinum Metals Review. V. 21, No. 2, April 1977, pp. 48-50.

[12]Graf, J. L., Jr. Rare Earth Elements as Hydrothermal Tracers During the Formation of Massive Sulfide Deposits in Volcanic Rocks. Econ. Geol., v. 72, No. 4, June-July 1977, pp. 527-548.

[13]Hafner, L. (assigned to Treibacher Chemische Werke A.G.). Recovery of Fluorine-Free Cerium. U.S. Pat. 4,051,219, Sept. 27, 1977.

[14]Mason, G. W., and S. Lewey (assigned to U.S. Energy Research & Development Administration, now U.S. Department of Energy). Solvent Extraction Separation of Rare Earths and Yttrium. U.S. Pat. 4,016,237, Apr. 5, 1977.

Rhenium

By Larry J. Alverson[1]

There was no rhenium production in 1977 from domestic ore. Consumption decreased about 12% from that of 1976 to 7,300 pounds; however, it was still at a relatively high level. Imports of ammonium perrhenate reached a record high of over 6,000 pounds, or 50% more than in the previous record year of 1976. Prices for both metal powder and compounds declined to the lowest level on record. Bimetallic catalysts continued to be the major use for rhenium domestically and worldwide.

Table 1.—Salient rhenium statistics

(Pounds of contained rhenium)

	1973	1974	1975	1976	1977
Mine production[e]	7,000	5,000	2,000	[r]1,500	--
Consumption[e]	4,400	4,500	6,000	8,300	7,300
Imports (metal and scrap)	1,437	40	59	82	148
Imports (ammonium perrhenate)	[e]3,040	[e]3,287	[e]966	4,047	6,111
Stocks, Dec. 31[e]	20,000	24,000	21,000	[r]18,300	17,300

[e]Estimate. [r]Revised.

DOMESTIC PRODUCTION

There was no rhenium production from domestic sources in 1977; all output was on a toll conversion basis from foreign molybdenite (MoS_2). This was the first year in over 20 years that no rhenium has been produced. Historically, the domestic rhenium industry has had four main producers: Shattuck Chemical Co., a subsidiary of Engelhard Minerals & Chemical Corp.; Kennecott Copper Corp.; M & R Refractory Metals, Inc.; and Molycorp, Inc. In the past few years, only Shattuck and M & R have been actively roasting domestic and foreign MoS_2 concentrates for rhenium recovery. However, Cleveland Refractory Metals, a subsidiary of Kennecott Copper Corp., sold rhenium from accumulated stocks and imports to augment the domestic supply.

CONSUMPTION AND USES

Consumption of rhenium in 1977 decreased about 12% from the record level of 1976, but it was still at a high level compared with the past several years. An estimated 80% went into platinum-rhenium bimetallic catalyst manufacture for use in petroleum-refining operations.

Semiregenerative bimetallic-reforming units in the petroleum industry increased 12% in capacity during the year, to 53.1% of total reforming capacity. This was the first time a single type of bimetallic reformer held over 50% of total reforming capacity. The total for all types of bimetallic reformers was 61.2% of total reforming capacity, the highest ever attained. This follows the trend of the past few years, brought about by the increasing demand for unleaded and low-lead gasolines, production of which is enhanced by bimetallic catalytic reforming.[2]

Eight States have 100% bimetallic-reforming capacity; 22 States have none. The remaining 20 States have bimetallic capacity ranging from 30% (Ohio) to 94% (Mississippi). The trend has been to convert older monometallic units to bimetallic because increasing demand has put a strain on existing production potential.

Most of the increased capacity in catalytic reforming took place in the smaller refineries (less than 200,000 barrels per day (bpd) of crude oil capacity). Reforming capacity in these refineries increased 22% over that of 1976; similar capacity of larger refineries (greater than 200,000 bpd) was virtually unchanged in the same period. However, the total reforming capacity of the larger refineries represented 84% of total reforming capacity.

One of the advantages of platinum-rhenium catalysts is that they can tolerate more carbon than monometallic catalysts and regenerate to comparable carbon levels. One of the Union Oil Co. refineries reported 18 weight-percent carbon on a R16H platinum-rhenium catalyst, after 115 barrels of feed per pound of catalyst at about 96 research octane number (RON); 14 weight-percent on R22, a bimetallic catalyst without rhenium, after 81 barrels per pound at 92 to 96 RON; and 13 weight-percent on R16G platinum-rhenium catalyst, after 117 barrels per pound at 90 to 92 RON. Carbon deposition rates tend to be lower for bimetallic catalysts than for monometallic ones, allowing for operation at lower pressure, lower hydrogen recycle ratio, and higher severity.[3]

The Wynnewood refinery of Kerr-McGee Refining Corp., with a reforming capacity of 7,500 barrels per stream-day, has used a bimetallic platinum-rhenium catalyst for about 8 1/2 years. The charge has been regenerated more than seven times, approaching 800 barrels per pound on the material, and is still performing like fresh catalyst. The initial charge of bimetallic platinum-rhenium catalyst was installed in 1967 in Chevron's El Segundo No. 1 reformer. The catalyst is still in service today. Some has been replaced, but most has gone over 700 barrels per pound, and has been regenerated 15 times. Tests indicate that it is as good as fresh catalyst.

Universal Oil Products (UOP) had over 50 continuous Platforming units onstream or under construction. A 42,000 bpd unit was placed in operation and larger ones were being designed. A valuable byproduct of the process is hydrogen, which is produced in greater amounts and at higher purity than was attainable before the continuous process was developed.

The remaining 20% of estimated domestic rhenium consumption was used in high-temperature thermocouples, X-ray tubes and targets, vacuum tube and flashbulb filaments, electrical contacts, electronic devices, heating elements, electromagnets, metallic coatings, and high-temperature alloys for research and development work.

Rhenium has experienced growth in the field of rotating anodes for diagnostic X-ray tubes. Many of the unique properties of rhenium are incorporated into composite anodes, composed of a molybdenum backing, surfaced with a tungsten-rhenium alloy layer. The rhenium content of the layer averages about 10%. Wear on the focal track is minimized because the tungsten-rhenium alloy layer withstands the electron bombardment better than pure tungsten. Also, rhenium resists the recrystallization and grain growth typical of tungsten and imparts ductility to the target surface. The composite targets have made possible the development of high-speed tubes with decreased anode angles. This permits the development of smaller focal spots without sacrificing X-ray intensity.[4]

A thermocouple that utilizes rhenium in two separate sections was manfactured by a domestic firm. The tube well is a Mo-50% Re alloy, and the thermocouple itself is either W versus W-26% Re or W-5% Re versus W-26% Re. Both thermocouples can be used up to 4,200° F in vacuum, or in hydrogen, nitrogen, or other inert atmospheres. The insulator used in both is beryllium oxide. Other thermocouples are available with tantalum or molybdenum tube wells and magnesium or beryllium oxide insulators in combination with both types of tungsten-rhenium thermocouples.

In modern mass spectrometry, rhenium was used in thermionic and thermoelectric emitters. The favorable combination of properties of rhenium has resulted in substantial replacement of previously used materials such as tungsten, tantalum, molybdenum, and other refractory metals. The main advantage of rhenium in this application is that it provides high stability of electronic emissions in atmospheres of various gases. This ensures higher accuracy of mass spectrometric analysis and reduces the memory effect in the instrument compared with other cathode materials.

The most important advantages of rhenium as the material for ionizers in surface ionization are: Higher work function, refractoriness, and ductility over a wide temperature range. Rhenium ionizers are heat-treated to improve the work function, the best results being obtained with zone-melted rhenium.

A proprietary nickel-rhenium alloy (NR10-UP) was used to eliminate a serious problem impairing the quality of cermet tube cathodes, which had insufficient shape stability under cyclic temperature changes. The cathode core would noticeably deform after a few hundred temperature cycles. The rhenium alloy core has higher heat resistance and recrystallization temperature than the nickel-tungsten alloy (NIV06-VP) currently in use. Alloying with rhenium was more effective in retarding thermal diffusion processes in nickel alloys and resulted in less softening when the tube had been heated to the working temperature. The use of the NR10-VP alloy for making the cathode core in some types of tubes increased the shape stability by 8 to 10 times, stabilized the main electrical parameters over the service life, and increased the service life from 500 to 1,000 hours.[5]

Rhenium continued to be used for filaments in electron tubes used in amplification, rectification, generation, direction, switching, and displaying applications. These filaments contain tungsten and molybdenum, and also rhenium in proportions up to 25 percent. Rhenium increases the ductility of the filaments and thus reduces their fragility. Rhenium applied as a coating to tungsten filaments in electron tubes increases the resistance of the filament to attack by water vapor inherent in the tube.

PRICES

There were three reported price reductions for rhenium in 1977. At the beginning of the year, the price for rhenium metal powder was $540 per pound, and the price for perrhenic acid ($HReO_4$) was $515 per pound. In July, the prices were reduced to $425 and $400 per pound for metal powder and perrhenic acid, respectively; in September, prices were reduced to $395 and $370 per pound; and in late December, prices were reduced to $375 and $350 per pound. Despite the decreasing trend in prices, the demand for rhenium strengthened in the last 2 years, with most of the demand coming from the petroleum industry.

FOREIGN TRADE

Imports for consumption of ammonium perrhenate increased over 50% in 1977 to a record high level of 6,111 pounds of contained rhenium. Imports came from Chile (69%) and the Federal Republic of Germany (31%). Most of the material was directly imported; however, approximately 15% was withdrawn from bonded warehouses. Imports reached record high levels because of no domestic production, relatively high demand, and low prices.

Imports for consumption of rhenium metal powder increased to 148 pounds valued at $55,854. Imports came from the Federal Republic of Germany (88%) and Belgium-Luxembourg (12%).

The duty on imports of ammonium perrhenate from market economy countries was 4% ad valorem; the duty on that from central economy countries was 25% ad valorem. The duty on rhenium metal from market economy countries remained at 5% ad valorem for unwrought metal and 9% ad valorem for wrought metal. The duty on wrought and unwrought rhenium metal from central economy countries remained at 45% and 25% ad valorem, respectively.

Table 2.—U.S. imports for consumption of rhenium metal (including scrap), by country

(Gross weight, pounds)

Country	1973		1974		1975		1976		1977	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Austria	--	--	--	--	1	$300	--	--	--	--
Belgium-Luxembourg	110	$74,500	--	--	28	11,136	17	$8,687	18	$4,120
Germany, Federal Republic of	1,116	782,497	40	$27,734	30	15,760	65	29,060	130	51,734
Netherlands	211	147,679	--	--	--	--	--	--	--	--
Total	1,437	1,004,676	40	27,734	59	27,196	82	37,747	148	55,854

Table 3.—U.S. imports for consumption of ammonium perrhenate, by country[1]

(Rhenium content)

Country	1973		1974		1975		1976[2]		1977[2]	
	Quantity (pounds)	Value (thousands)	Quantity (pounds)	Value (thousands)	Quantity (pounds)	Value (thousands)	Quantity (pounds)	Value (thousands)	Quantity (pounds)	Value (thousands)
Chile	--	--	1,232	$449	--	--	1,280	$606	4,187	$1,087
Germany, Federal Republic of	1,450	$1,913	1,520	1,185	401	$165	2,767	801	1,924	533
Sweden	1,590	1,916	535	171	565	277	--	--	--	--
Total	3,040	3,829	3,287	1,805	966	442	4,047	1,407	6,111	1,620

[1]Years 1973 through 1975 are estimated.
[2]Adjusted by Bureau of Mines.

WORLD REVIEW

Porphyry copper deposits in Canada, Chile, Peru, and the U.S.S.R. were the major worldwide sources of rhenium. Known recovery facilities outside of the United States were located in Belgium-Luxembourg, Bulgaria, Chile, France, the German Democratic Republic, the Federal Republic of Germany, Sweden, the United Kingdom, and the U.S.S.R.

Canada.—The Island Copper mine of Utah International, Inc., produced all of the Canadian rhenium output. In 1977, an estimated 2,000 tons of molybdenite concentrate containing approximately 5,700 pounds of rhenium was shipped to the United States. The contained rhenium was processed into ammonium perrhenate and perrhenic acid in the United States and returned to Utah International for disposition. The Island Copper ore deposit contains one of the highest concentrations of rhenium in the world, with the rhenium content consistently averaging above 1,100 parts per million in molybdenite concentrate.

Catalytic reforming capacity in Canada increased 8% during the year, resulting from pressure to produce higher octane, low-lead, and lead-free gasolines. Nearly all of the increased capacity was accounted for by bimetallic catalysts.

Chile.—Rhenium production in Chile totaled an estimated 3,200 pounds contained in about 5,200 pounds of ammonium perrhenate. Potential rhenium output is steadily increasing because of increasing molybdenum capacity. This was made possible by the high molybdenum content of the porphyry copper ores and the construction of new byproduct recovery plants at Chuquicamata and Andina. As a result, rhenium production may reach 7,000 pounds per year in the near future.[6]

The Chilean copper mining company Compania Minera Disputada de las Condes S.A. was purchased by Exxon Corp. late in 1977. Exxon planned to carry out studies to determine the feasibility of expanding operations. Reserves of rhenium were estimated to be over 16,000 pounds averaging 350 parts per million of rhenium in molybdenite. To date, the molybdenum and rhenium have not been exploited.

Corporación del Cobre de Chile (CODELCO), the National Copper Corporation of Chile, renewed its agreement with Philipp Brothers, a division of Engelhard Minerals & Chemical Corp., to market its molybdenum and rhenium output worldwide. CODELCO is the world's largest holder of copper reserves, and was also the world's largest byproduct molybdenum producer. CODELCO's rhenium output made Chile one of the largest rhenium producers in the world in 1977.

Germany, Federal Republic of.—Herman C. Starck, one of the largest processors of molybdenum and rhenium in Europe, began marketing rhenium in the United States in 1977. The main rhenium product marketed was ammonium perrhenate, but perrhenic acid and rhenium metal powder were also sold. Germany has the most rigid restrictions on the use of tetraethyl lead in gasoline in the world. To meet motor gasoline specifications that became effective January 1, 1976, $400 million has been spent. As a result, the use of platinum-rhenium catalysts in petroleum-reforming operations increased significantly. Esso A. G., Germany's second largest refiner, switched to bimetallic platinum-rhenium catalysts in four of its reformers and substantially modified the reformers' downstream equipment. Deutsche B. P. switched from conventional to bimetallic catalysts in its Dinslaken, Hamburg, and Vohburg refineries. Wintershall A.G. was modernizing its Lingen refinery. Part of the project includes a 650,000-ton-per-year catalytic reformer and hydrogen plant. Oberrheinische Mineraloelwerk GmbH was upgrading and modernizing its Karlsruhe refinery in order to supply 15% of Germany's current gasoline demand by the end of 1978. A new continuous catalytic reformer will be installed and an existing one will be converted to desulfurization service.[7]

Iran.—A new reforming unit was being constructed as part of a petroleum-refining complex in Bandar Shahpur for the production of 500,000 tons per year of xylenes. The unit will employ Engelhard's bimetallic platinum-rhenium "Magnaforming" catalyst. This catalyst has proven itself in the United States over the past several years and is in worldwide use.

TECHNOLOGY

Bureau of Mines researchers presented a paper[8] on the operation of a prototype industrial-size bipolar electrooxidation cell for the recovering molybdenum and rhenium from offgrade molybdenite concentrate. The cell was operated in cooperation with the Nevada Division of Kennecott Copper Corp. Extractions of 94% to 98% of molybdenum and rhenium were reportedly achieved from a concentrate containing up to 6% copper. The Bureau provided data on the process to aid in the technology transfer to interested industry representatives.

A process was developed for treating molybdenite concentrate containing rhenium for efficient production of high-purity rhenium and molybdenum products.[9] The process consists of flash roasting molybdenite concentrate in an oxygen atmosphere, wet scrubbing the roaster offgas to remove dust and volatilized molybdenum and rhenium, recovering molybdenum and rhenium by solvent extraction, precipitation, and crystallization of rhenium as a high-purity ammonium perrhenate. Rhenium recoveries of 90% from concentrates containing 1,400 parts per million of rhenium have been demonstrated in a pilot plant. Over 75% rhenium recovery has been proven from concentrates containing 250 parts per million of rhenium. Pyridene was used to extract the rhenium from the stripping solution. The pyridene extract was fed to a still where the rhenium was concentrated in the still bottoms as a sodium perrhenate solution containing up to 150 grams per liter of rhenium. The rhenium was recovered as ammonium perrhenate crystals by addition of ammonium sulfate to the still bottoms. The ammonium perrhenate was further purified by recystallization and the pure product dried for sale or conversion to other end products.

Wide use of molybdenum-rhenium alloys with high rhenium contents for large structures is precluded due to the high cost and limited availability of rhenium. However, it has been shown that the plasticity of weld joints of low-alloy materials such as the VM1 and TsM2 alloys can be improved by alloying only the joint metal with rhenium. Increasing the rhenium content in the joint beyond 50% results in a sharp rise in the hardness and brittleness because of the formation of the sigma phase. At contents below 20 weight-percent rhenium, the plasticity of joint metal does not differ from that of unalloyed metal. This use of rhenium as an alloy addition to increase the plasticity of weld joints in molybdenum considerably widens the field of application of molybdenum as a structural material at relatively low consumption of rhenium.[10]

GTE Sylvania developed an improved process for the extraction of rhenium from molybdenum. The process employs solvent extraction for the separation and recovery of rhenium from sodium molybdate solutions obtained from molybdenite concentrate using a quaternary amine (Aliquat 336) as the extractant. The solvent system initially investigated was the decanol-kerosine system. However, rhenium extraction decreased with time, due to the formation of an insoluble amine-rhenium complex. As a result, the solvent system was replaced with a high-aromatic solvent (SC #28), and the rhenium extraction efficiency was found to be constant. Nitric acid was used as the stripping agent in both systems. A continuous countercurrent, mixer-settler extraction system was employed, and the concentrated rhenium solution was subjected to ion exchange for further purification and isolation.[11]

Rhenium has a unique effect on tungsten, molybdenum, and chromium, increasing strength and ductility, especially in the region of saturated solid solutions with body-centered cubic structure. This phenomenon, known as the "rhenium effect," was discovered in 1955 in England and was used to develop a range of alloys of tungsten and molybdenum with rhenium. Research was conducted on the rhenium effect through the structure and properties of the ternary Mo-Re-C system. It was found that one of the main reasons for the rhenium effect was the higher solubility of carbon in the saturated Mo-Re solid solution than in pure molybdenum, (about five times higher), and also the appearance of a new carbide having higher strength and plasticity than Mo_2C in the Mo-Re alloy. The carbide is a solid solution of rhenium in molybdenum carbide. At 1,500° C, the solubility of carbon in the solid solution was about 0.05 weight-percent in Mo-95% Re alloy; 0.025 weight-percent in Mo-20% Re alloy; and less than 0.01 weight-percent in pure molybdenum.[12]

The effect of thermal cycling on the properties of Ta-Cb-Re alloys was studied. The addition of rhenium has a positive effect on increasing the thermocyclic resistance of tantalum and tantalum-columbium alloys. The effect was attributed to strengthening of the solid solution and increasing of interatomic forces.[13]

Two major improvements were made to Chevron Research Co.'s Rheniforming technology during the year. These were an improved catalyst called Type F, and a sulfur-control system. The main advantage of the Type F catalyst over previous catalysts reportedly is greatly increased stability which allows the reforming units to operate at higher octane, increased feed rate, or decreased pressure to increase yields without shortening run length. After regeneration, the catalyst can be returned to performance nearly identical to that of fresh catalyst. The catalyst was undergoing testing in 1977, and is scheduled to be in commercial service in late 1978. Use of the sulfur-control system showed a significantly higher yield and longer run lengths. Rates of return on investment for the system were in the 60% to 100% range for three operating units employing the system. Design and construction of nine more units at existing refineries were planned. Ten licensees will install the sulfur-control system, and new Rheniformers will include this technology as a standard part of the system.[14]

A new alloy of rhenium was developed for use as a cathode connector for a structural element subjected to mechanical load. The connector must have specific electrical properties, since voltage is applied through it across the cathode-anode circuit. The strength of the cathode connector can be increased by increasing its resistance to thermal cycles. The alloy consists of 50% iron, 40% nickel, and 10% rhenium. Because of its superior physical properties, this alloy reportedly has given good results in numerous test devices. Rhenium raises the recrystallization temperature of the alloy by 300° C, and the material has a finer grain size after recrystallization. Because of the finer grain size, grain growth in the connector material is limited during welding, the grain size in the alloy being 5 to 10 times finer even after prolonged tests and annealing at 600° C to 1,000° C. The addition of rhenium to the iron-nickel solid solution improved its mechanical properties by at least 1.5 times at the usual cathode temperatures. At temperatures above 300° C, the grain growth is checked, the strength is greater at a given grain size, and softening takes place more gradually.[15]

Research continued on use of rhenium-bearing alloys as gas absorbers in electrovacuum devices. A titanium-rhenium alloy, in wire form used as a directly heated atomizable gas absorber in photoelectronic devices, had two advantages: The film obtained by evaporation of titanium when the absorber was heated to 1,330° C had sorptional activity with respect to hydrogen greater than that of barium absorbers used at present in photoelectronics; another advantage was its low coefficient of linear thermal expansion, which ensures constancy of shape of the absorber in use in the device. The main disadvantage was the embrittlement of the wire as titanium evaporates, which makes their use impossible in vibration-resistant devices.[16]

A patent was issued for the recovery of rhenium values from an aqueous sodium molybdate solution obtained in the hydrometallurgical processing of roasted molybdenite. The solution was contacted with a quaternary ammonium compound dissolved in at least 50 volume-percent of a highly aromatic solvent. The rhenium-enriched organic phase was separated and stripped of values, and the extractant solution was recycled.[17]

---

[1]Industry economist, Division of Ferrous Metals.

[2]Oil & Gas Journal. Federals Shape U.S. Refining Industry. V. 76, No. 12, Mar. 20, 1978, pp. 63-66.

[3]Oil & Gas Journal. Analyzers Important in Cat Reforming. NPRA 1977 Question and Answer Session. V. 76, No. 19, May 8, 1978, p. 258.

[4]Knipple, W. R. Rhenium. Metals Bull., 1977 Minor Metals Survey.

[5]Margulis, R. B., E. M. Savitskii, M. A. Tylkina, and E. P. Arskaya. Paper in Russian (Use of Rhenium Alloys in Ultra-High Frequency Cermet Tubes). Akademiya Nauk SSSR, Moscow, 1975, pp. 181-188; English translation published for the U.S. Department of the Interior and the National Science Foundation, TT 76-52045, 1977, 343 pp.

[6]Metal Bulletin. Chile's Mo Place. No. 6221, Sept. 2, 1977, p. 25.

[7]Oil & Gas Journal. Germany Sets Tough Pace for Other EEC Refiners. V. 75, No. 49, Nov. 28, 1977, pp. 55-64.

[8]Scheiner, B. J., D. L. Pool, and R. E. Lindstrom. Extraction and Recovery of Molybdenum and Rhenium From Molybdenite Concentrates by Electrooxidation: Prototype Cell Demonstration. Pres. at Ann. Meeting of The Canadian Institute of Mining and Metallurgy (CIM), Vancouver, B. C., Aug. 21-25, 1977, 12 pp.

[9]Litz, J. E., and R. B. Coleman. Recovery of Rhenium From Molybdenite Concentrates. Pres. at Ann. Meeting of CIM, Vancouver, B. C., Aug. 21-25, 1977, 19 pp.

[10]Morozov, B. P., B. B. D'yachenko, V. I. Perezhogin, and A. A. Delezha. Paper in Russian (Use of Rhenium for Increased Plasticity of Weld Joints in Molybdenum Alloys). Akademiya Nauk SSSR, Moscow, 1975, pp. 312-318; English translation published for the Department of the Interior and the National Science Foundation, TT 76-52045, 1977, 343 pp.

[11]MacInnis, M. B., L. R. Quatrini, and T. K. Kim. An Improved Solvent Extraction Process for the Separation of Rhenium From Molybdenum. Pres. at Ann. Meeting of American Institute of Mining, Metallurgical, and Petroleum Engineers, Atlanta, Ga., Mar. 6-10, 1977, 19 pp.

[12]Savitskii, E. M., M. A. Tylkina, and L. Z. Konieva. Paper in Russian. (Mechanism of the Rhenium Effect). Akademiya Nauk SSSR, Moscow, 1975, pp. 43-53; English translation published for the U.S. Department of the Interior and the National Science Foundation, TT 76-52045, 1977, 343 pp.

[13]Savitskii, E. M., M. A. Tylkina, V. E. Alyushin, A. M. Levin, L. N. Potemina, E. V. Rudenskii, and T. V. Semenova. Paper in Russian (Effect of Thermal Cycling on the Properties of Ta-Cb-Re Alloys). Akademiya Nauk SSSR, Moscow, 1975, pp. 84-90; English translation published for the U.S. Department of the Interior and the National Science Foundation, TT 76-52045, 1977, 343 pp.

[14]Buss, W. C., R. L. Jacobson, F. H. Vorhis, and A. I. Salka. New Developments in Rheniforming. Pres. at Ann. Meeting of National Petroleum Refiners Association, San Antonio, Tex., Mar. 19-21, 1978, 20 pp.

[15]Iofis, N. A. Paper in Russian. (The Use of Rhenium in Electronics). Akademiya Nauk SSSR, Moscow, 1975, pp. 175-180; English translation published for the U.S. Department of the Interior and the National Science Foundation, TT 76-52045, 1977, 343 pp.

[16]Pages 179 and 180 of work cited in footnote 15.

[17]Quatrini, L. R., and M. B. MacInnis (assigned to GTE Sylvania, Inc., Stamford, Conn.). Extraction Process for Recovery of Rhenium. U.S. Pat. 4,049,771, Sept. 20, 1977.

Salt

By Russell J. Foster[1]

Production of salt in the United States decreased 2% in 1977 to 42.9 million tons. The amount of salt sold or used by domestic producers was also down 2%, primarily because of reduced synthetic soda ash capacity. Salt in pressed block form exhibited the most substantial change from that of the previous year, down 7%. Prices of all forms of salt except solar advanced, with the largest price increase occurring in rock salt. Imports reached a record level of 4.5 million tons.

Legislation and Government Programs.—The Federal Energy Administration accelerated the strategic petroleum reserve program by advancing the target date for the underground storage of 500 million barrels of crude oil to yearend 1980 instead of 1982. Four salt deposits in Louisiana and Texas were selected as storage sites for the reserve, and in July 1977 the initial increment of oil was stored. Two other candidate sites are also salt deposits.[2]

Solution mining has apparently gained the acceptance of the Environmental Protection Agency (EPA) as being compatible with the objectives of the Safe Drinking Water Act, which was created to safeguard the Nation's underground water supplies. EPA has made major revisions to a stringent set of proposed regulations that could have impeded the use of solution mining.[3]

Table 1.—Salient salt statistics

(Thousand short tons and thousand dollars)

	1973	1974	1975	1976	1977
United States:					
Production[1]	44,298	46,423	41,710	43,801	42,922
Sold or used by producers[1]	43,910	46,536	41,030	44,191	43,412
Value	$306,103	$360,763	$368,063	$430,959	$451,579
Exports	609	521	1,332	1,007	1,008
Value	$4,400	$4,276	$9,070	$10,326	$10,881
Imports for consumption	3,207	3,358	3,215	4,352	4,529
Value	$12,554	$14,428	$15,272	$23,476	$26,694
Consumption, apparent	46,508	49,373	42,913	47,536	46,933
World: Production	170,483	183,236	[r]178,207	[r]185,324	187,292

[r]Revised.
[1]Excluding Puerto Rico: 29,000 short tons (1973-74), and an estimated 27,000 short tons (1975-77).

DOMESTIC PRODUCTION

The amount of salt sold or used by domestic producers in 1977 declined 2%. Solar salt showed a gain of 3% and vacuum-pan and open-pan salt combined were up 1%, but the quantities of other forms of salt sold or used by producers declined. In 1977, 51 salt-producing companies operated 92 plants in 16 States and Puerto Rico. Twelve of the companies sold or used over 1 million tons each, accounting for 86% of the U.S.

total. The five leading States in the amount of salt sold or used follow:

State	Percent of total
Louisiana	30
Texas	25
New York	15
Michigan	9
Ohio	9
Total	88

The percentage of salt sold or used by domestic producers in 1977 by type follows:

	Percent
Salt in brine	53
Mined rock salt	34
Vacuum-pan salt and grainer or open-pan salt	9
Solar-evaporated salt	4

Morton Salt Co. authorized the construction of a new rock salt mine at Weeks, La., as a replacement for the existing mine, which was purchased for $30 million by the Federal Energy Administration as a storage site for the strategic petroleum reserve. The new mine is expected onstream by June 30, 1980.[4] In September the company completed an expansion that increased evaporated salt capacity at Manistee, Mich.[5]

Diamond Crystal Salt Co. brought a $1.8 million vacuum-pan salt expansion project onstream at St. Clair, Mich., in December.[6]

Preliminary engineering for a new salt plant was underway at the Ogden, Utah, complex of Great Salt Lake Minerals & Chemicals Corp. The capacity of the new plant will triple the company's present volume of processed salt and allow for an expanded product line. Upon completion of the project in 1979, present salt facilities will be used for increasing potassium sulfate production capacity.[7]

CONSUMPTION AND USES

Consumption of salt by the U.S. chemical industry declined in 1977. The principal reason for the downturn was a reduction in synthetic soda ash capacity, since the amount of salt sold or used by domestic producers for the manufacture of chlorine-caustic soda increased and for other chemicals was down just slightly. Over 58% of all salt sold or used by U.S. producers was raw material for the production of chemicals.

Strong demand for highway deicing salt at the beginning of the year resulted in shortages in a number of States. In some areas river ice hindered resupply by barge.

Categories of distribution which exhibited notable gains in 1977 were the rubber, oil, and water softening industries. Also, the amount of salt handled by distributors continued to rise and has nearly doubled since 1974. Demand for salt by feed dealers and feed mixers was down mainly because of reductions in the size of cattle herds.

STOCKS

At yearend 1977 total salt stocks reported by producers amounted to 2.2 million tons, which represented 5% of production. Nearly 54% was in the form of rock salt and 36% was solar salt. Solar salt had the largest share of its production in stocks, 43%. Rock salt stocks were 8% of production, and the combined amount of open-pan and vacuum-pan salt production in stocks was 3%. Yearend brine inventory was small.

Table 2.—Salt sold or used by producers in the United States,[1] by method of recovery

(Thousand short tons and thousand dollars)

Recovery method	1976 Quantity	1976 Value	1977 Quantity	1977 Value
Evaporated:				
Bulk:				
Open pans or grainers, and vacuum pans	3,444	174,731	3,481	181,039
Solar	1,752	25,156	1,808	25,685
Pressed blocks	412	18,401	388	19,307
Total[2]	5,607	218,288	5,677	226,031
Rock:				
Bulk	15,592	121,875	14,893	133,156
Pressed blocks	76	3,807	65	3,281
Total	15,668	125,682	14,958	136,437
Salt in brine (sold or used as such)	22,917	86,989	22,777	89,111
Grand total[2]	44,191	430,959	43,412	451,579

[1]Excludes Puerto Rico.
[2]Data may not add to totals shown because of independent rounding.

Table 3.—Salt sold or used by producers in the United States, by State

(Thousand short tons and thousand dollars)

State	1976 Quantity	1976 Value	1977 Quantity	1977 Value
Kansas[1]	1,310	35,291	1,430	41,154
Louisiana	13,491	91,952	13,201	96,878
Michigan	4,219	79,740	3,939	78,808
New York	6,495	66,441	6,452	72,623
Ohio	5,052	66,332	3,701	63,485
Texas	9,718	48,875	10,941	53,264
Utah	705	10,090	843	10,831
West Virginia	1,118	W	1,048	W
Other States[2]	2,083	32,239	1,857	34,538
Total[3]	44,191	430,959	43,412	451,579
Puerto Rico[e]	27	639	27	639

[e]Estimate. W Withheld to avoid disclosing company proprietary data; included with "Other States."
[1]Quantity and value of brine included with "Other States."
[2]Includes Alabama, Arizona, California, Colorado, Kansas (brine only), Nevada, New Mexico, North Dakota, Oklahoma, and items indicated by symbol W.
[3]Data may not add to totals shown because of independent rounding.

Table 4.—Evaporated salt sold or used by producers in the United States

(Thousand short tons and thousand dollars)

State	1976 Quantity	1976 Value	1977 Quantity	1977 Value
Kansas	785	30,795	822	34,790
Louisiana	297	19,014	295	18,975
Michigan	1,190	60,641	1,182	60,179
New York	617	29,780	615	32,290
Utah	673	9,848	815	10,668
Other States[1]	2,046	68,210	1,947	69,130
Total[2]	5,607	218,288	5,677	226,031
Puerto Rico[e]	27	639	27	639

[e]Estimate.
[1]Includes Arizona, California, New Mexico, North Dakota, Ohio, Oklahoma, and Texas.
[2]Data may not add to totals shown because of independent rounding.

Table 5.—Rock salt sold by producers in the United States

(Thousand short tons and thousand dollars)

Year	Quantity	Value
1973	12,347	78,544
1974	14,835	108,692
1975	14,283	107,912
1976	15,668	125,682
1977	14,958	136,437

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
1973	451	14,508	72	2,551	523	17,059
1974	440	15,888	82	3,308	522	19,196
1975	436	17,808	84	3,733	520	21,541
1976	412	18,401	76	3,807	[1]487	22,208
1977	388	19,307	65	3,281	453	22,588

[1]Data do not add to total shown because of independent rounding.

Table 7.—Distribution of salt sold or used by producers in the United States, by use

(Thousand short tons)

Consumer or use	1976				1977			
	Evaporated	Rock	Brine	Total[1]	Evaporated	Rock	Brine	Total[1]
Chlorine	280	2,256	18,411	20,947	240	1,958	19,323	21,522
Soda ash	W	W	4,060	4,061	W	W	2,612	2,620
All other chemicals	W	623	W	1,158	W	540	W	1,122
Textile and dyeing	130	73	--	204	127	70	--	196
Meatpackers, tanners, and casing manufacturers	246	332	--	578	238	331	--	569
Dairy	68	6	--	74	64	6	--	71
Canning	161	96	(2)	257	152	103	(2)	255
Baking	W	W	--	126	W	W	--	112
Flour processors (including cereal)	77	21	(2)	98	71	23	(2)	95
Other food processing	602	33	(2)	635	572	39	(2)	611
Feed dealers	893	439	--	1,332	850	419	--	1,269
Feed mixers	296	296	(2)	593	272	285	--	556
Metals	39	303	(2)	342	39	312	(2)	351
Rubber	W	9	W	108	W	12	W	125
Oil	92	89	132	312	111	94	156	361
Paper and pulp	W	148	W	213	W	155	W	222
Water softener manufacturers and service companies	294	W	W	580	316	W	W	650
Grocery stores	784	214	--	998	816	224	W	1,043
Highway use	W	8,707	W	8,930	W	8,395	W	8,678
U.S. Government	27	47	(2)	74	23	48	(2)	72
Distributors (brokers, wholesalers, etc.)	328	576	--	904	380	649	--	1,029
Miscellaneous[3]	1,333	1,365	548	[4]1,910	1,428	1,411	573	[4]1,909
Total[1]	[5]5,651	[5]15,633	[5]23,151	[6]44,435	[5]5,700	[5]15,075	[5]22,664	[6]43,439

W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous."
[1]Data may not add to totals shown because of independent rounding.
[2]Less than 1/2 unit; included with "Miscellaneous."
[3]Includes withheld figures and some exports and consumption in overseas areas administered by the United States.
[4]Incomplete totals; withheld totals are included with total for each specific use.
[5]Differs from totals shown in tables 2, 4, and 5 because of changes in inventory.
[6]Differs from totals shown in tables 1, 2, and 3 because of changes in inventory.

Table 8.—Distribution (shipments) of evaporated and rock salt in the United States, by destination

(Thousand short tons)

Destination	1976				1977			
	Evaporated		Rock		Evaporated		Rock	
	Domestic	Imported	Domestic	Imported	Domestic	Imported	Domestic	Imported
Alabama	50	--	457	([1])	53	--	438	--
Alaska	W	--	--	--	W	--	--	--
Arizona	W	W	W	--	W	W	W	--
Arkansas	25	--	99	--	27	--	87	--
California	947	W	W	--	888	W	W	--
Colorado	151	--	W	--	156	--	27	--
Connecticut	17	W	W	([1])	17	W	W	([1])
Delaware	5	16	W	--	5	W	W	--
District of Columbia	2	W	W	--	2	W	W	--
Florida	58	W	136	--	61	W	125	--
Georgia	66	W	242	([1])	65	--	233	([1])
Hawaii	W	([1])	--	--	W	([1])	--	--
Idaho	59	--	W	--	60	--	W	--
Illinois	364	([1])	1,059	W	366	W	1,035	W
Indiana	153	([1])	640	W	157	W	596	123
Iowa	181	([1])	276	([1])	182	W	268	([1])
Kansas	100	--	196	--	115	--	197	--
Kentucky	43	([1])	576	([1])	44	([1])	565	([1])
Louisiana	54	--	W	--	53	([1])	419	--
Maine	9	([1])	W	W	9	W	W	W
Maryland	38	61	W	([1])	41	W	W	([1])
Massachusetts	39	W	428	W	40	W	380	W
Michigan	191	([1])	W	569	188	W	W	605
Minnesota	168	W	326	W	178	([1])	310	W
Mississippi	23	--	110	--	24	--	106	--
Missouri	110	--	345	--	107	--	422	--
Montana	56	--	2	--	48	--	1	--
Nebraska	107	--	85	--	107	--	95	--
Nevada	52	W	W	--	61	W	W	--
New Hampshire	W	([1])	W	W	W	([1])	W	W
New Jersey	135	118	608	([1])	145	104	W	W
New Mexico	51	--	27	W	53	--	37	--
New York	305	74	1,898	W	295	47	W	125
North Carolina	114	W	W	([1])	121	W	152	([1])
North Dakota	W	--	6	([1])	W	--	5	([1])
Ohio	368	--	1,687	W	372	W	1,725	138
Oklahoma	50	--	67	--	49	--	74	--
Oregon	[r]47	W	W	--	49	W	([1])	--
Pennsylvania	176	68	[r]1,319	W	180	66	1,273	W
Rhode Island	12	W	W	--	6	W	W	([1])
South Carolina	49	--	15	([1])	43	W	14	--
South Dakota	60	--	34	--	59	--	33	--
Tennessee	118	--	656	([1])	123	([1])	563	([1])
Texas	204	--	277	--	202	([1])	273	--
Utah	195	--	W	--	257	--	W	--
Vermont	W	([1])	242	([1])	W	([1])	W	W
Virginia	89	49	131	([1])	86	72	187	([1])
Washington	65	707	([1])	--	64	711	([1])	--
West Virginia	20	W	243	([1])	21	W	243	([1])
Wisconsin	192	W	547	W	202	W	631	170
Wyoming	35	--	W	--	39	--	W	--
Other[2]	298	539	2,899	822	283	802	4,560	392
Total[3]	[4]5,651	[5]1,632	[4]15,633	[5]1,391	[4]5,700	[5]1,802	[4]15,075	[5]1,551

[r]Revised. W Withheld to avoid disclosing company proprietary data; included with "Other."
[1]Less than 1/2 unit.
[2]Includes shipments to overseas areas administered by the United States, Puerto Rico, exports, some shipments to unspecified destinations, and States indicated by symbol W.
[3]Data may not add to totals shown because of independent rounding.
[4]Differs from totals in tables 2, 4, and 5 because of changes in inventory.
[5]Differs from totals in tables 1, 11, 12, and 13 because of incomplete data on the distribution of imported salt.

PRICES

The average values of different classes of salt in bulk, f.o.b. works, as reported by producers follow:

	Per ton	
	1976	1977
Evaporated:		
Open pans or grainers, and vacuum pans	$50.73	$52.01
Solar	14.36	14.21
Pressed blocks, all sources	45.51	49.86
Rock salt, bulk	7.82	8.94
Salt in brine	3.80	3.91

The following salt prices were quoted at yearend 1977 in Chemical Marketing Reporter:[8]

	Per 100 pounds
Salt, evaporated, common, 100-pound bags, carlots or trucklots, North, works	$2.19
Salt, chemical-grade, same basis	2.23
Salt, rock, medium coarse, same basis	$1.35-1.475
Salt, rock, extra coarse, same basis	1.40-1.525

Rock salt had the largest percentage increase in price, 14%. Three major salt producers, Diamond Crystal Salt Co., International Salt Co., and Morton Salt Co., announced price increases ranging from 4% to 18% for evaporated and rock salt, effective in September and October. Rising costs of energy, labor, packaging, and equipment were cited as the reasons.[9]

FOREIGN TRADE

Salt exports from the United States in 1977 were essentially unchanged at 1 million tons. The principal destination of U.S. salt was Canada, 96%.

The United States imported a record 4.5 million tons of salt, an increase of 4%. The principal foreign sources were Canada, 33%; Bahamas, 30%; and Mexico, 28%. Net import reliance of salt totaled nearly 8% of apparent consumption.

Table 9.—Salt shipped to the Commonwealth of Puerto Rico and overseas areas administered by the United States

Area	1976		1977	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
American Samoa	[1]213	[1]$11	NA	NA
Puerto Rico	17,106	2,197	16,684	$2,154
Virgin Islands	398	22	584	51

NA Not Available.

[1]Effective August 1976, data on shipments from the United States to American Samoa were no longer compiled by the Bureau of the Census owing to elimination of the requirement for filing export declarations for such shipments. The 1976 figure, therefore, reflects only the months January through July.

Table 10.—U.S. exports of salt, by country

(Thousand short tons and thousand dollars)

Destination	1976		1977	
	Quantity	Value	Quantity	Value
Algeria	--	--	4	20
Bahamas	2	137	2	133
Canada	958	7,918	963	8,373
Costa Rica	1	60	1	62
Denmark	(1)	29	(1)	41
Haiti	(1)	25	(1)	31
Mexico	12	287	24	311
Netherlands Antilles	1	133	1	146
New Zealand	1	47	1	29
Saudi Arabia	5	863	2	456
Trust Territory of the Pacific Islands	(1)	14	(1)	24
United Arab Emirates	3	279	2	216
United Kingdom	20	73	(1)	70
Venezuela	1	8	4	557
Other	r3	r453	1	411
Total[2]	1,007	10,326	1,008	10,881

[1]Less than 1/2 unit.
[2]Data may not add to totals shown because of independent rounding.

Table 11.—U.S. imports for consumption of salt, by country

(Thousand short tons and thousand dollars)

Country	1976		1977	
	Quantity	Value	Quantity	Value
Bahamas	1,397	6,295	[1]1,353	[1]7,078
Canada	1,654	9,980	1,482	9,294
Chile	146	667	48	213
Germany, Federal Republic of	1	144	(2)	152
Mexico	686	4,139	1,263	7,605
Netherlands Antilles	151	802	109	747
Norway	20	117	--	--
Spain	252	1,134	275	1,538
United Kingdom	24	68	[3](2)	[3]12
Other	[4]21	[4]130	[5](2)	[5]54
Total[6]	4,352	23,476	4,529	26,694

rRevised.
[1]Includes salt brine through San Juan customs district, 35,870 short tons ($182,221).
[2]Less than 1/2 unit.
[3]Includes salt brine through Baltimore customs district, 1 short ton ($963).
[4]Includes salt brine from Denmark through Cleveland customs district, 10 short tons ($10,829); from Japan through Chicago customs district, 11 short tons ($730).
[5]Includes salt brine from Denmark through Cleveland customs district, 3 short tons ($3,695).
[6]Data may not add to totals shown because of independent rounding.

Table 12.—U.S. imports for consumption of salt, by class

(Thousand short tons and thousand dollars)

Year	In bags, sacks, barrels or other packages (dutiable)		Bulk (dutiable)	
	Quantity	Value	Quantity	Value
1975	10	580	[1]3,205	[1]14,692
1976	19	691	[2]4,333	[2]22,774
1977	23	883	[3]4,506	[3]25,811

[1]Includes salt brine from Canada through San Francisco customs district, 12 short tons ($449); from Denmark through Cleveland customs district, 3 short tons ($2,247); from the Netherlands through Baltimore customs district, 11 short tons ($720).
[2]Includes salt brine from Denmark through Cleveland customs district, 10 short tons ($10,829); from Japan through Chicago customs district, 11 short tons ($730).
[3]Includes salt brine from the Bahamas through San Juan customs district, 35,870 short tons ($182,221); from the United Kingdom through Baltimore customs district, 1 short ton ($963); from Denmark through Cleveland customs district, 3 short tons, ($3,695).

Table 13.—U.S. imports for consumption of salt, by customs district

(Thousand short tons and thousand dollars)

Customs district	1976 Quantity	1976 Value	1977 Quantity	1977 Value
Baltimore, Md	240	1,087	420	2,238
Boston, Mass	261	1,101	316	1,496
Buffalo, N.Y	51	281	146	811
Chicago, Ill	155	905	224	1,266
Cleveland, Ohio	64	374	188	1,022
Detroit, Mich	861	4,964	634	4,055
Duluth, Minn	162	1,106	48	499
Houston, Tex	(1)	126	(1)	114
Los Angeles, Calif	145	696	205	1,292
Milwaukee, Wis	340	2,073	138	685
New Orleans, La	9	70	12	97
New York City	182	1,055	231	1,683
Norfolk, Va	25	124	71	530
Ogdensburg, N.Y	14	81	71	408
Philadelphia, Pa	(1)	2	16	101
Portland, Me	287	1,431	263	1,631
Portland, Oreg	411	2,216	364	2,068
Providence, R.I	49	197	107	498
St. Albans, Vt	3	113	4	135
San Juan, P.R	315	1,261	181	910
Savannah, Ga	260	1,093	251	1,208
Seattle, Wash	498	3,000	539	3,381
Tampa, Fla	--	--	20	81
Wilmington, N.C	20	117	61	395
Other	(1)	3	15	89
Total[2]	4,352	23,476	4,529	26,694

[1]Less than 1/2 unit.
[2]Data may not add to totals shown because of independent rounding.

Table 14.—U.S. imports for consumption of salt, by use as reported by salt producers

(Thousand short tons)

Use	1976	1977
Government (highway use)	1,263	1,738
Chemical industry	962	969
Water-conditioning service companies	140	162
Other	659	485
Total[1]	3,024	3,354

[1]Disagreement with totals in tables 1, 11, 12, and 13 is because of incomplete data on the uses of imported salt.

WORLD REVIEW

World salt production in 1977 was estimated at 187 million tons. Distribution of the production by continent was as follows:

	Million tons	Percent
Europe	73.0	39
North America	57.6	31
Asia	43.4	23
Oceania	5.4	3
South America	5.3	3
Africa	2.6	1

The 12 principal salt-producing nations, which together accounted for 82% of the world's salt, follow:

	Percent
United States	23
People's Republic of China	18
U.S.S.R	9
Germany, Federal Republic of	7
United Kingdom	5
France	4
Canada	3
Australia	3
Mexico	3
Romania	3
Italy	2
Poland	2

Algeria.—Société Nationale de Recherches et d'Exploitations Mineriès (SONAREM) has proposed the construction of a rock salt mine and associated processing facilities at Djalfa.[10]

Australia.—W. A. Salt Supply Pty. and Cheetham Salt Ltd. have formed a joint venture, Western Salt Refinery Pty. Ltd., as the first producer of table salt in Western Australia. When completed, the South Cooge plant will refine salt harvested at Pink Lake for domestic and export markets.[11]

The Australian salt industry has been troubled by overcapacity and has a strong dependence on exports to Japan. Representatives of the Japan Soda Association and the Australian Government have been engaged in negotiations since a higher minimum price for Australian salt was established in early 1976, in line with prices of Japan's other principal salt supplier, Mexico.[12]

Bahamas.—Excessive spring rainfall caused production setbacks at the solar salt facilities of Morton Salt Co. and Diamond Crystal Salt Co.[13] UOP, Inc., commissioned a reverse-osmosis desalination plant at Paradise Island. The performance of the 30,000-gallon-per-day unit will be evaluated to aid in planning larger systems.[14]

Egypt.—The extraction of salt from Lake Qarun has been proposed. Anticipated production of 220,000 tons per year could result in substantial import savings.[15]

Israel.—Dead Sea Works, Ltd., announced plans to expand annual salt production capacity from the present 22,000 tons to 55,000 tons.[16] In April, Israel Salt brought a solar evaporation plant onstream at Eilat to produce salt from seawater. Exports of 2.8 million tons per year to eastern Africa are anticipated.[17]

Kuwait.—Ishikawajima-Harima Heavy Industries received a turnkey contract to build four 6-million-gallon-per-day seawater desalination plants at Doha during 1979. Three other identical plants are scheduled onstream by the end of 1978.[18]

Pakistan.—The Pakistan Mineral Developments Corp. has proposed to nearly double the production of the salt mines in the Punjab to 600,000 tons per year.[19]

Poland.—The projected expansion of chlor-alkali production at three existing units and the construction of two new plants at Wloclawek and Rokita will require an additional salt output of nearly 1 million tons by 1980. Salt production at Siedlce, the site of one of Poland's oldest salt mines, will be resumed to supply the chlor-alkali expansion at Tarnow. A new soda ash plant at Matwy, due onstream by 1980, will be supplied by salt brine from Inowroclaw.[20] A bulk salt terminal designed for annual throughput of 250,000 tons has been established at Gdansk.[21]

Saudi Arabia.—The U.S. Departments of the Interior and the Treasury signed an agreement with Saudi officials for two cooperative desalination projects to be carried out under the auspices of the United States-Saudi Arabia Joint Commission on Economic Cooperation. A desalination research, development, and training center in Saudi Arabia will be established and a technology development program implemented to produce designs for a new generation of multistage flash desalting plants. In return for the technology and expertise provided, the United States acquired the right to use any of the new technology developed with no royalty payment or cost.[22]

UOP, Inc., has been awarded a $35 million contract for the construction of a 3.2-million-gallon-per-day reverse-osmosis system at Jidda that is capable of producing drinking water from seawater. The modular construction of the system can provide fast delivery and installation.[23]

Spain.—A 220,000-ton-per-year salt operation was scheduled to come onstream at Huelva for Energia e Industrias Aragonesas S.A.[24]

Sri Lanka.—The Sri Lankan Salt Corp. discontinued harvesting at the solar salt works because of large stocks on hand. Export markets were being sought to reduce the supplies.[25]

Thailand.—The Asian Development Bank has funded a feasibility study of a rock salt and synthetic soda ash project. The high-purity salt that would serve as the raw material for the soda ash plant exists in large quantities in northeastern Thailand.[26]

Turkey.—The annual capacity of the State-owned salt plant at Camalti was being expanded from 400,000 to 1.1 million tons per year.[27]

United Kingdom.—BP Chemicals Ltd. announced plans to cease salt production at Sandbach in Cheshire because of subsidence problems. The decision was contingent on the availability of a satisfactory alternative source of supply.[28]

Yemen Arab Republic.—Production of rock salt by the Yemen Salt Mining Corp. restarted in July at Salif. The modernization project over the last few years has expanded capacity from an original 110,000 tons per year to a potential 1.1 million tons per year and provided new shiploading facilities.[29]

Table 15.—Salt: World production, by country

(Thousand short tons)

Country[1]	1975	1976	1977[p]
North America:			
Bahamas	1,359	1,491	1,841
Canada	[r]5,330	6,607	6,540
Costa Rica	17	22	30
Dominican Republic[e]	44	44	18
El Salvador[e]	25	25	28
Guatemala	10	12	12
Honduras	34	[r] [e]20	3
Leeward and Windward Islands	55	[e]55	[e]55
Martinique[e]	180	180	165
Mexico	5,902	5,061	[e]5,000
Netherlands Antilles[e]	530	530	440
Nicaragua	[e]13	15	[e]17
Panama	[r]32	14	23
United States, including Puerto Rico:			
Rock salt	14,283	15,668	14,958
Other salt:			
United States	26,747	28,523	28,454
Puerto Rico[e]	27	27	27
South America:			
Argentina:			
Rock salt	[r]1	2	2
Other salt	[r]1,727	727	775
Brazil	2,365	2,726	[e]2,760
Chile	330	472	467
Colombia:			
Rock salt	204	204	201
Other salt	817	577	476
Peru	[e]390	335	342
Venezuela	320	[r] [e]330	266
Europe:			
Albania[e]	55	55	55
Austria:			
Rock salt	1	1	1
Other salt	509	634	356
Bulgaria	98	[e]110	[e]110
Czechoslovakia	102	101	[e]110
Denmark	269	385	346
France:			
Rock salt and brine salt	4,862	5,495	[e]5,500
Marine salt	1,242	1,577	[e]1,650
German Democratic Republic	[r]2,679	2,821	[e]2,860
Germany, Federal Republic of (marketable):			
Rock salt	5,929	7,584	8,167
Marine salt and other	4,340	5,448	[e]5,500
Greece	63	54	209
Italy:			
Rock salt and brine salt	3,518	3,759	3,969
Marine salt	1,345	664	660
Malta	(2)	(2)	(2)
Netherlands	2,965	3,336	3,429
Poland:			
Rock salt	1,744	1,821	[e]1,870
Other salt	[r]2,141	2,388	[e]2,400
Portugal:			
Rock salt	[r]327	334	386
Marine salt	234	[r] [e]240	[e]240
Romania	4,225	4,641	[e]5,000
Spain:			
Rock salt	2,021	2,204	[e]2,200
Marine salt and other evaporated[3]	1,432	1,277	1,320
Switzerland	261	343	393
U.S.S.R.[e]	[r]15,100	[r]15,430	17,100
United Kingdom:			
Rock salt	[r]831	674	[e]660
Other salt	7,579	8,152	[e]8,160
Yugoslavia:			
Rock salt	86	101	[e]100
Other salt	239	218	[e]225
Africa:			
Algeria	138	150	165
Angola[e]	110	110	110
Dahomey	[r](2)	(2)	(2)
Egypt	[r]685	530	658
Ethiopia:			
Rock salt	11	[e]11	6
Marine salt	84	97	[e]80
Ghana[e]	57	57	55

See footnotes at end of table.

Table 15.—Salt: World production, by country —Continued

(Thousand short tons)

Country[1]	1975	1976	1977[p]
Africa: —Continued			
Kenya	6	16	44
Libya[e]	11	11	11
Madagascar	29	30	29
Mali[e]	6	6	6
Mauritania[e]	1	1	1
Mauritius	[r]7	6	7
Morocco	46	[r e]33	14
Mozambique	35	[e]31	[e]31
Niger[e]	1	1	1
Senegal	146	156	154
Sierra Leone	199	[e]200	[e]200
Somali Republic[e]	2	2	2
South Africa, Republic of	291	247	267
South-West Africa, Territory of (marine salt)	[r]230	240	240
Sudan	73	77	101
Tanzania	49	24	8
Togo	3	[e]([2])	--
Tunisia	[r]507	480	446
Uganda[e]	3	3	3
Asia:			
Afghanistan[4]	[r]66	77	86
Bangladesh	[r]823	617	747
Burma	[r]106	35	34
China, People's Republic of[e]	33,000	[r]33,000	33,000
Cyprus	4	3	--
Democratic Kampuchea[e]	33	33	33
India	[r]5,353	3,382	1,937
Indonesia	57	234	621
Iran[4]	440	772	772
Iraq[e]	[r]70	[r]70	66
Israel	[r]127	117	[e]110
Japan[5]	[r]1,115	1,125	1,164
Jordan	[r]28	28	33
Korea, North[e]	600	600	600
Korea, Republic of	733	762	875
Kuwait	20	17	[e]17
Laos[e]	11	11	11
Lebanon[e]	[r]40	[r]40	40
Mongolia[e]	12	12	16
Pakistan:			
Rock salt[6]	446	462	[e]465
Other salt	140	156	[e]165
Philippines	[r]223	224	235
Sri Lanka	[r]134	155	[e]165
Syrian Arab Republic	36	60	[e]61
Taiwan	296	548	547
Thailand:			
Rock salt	[r]3	[r]6	14
Other[e]	[r]165	[r]165	165
Turkey	[r]749	[e]750	[e]750
Vietnam[e]	[r]390	[r]390	390
Yemen Arab Republic[e]	55	110	220
Yemen, People's Democratic Republic of[e]	83	83	83
Oceania:			
Australia (marine and brine salt)	[r]5,136	[e]5,200	[e]5,300
New Zealand	44	47	[e]55
Total	[r]178,207	185,324	187,292

[e]Estimate. [p]Preliminary. [r]Revised.

[1]Salt is produced in many other countries, but quantities are relatively insignificant or reliable production data are not available.

[2]Less than 1/2 unit.

[3]Includes an average annual production in the Canary Islands of about 30,000 short tons of marine salt.

[4]Year beginning March 21 of that stated.

[5]Includes an estimated 7,000 tons for Ryukyu Islands.

[6]Quantity shown is for 12 months ending June 30th of the year stated.

TECHNOLOGY

Water and deicing salt can penetrate concrete and corrode embedded steel reinforcement rods, which then expand and crack the concrete. A new treatment consists of drying the road surface thoroughly with infrared heaters, then pouring on a mixture of linseed oil and mineral spirits. This sealing process could extend the lifetime of the surface fourfold and significantly reduce repair expenditures.[30] In addition, a hydrophobic road surface, to which snow and ice will not adhere, has been developed at Rice University and was being tested at Washington State University.[31]

Research has indicated that salt increases beet crop yields, so Albright & Wilson, Ltd., of the United Kingdom, has introduced new autumn-applied beet fertilizers with a high salt content.[32]

A flash-distillation desalination process developed at Israel's Technion Institute has eliminated the extensive copper tubing normally required. Direct contact heat transfer is used to achieve evaporation.[33]

E. I. du Pont de Nemours & Co. has manufactured a reverse-osmosis permeator that can desalinate 5,000 gallons of seawater per day, a threefold capacity increase over the prototype hollow-polyamide-fiber unit. According to the company, large plants of this type are cheaper to construct and operate than distillation facilities.[34]

The U.S. Bureau of Reclamation recommended to the U.S. Department of the Interior that contract awards for the Yuma, Ariz., project to desalt the Colorado River go to UOP, Inc., and Hydranautics, which offered spiral-wound, reverse-osmosis technology. The 100-million-gallon-per-day desalination plant must be built to make the river water that flows into Mexico suitable for domestic use and irrigation, as mandated by treaty obligations made in 1973. A controversy over costs versus performance parameters has led du Pont to challenge the Bureau's recommendation.[35]

Kaiser Engineers received a contract from the Energy Research and Development Administration for conceptual designs of a facility for long-term storage of high-level nuclear reactor wastes in bedded salt deposits. The project is part of the National Waste Terminal Storage program, which was established to identify potential geologic sites for waste depositories.[36]

---

[1]Physical scientist, Division of Nonmetallic Minerals.
[2]Chemical Week. Salt Makers Map Impact of Oil Storage. V. 121, No. 8, Aug. 24, 1977, p. 36.
[3]———. Scowl, Then a Smile for Solution Mining. V. 120, No. 5, Feb. 2, 1977, pp. 13-14.
[4]Wall Street Journal. Morton-Norwich Says U.S. To Pay $30 Million for Rock Salt Mine. V. 190, No. 40, Aug. 26, 1977, p. 12.
[5]Morton-Norwich Products, Inc. 1978 Annual Report. P. 4.
[6]Diamond Crystal Salt Co. 1978 Annual Report. Pp. 2, 4.
[7]Great Salt Lake Minerals & Chemicals Corp. 1977 Annual Report. Pp. 14-15.
[8]Chemical Marketing Reporter. Current Prices of Chemicals and Related Materials. V. 213, No. 26, Dec. 26, 1977, p. 34.
[9]———. Sodium Chloride. V. 212, No. 2, July 11, 1977, pp. 28-29.
———. Sodium Chloride. V. 212, No. 7, Aug. 15, 1977, pp. 32-33.
[10]Industrial Minerals. Company News & Mineral Notes. No. 122, November 1977, p. 79.
[11]———. New Salt Refinery. No. 119, August 1977, p. 9.
[12]———. Australian Salt—Troubles Continue. No. 116, May 1977, p. 9.
[13]Work cited in footnote 6.
Morton-Norwich Products, Inc. 1977 Annual Report. P. 9.
[14]European Chemical News. Technology. In Brief. V. 30, No. 771, Jan. 28, 1977, p. 27.
[15]Industrial Minerals. Company News & Mineral Notes. No. 117, June 1977, p. 69.
[16]European Chemical News. Dead Sea Works Expands Salt Production. V. 30, No. 768, Jan. 7, 1977, p. 31.
[17]Chemical Week. Israeli Salt Unit Gets Under Way. V. 120, No. 14, Apr. 6, 1977, p. 23.
[18]European Chemical News. New Projects. In Brief. V. 31, No. 802, Sept. 9, 1977, p. 45.
[19]Industrial Minerals. Company News & Mineral Notes. No. 121, October 1977, p. 68.
[20]European Chemical News. Polish Chlorine Plans Boost Salt Output. V. 30, No. 774, Feb. 18, 1977, p. 33.
———. In Brief. V. 31, No. 806, Oct. 7, 1977, p. 44.
[21]Work cited in footnote 15.
[22]Chemical Marketing Reporter. U.S., Saudi Arabia Agree on Desalination Program. V. 211, No. 20, May 16, 1977, p. 15.
[23]———. Desalination Contract is Awarded to UOP, Inc. V. 212, No. 11, Sept. 12, 1977, p. 16.
[24]European Chemical News. Aragonesas Commissions First of Several New Plants. V. 30, No. 773, Feb. 11, 1977, p. 16.
[25]Mining Journal. Sri Lanka Seeks Salt Markets. V. 289, No. 7414, Sept. 23, 1977, p. 247.
[26]Industrial Minerals. ADB Finance for Soda Ash Project. No. 115, April 1977, p. 14.
[27]———. Company News & Mineral Notes. No. 113, February 1977, p. 44.
[28]———. BP Terminates Salt Production. No. 113, February 1977, p. 13.
[29]Chemical Age. Yemen Salt Project is Commissioning. V. 115, No. 3024, July 1, 1977, p. 6.
Mining Journal. Yemen Salt Sales. V. 289, No. 7426, Dec. 16, 1977, p. 502.
[30]Chemical & Engineering News. Treatment Adds New Life to Bridge Decks. V. 55, No. 45, Nov. 7, 1977, p.35.
[31]Rock Products. EPA May Encourage New Surfacing in Place of De-Icing Salt. V. 80, No. 4, April 1977, p. 18.
[32]European Chemical News. New Beet Fertilizer from Albright & Wilson. V. 31, No. 793, July 1, 1977, p.12.
[33]———. Technology. In Brief. V. 31, No. 802, Sept. 9, 1977, p. 32.
[34]Chemical & Engineering News. Large Desalination Unit Introduced. V. 55, No. 31, Aug. 1, 1977, p. 14.
[35]Chemical Marketing Reporter. DuPont Petitions Court for New Bid on Desalination Plant in Yuma, Ariz. V. 212, No. 20, Nov. 14, 1977, pp. 4, 45.
[36]Chemical & Engineering News. Nuclear Waste Disposal Contract Awarded. V. 55, No. 41, Oct. 10, 1977, p. 30.

Sand and Gravel

By James R. Evans[1]

In 1977, a total of 929 million tons of sand and gravel was reportedly produced in the United States. This tonnage is the second highest ever recorded. The highest was 984 million tons in 1973. The 1977 f.o.b. value was a record $2 billion. Of the totals, construction sand and gravel was 898 million tons, with a value of $1.8 billion, and industrial sand and gravel was 31 million tons with a value of $210.6 million.

Table 1.—Salient sand and gravel statistics[1]

(Thousand short tons and thousand dollars)

	1973	1974	1975	1976	1977
Sold or used:					
Construction:					
Processed:					
Sand:					
Quantity	346,996	322,607	265,404	418,495	439,400
Value	472,292	490,718	448,583	654,389	848,200
Gravel:					
Quantity	510,031	404,411	353,652	436,747	458,400
Value	706,329	683,408	634,931	949,405	968,700
Unprocessed:					
Sand and gravel:					
Quantity	97,627	148,558	143,097	(2)	(2)
Value	70,684	104,205	106,827	(2)	(2)
Total construction:[3]					
Quantity	954,654	875,576	762,153	855,242	897,900
Value	1,249,305	1,278,331	1,190,341	1,603,794	1,817,000
Industrial:					
Sand:					
Quantity	28,974	28,024	26,723	29,669	29,610
Value	110,065	135,357	146,982	169,127	201,900
Gravel:					
Quantity	--	1,046	560	245	1,745
Value	--	3,342	2,996	1,109	8,704
Total industrial:[3]					
Quantity	28,974	29,070	27,283	29,914	31,360
Value	110,065	138,699	149,978	170,236	210,600
Total:[3]					
Quantity	983,629	904,646	789,436	885,156	929,200
Value	1,359,370	1,417,030	1,340,319	1,774,030	2,028,000
Exports:					
Quantity	1,744	2,256	3,219	3,692	3,689
Value[4]	8,597	11,664	15,047	19,516	21,515
Imports:					
Quantity	800	394	374	353	386
Value[5]	1,576	839	777	909	1,278
Apparent consumption	983,000	904,000	787,000	883,000	926,000
Value (f.o.b., per ton):					
Construction sand and gravel	1.31	1.46	1.56	1.88	2.02
Industrial sand and gravel	3.80	4.77	5.50	5.69	6.72
Total sand and gravel	1.38	1.57	1.70	2.00	2.18

[1]Puerto Rico excluded from all sand and gravel statistics.
[2]Processed and unprocessed are no longer separated.
[3]Data may not add to totals shown because of independent rounding.
[4]F.a.s. (free alongside ship).
[5]Customs import value.

Production for 1977 was up 5% over that of 1976 for both construction and industrial sand and gravel, reflecting the strengthened building and construction markets. Also the per ton price of all sand and gravel increased from $2.00 to $2.18. Imports and exports of sand and gravel in 1977 were nearly the same as for 1976, at about 360,000 and 3.7 million tons, respectively. About 2.5 million tons of the exports was industrial sand and gravel. Domestic consumption of all sand and gravel was about 926 million tons.

Legislation and Government Programs.—Federal regulations for particulate matter in the air are administered by the Environmental Protection Agency (EPA) under the Clean Air Act of 1970. Waste water discharges from and around sand and gravel operations are also administered by EPA. These regulations were put forth under the National Pollutant Discharge Elimination System (NPDES) from the Federal Water Pollution Control Act of 1972. The administration of NPDES for both nonpoint and point discharges can be handled by States if they have a federally approved program. Final regulations for limitation of point source discharges (discharges into navigable waters) were published in the Federal Register, v. 42, No. 133, July 12, 1977. An important point is that EPA has recognized that some sand and gravel operations may have occasional discharge from tailing ponds due to heavy rainfall and/or seepage. Therefore, limited discharge may be allowed from those operations which recycle water for processing. EPA's clear view is that the best practicable control technology currently available includes recycling of process water.

The Federal Surface Mining Control and Reclamation Act was signed into law on August 3, 1977. While this act pertains only to coal mining and reclamation, there is a provision in it which requires studies of noncoal minerals that may come under Federal legislation. Sand and gravel is one of the noncoal minerals. On April 1, 1978, the National Academy of Sciences (NAS) was given a contract to make a study and recommendations for mining and reclamation of noncoal minerals, with sand and gravel to be treated as a separate commodity, to see if these minerals could be administered under the existing act. Their report is due about March 15, 1979. A Federal act to control the mining and reclamation of sand and gravel would have a major impact on those States that do not already have a State act in force. In many States mining and reclamation are controlled by local governments under guidelines from the States. Generally rigorous requirements are in force and a mining and reclamation plan must be approved before extraction of sand and gravel can begin.

On March 9, 1978, the Federal Mine Safety and Health Act of 1977 became effective, and will have a significant impact on the sand and gravel industry. The act will be enforced by the Mine Safety and Health Administration (MSHA) of the Department of Labor, successor to the Mining Enforcement and Safety Administration (MESA) of the Department of the Interior.

All mandatory standards under the 1966 Metal and Nonmetallic Mine Safety Act are retained in the new 1977 act. The advisory standards from the old act are under review by a committee appointed by the Secretary of Labor. The Secretary is to develop and adopt mandatory standards on "toxic materials and harmful physical agents." All proposed mandatory standards or regulations will be published in the Federal Register. The Secretary must provide every sand and gravel operator with a copy of the prefaced standard or regulation as soon as it is published. Operators who violate mandatory standards can be fined as much as $10,000 per violation.

Under the new act an inspector can issue a citation if he believes there was a violation of the rules. Previously, the inspector had to find the violation. Now if an inspector finds what he thinks is a condition of imminent danger, he can issue a closure order. The operator must correct the condition or contest the closure order within 30 calendar days from receipt of the order, and request a hearing before the Administrative Law Judges of the Mine Safety and Health Review Commission. Until satisfaction is obtained by this group, the operation must remain closed.

Safety and health training for new miners are required under the new act; a minimum of 40 hours for underground workers and 24 hours for surface workers. Every year each miner must complete at least 8 hours of refresher safety and health training. The training programs should be given by or through MSHA certified instructors. Mines are to be given certificates after completing the training programs.

The new 1977 Act has placed responsibility for the health and safety of sand and gravel miners, as well as all other miners, directly on the management staff. Also the

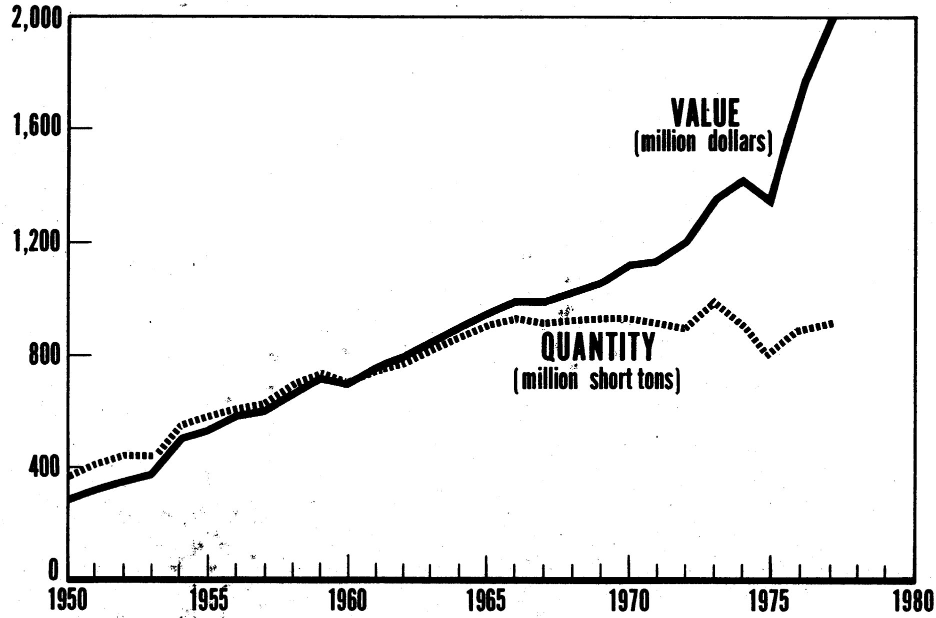


Figure 1.—Production and value of sand and gravel in the United States for 1950-77.

act provides for the participation of the miners in decisions that could relate to their own safety and health. Compliance with the new act probably will result in an increased cost of doing business in the sand and gravel industry.

During 1977, several important articles were published regarding health and safety in the sand and gravel industry.[2]

DOMESTIC PRODUCTION

Production and value of both construction and industrial sand and gravel in 1976 and 1977 for all nine geographic regions are shown in table 2 and figure 2. Table 3 shows the percentage produced from each geographic region. Even though the tonnage produced in 1977 was 5% higher than for 1976, the percentage produced from each geographic region for each year is very close. Production of construction and industrial sand and gravel from 1970 to 1977 is shown graphically in figures 3 and 4.

As in 1976, the Pacific region led the Nation in production of construction sand and gravel with 209 million tons, 23% of the national total. The East North Central region was next with 173 million tons, followed by the West North Central region with 102 million tons. In industrial sand and gravel, the East North Central region led the Nation with 13 million tons; 41% of the national total and nearly three times the tonnage of the second-place South Atlantic region.

On a State basis, California again led the Nation in production and value of construction sand and gravel with 109 million tons valued (f.o.b.) at $251 million (table 4). California's total sand and gravel production was 12% of the national total tonnage and 12% of the total f.o.b. value. Next in order were Alaska, Texas, Ohio, and Michigan. Collectively, these five States provided 35% of the national total, the same percentage of the national total as for 1976. The five leading States for industrial sand and gravel, in order, were Michigan, Illinois, New Jersey, California, and West Virginia. Their combined tonnage made up 51% of the national industrial sand and gravel output.

The 10 largest construction sand and gravel producing companies in the Nation (exclusive of contractors to the Bureau of

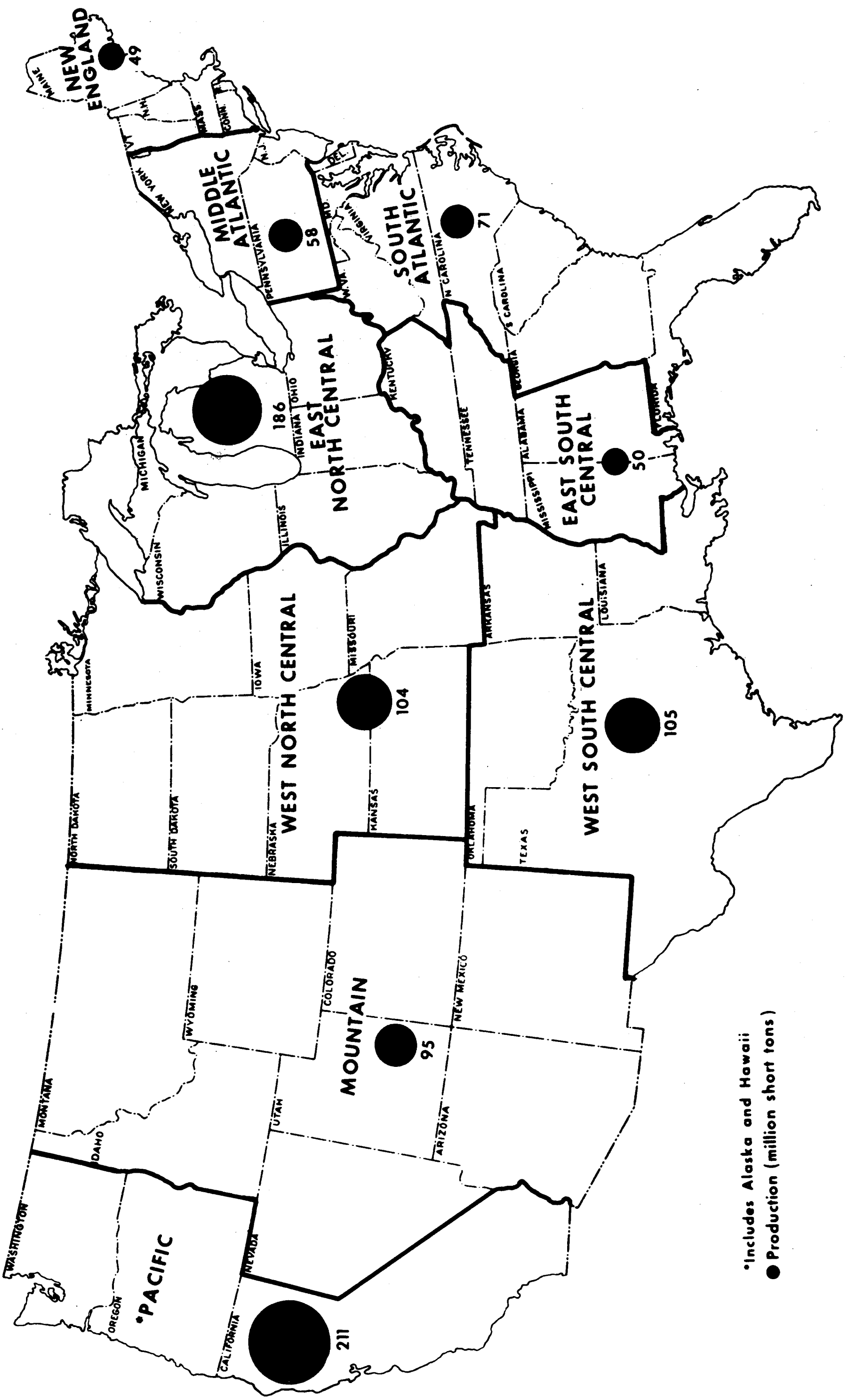


Figure 2.—Production of sand and gravel by geographic region in the United States in 1977.

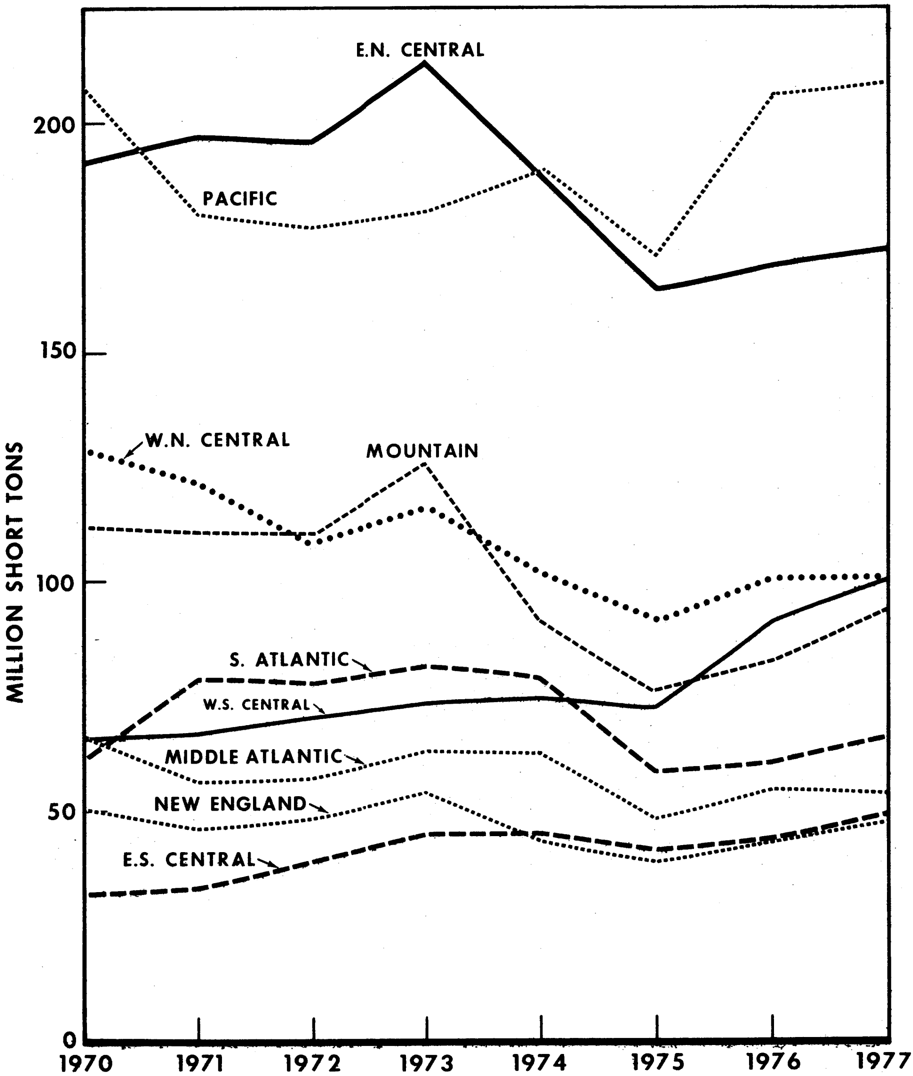


Figure 3.—Production of construction sand and gravel by geographic region in the United States for 1970-77.

Land Management in Alaska), in order of decreasing tonnage, were as follows: Lone Star Industries, Inc.; Conrock Co.; Dravo Corp.; American Aggregates Corp.; Gifford-Hill & Co., Inc.; Martin Marietta Aggregates; Kaiser Sand and Gravel; General Development Corp.; Livingston-Graham, Inc.; and Owl Rock Products Co. Collectively, these companies produced about 10% of the national total of construction sand and gravel. In industrial sand and gravel the 10 largest producing companies, in order of decreasing tonnage, were as follows: Pennsylvania Glass Sand Corp.; Ottawa Silica Co.; Del Monte Properties Co.; Martin Marietta Aggregates; Manley Brothers of Indiana, Inc.; Sargent Sand Co.; Dallas Sand & Gravel Co.; Owens-Illinois, Inc.; Hardy Sand Co.; and Standard Sand & Silica Co. Collectively, these companies produced 58% of the national total of industrial sand and gravel.

Production was reported from 7,402 deposits in 1977. Construction sand and

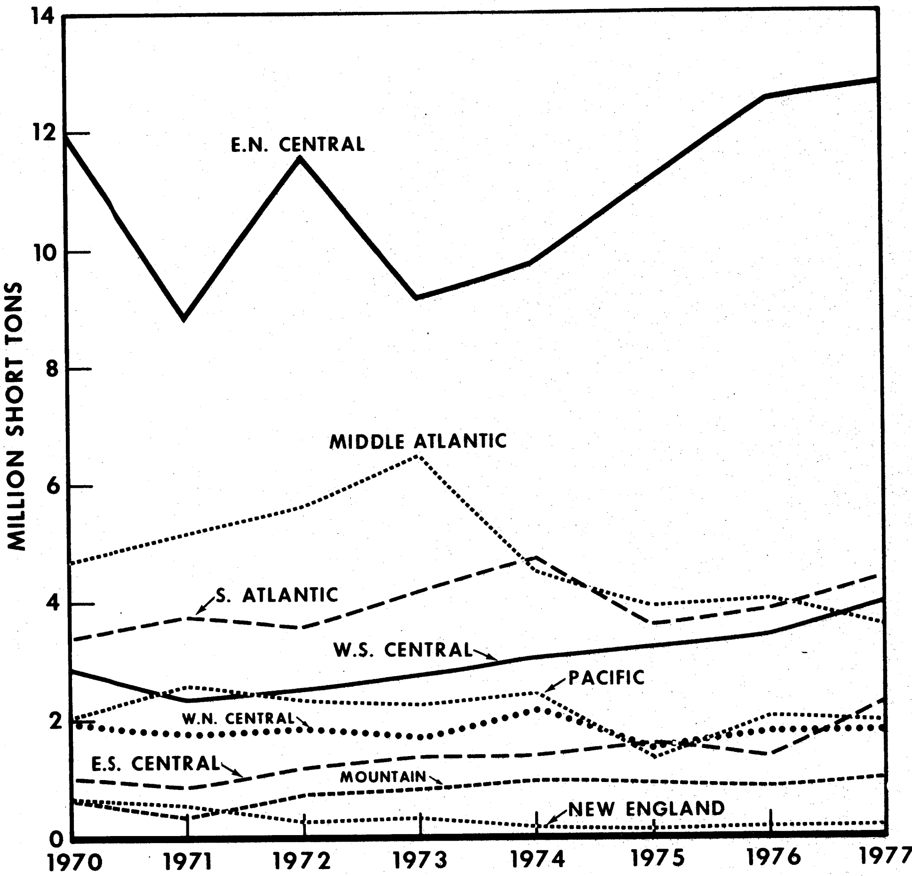


Figure 4.—Production of industrial sand and gravel by geographic region in the United States for 1970-77.

gravel was taken from 7,222 deposits, and industrial sand and gravel from 180 deposits. A deposit is here defined as one extraction area, or several adjacent extraction areas within a single county. Most of the tonnage came from deposits that produced over 200,000 tons even though they were few in number compared with deposits that produced less than 200,000 tons. For example, there were 6,163 construction sand and gravel deposits (85% of the total number) that produced less than 200,000 tons, and only 1,059 deposits (15% of the total) that produced over 200,000 tons. However, those 1,059 deposits accounted for 63% of the total tonnage produced. See table 5 for a detailed presentation of the number and percentage of deposits within different tonnage levels.

There were 6,179 sand and gravel processing plants reported in operation in 1977. Of these, 5,134 were associated with extraction areas on land, and 1,045 were associated with dredging operations. Many plants had only simple crushing, washing, and screening operations, while others were sophisticated and automated plants that could process several million tons per year. Tables 6 and 7 show the type and distribution of plants by State and by geographic region in the United States.

Most of the sand and gravel tonnages reported to the Bureau of Mines is actually that sold or used and not production. Some companies may have produced more than they sold on the market and/or sold to themselves as a user. Other companies, because of existing stockpiles, sold or used more than they produced. Over a period of a few years, a company's production should be equivalent to material sold or used.

During late 1977, Kaiser Industries Corp. sold its sand and gravel division, nearly all of which is in California, to Koppers Co., Inc., of Pittsburgh, Pa., for about $21.5 million. Also, Dravo Corp. purchased Laughery Gravel Co. of Aurora, Ind., and made it part of the corporation's Ohio Gravel Div. The purchase should allow the expansion of Dravo's market area into southeastern Indiana and northern Kentucky. Presently, the corporation's market area is the greater Pittsburgh and southwestern Ohio areas. M. T. Epling Co., of Gallipolis, Ohio, has put a new 400-tons-per-hour aggregate plant onstream, one of the largest in the mid-Ohio Valley area.

Several important articles relating to the production of both construction and industrial sand and gravel were published in 1977 on dredging,[3] on glass,[4] on mine and plant operations,[5] and on supply-demand studies.[6]

CONSUMPTION AND USES

United States consumption of construction sand and gravel was about 898 million tons, 97% of all sand and gravel consumption. Of this tonnage 38% went into concrete aggregate blends for use in residential and nonresidential buildings, and engineered construction works such as highways, bridges, dams, waterworks, and airports. About 6% went into concrete products such as blocks, bricks, and pipe; 15% into asphaltic concrete aggregate and other bituminous mixtures, and 21% into roadbases and coverings for construction and repair of highways and roads. Nearly 18% went into construction fills, less than 1% for railroad ballast, and about 2% into other unspecified uses (table 8).

The major use pattern for construction sand and gravel by geographic region in the United States is shown in table 9. Compared with 1976, the 1977 data indicate great differences between use categories and in use between certain geographic regions. For example, the Pacific region leads the United States in use of total construction sand and gravel, concrete aggregate, and fill. However, the East North Central region leads the Nation in use of asphaltic concrete aggregate, concrete products, and roadbases and coverings.

Table 10, which is based on data from table 9, shows a percentage breakdown by major uses, by geographic regions for 1976-77. The percentage figures aid in quickly determining the relative proportions of sand and gravel by major use and region.

In table 11 the major uses of construction sand and gravel by State are shown. The top 10 States in order of decreasing total tonnage were as follows, in millions of tons used: California, 107; Alaska, 66; Texas, 54; Ohio, 45, Michigan, 40; Illinois, 33; Minnesota, 30; New York, 29; Wisconsin, 28; and Indiana, 26. These States made up 51% of the total national consumption. Table 13 shows the f.o.b. price per ton for each of the categories shown in table 11.

Total production of industrial sand and gravel in the United States was 31.4 million tons, but about 2.5 million tons was exported for uses which are undetermined. Therefore, for purposes of this report the data in table 12 are considered to represent apparent consumption. On this basis the top 10 States in order of decreasing tonnage were as follows: Michigan, Illinois, New Jersey, California, West Virginia, Texas, Oklahoma, Pennsylvania, Ohio, and Missouri. These States produced 69% of the national total (table 4). The main uses of industrial sand and gravel are for container, flat, specialty glasses, fiberglass, foundry purposes, and manufacture of the metals silicon carbide, silicon, and ferrosilicon.

Several important articles were published in 1977 on abrasives,[7] on concrete products,[8] on foundry products,[9] on glass,[10] on highway construction,[11] and on sulfur and sulfur-asphalt-concrete mixtures.[12]

Environmental Factors.—Although much progress is being made through premining planning, the sand and gravel industry continues to have problems with environmental controls, land use conflicts, and reclamation practices. Many of these problems are acute because extraction areas and plants must be reasonably near to consumers who are largely in metropolitan areas. Major environmental considerations that must be dealt with in mining and processing sand and gravel are emission of particulate matter into the air, processing water discharge, and noise abatement.

Several important articles on environment,[13] land use and reclamation,[14] and recycling[15] as related to sand and gravel mining and processing, or products made from sand and gravel were published in 1977.

TRANSPORTATION

In 1977, transportation costs made up a major part of the delivered price of sand and gravel, and locally, were greater than the sales (f.o.b.) value of the material at the processing plants. An estimated 75% of transported sand and gravel was hauled by truck. Costs were from about $0.05 to $0.10 per ton-mile. Many companies with their own truck fleet transported their own raw materials and products. A significant, but unknown, amount of sand and gravel was hauled by independent truckers. An estimated 5% of transported sand and gravel was moved by rail. It may be possible or necessary in the future to move more sand and gravel by rail. Rail networks exist in most parts of the country and transportation costs per ton-mile (about $0.03) of sand and gravel are significantly lower than trucking costs, but problems exist in the quantities involved and in delivery point flexibility. The railroad cost per ton-mile is often based on trainloads of about 10 to 15 or more cars each holding 80 to 100 tons for 100- to 200-mile hauls. It is more expensive to make up small loads for short hauls. Also, it is difficult to replace loading and truck hauling at the delivery end to get the product from the railhead to the job site throughout the market area.

An estimated 4% of transported sand and gravel was moved by river barge. River barge costs per ton-mile are the cheapest and are roughly $0.015 per ton-mile through haulage of several barges by small tug. This type of transportation is limited to parts of the United States that have navigable rivers.

Several important articles having to do with transportation of sand and gravel and products made with sand and gravel were published.[16]

PRICES AND SPECIFICATIONS

For purposes of this chapter, price means f.o.b. value per ton of sand and gravel at the first point of sale or self-use. The first point may be adjacent to the extraction area, or it may be at a yard or batching plant some distance from the extraction area. The value reflects any transportation or other costs needed to bring material to the first point of sale or self-use. However, it does not reflect any transportation or other costs needed to bring sand and gravel from a plant or yard to the consumer.

Based on this canvass, the average national value per ton of construction sand was $1.93; gravel, $2.11; and construction sand and gravel, $2.02. Industrial sand was $6.82; gravel, $4.99; and industrial sand and gravel, $6.72. For all sand and gravel the national value per ton was $2.18.

National values per ton for major construction sand and gravel uses are given in table 8, values per ton for States in the United States are given in table 13. A significant difference in values between national major use categories, and between States, and their major use categories is evident. As in 1976, nationally, concrete products and concrete aggregate had the highest value per ton at $2.43 and $2.34, respectively. Next in order were railroad ballast, $2.29; asphaltic concrete aggregate, $2.15; roadbases and coverings, $1.82; and fill, $1.33.

The average values per ton for industrial sand and gravel were much higher than for construction sand and gravel because of the required chemical and physical properties. Values range from $3.95 for fire or furnace sand to $16.89 for ground filler sand. Unground glass sand has the highest total tonnage of any of the use categories, and the average value per ton is $6.02 (table 12).

The American Society for Testing and Materials issued two new books in 1977 that contain standard specifications for aggregates for use in concrete and in road and paving materials.[17]

FOREIGN TRADE

Exports.—Construction sand and gravel and industrial sand export patterns did not change appreciably from those of 1976. Most of the materials went to Canada (63%) with the remainder to France, Mexico, the Federal Republic of Germany, and several other countries. Total 1977 exports were 3.7 million tons, very close to those of 1976.

Imports.—As in 1976, about 99% of the construction sand and gravel imports came from Canada, and about 97% of the industrial sand imports came from Australia. Total 1977 imports were slightly above those of 1976 at 386,000 tons.

Tariffs

Item	Number	Rate of duty (per long ton)	
		General system of preferences	Statutory
95% or more silica (no more than 0.6% Fe_2O_3)	513.11	$0.25	$2.00
Common	513.14	Free	Free

TECHNOLOGY

A joint National Ready-Mix Concrete (NRMCA) - National Sand and Gravel Association (NSGS) - National Crushed Stone Association (NCSA) aggregate production and handling equipment show, with simultaneous business and technical sessions, was held in Las Vegas, Nev., in January 1977. Not only was this the largest show of its type (over 15,000 registrants and 200 exhibitors) ever held, but it was international in scope. At least 40 foreign countries had representatives in attendence. Several foreign countries had equipment displays. On International Day the technical programs were simultaneously translated from English into French, German, Spanish, and Japanese.

During 1977, a number of reports were published concerning the extraction, processing, and use of sand and gravel.[18]

[1]Physical scientist, (formerly with Division of Nonmetallic Minerals, now with U. S. Geological Survey).

[2]Modern Concrete. If You Can't Stop Noise You Can Try to Contain It - Interpace Corp.'s East Brunswick, N.J. Concrete Pipe Plant Solves Noise Problem With Lead-Vinyl Barrier Curtain. V. 41, No. 4, August 1977, pp. 23-24.
Robertson, J. L. (United Metro's No. 6) Aggregate Plant (Phoenix, Ariz.) Solves Processing Dust Problems With a Baghouse. Rock Prod., v. 80, No. 9, September 1977, pp. 61-66.
U.S. Code of Federal Regulations. Title 30—Mineral Resources, Parts 55, 56, 57, and 58— Metal and Nonmetallic Mines. Revised as of July 1, 1977.
Wright, R. E. Electrostatic Precipitators For Emission Control. Glass Ind., v. 58, No. 5, May 1977, pp. 12-16, 18, 20-21, 34-35.

[3]Grinstead, W. D. Aggregate Dredging in the Flatlands. World Dredging, v. 13, No. 6, May 1977, pp. 20-21.
World Dredging. Sand and Gravel Production Depends on Dredges (Ritchie Sand Co., Wichita, Kansas). V. 13, No. 6, May 1977, pp. 12-14.

[4]Bentzen, E. H., III. Producing Sand for the Glass Industry. AIME Ann. Meeting, Atlanta, Ga., Mar. 16-18 1977, Preprint 77-H-37, 23 pp.
Edwards, G. H., and J. C. Copley, Jr. Raw Materials for the Speciality Glass Industry, Part I. Glass Ind., v. 58, No. 3, March 1977, pp. 18-20.
———.Raw Materials for the Specialty Glass Industry, Part II. Glass Ind., v. 58, No. 4, April 1977, pp. 24-26.
The Glass Industry. The Natural Gas Shortage's Effect on Glassmakers. V. 58, No. 3, March 1977, pp. 21, 22, 27.
Harben, P. W. Raw Materials for the Glass Industry. Metal Bull. Ltd., 1977, 131 pp.
Mills, H. N. Raw Materials for Glass Manufacture. Glass Ind., v. 58, No. 11, November 1977, pp. 10-15, 30.
Shufflebarger, T. E., Jr. Economics of Glass Sand Prospects. Ind. Miner., No. 120, September 1977, pp. 57-63.

[5]Blaha, B. Firm Builds Concrete Image at the Top of Wisconsin (On Land and Offshore Bay Mobile Concrete, Inc. is Prepared to Tackle Every Kind of Job Requirement). Concr. Prod., v. 80, No. 4, April 1977, pp. 44-46.
Concrete Products. River Plays Vital Role in Slider's R/M Operation (E.T. Slider Co., Jeffersonville, Ind.). V. 80, No. 3, March 1977, pp. 46-48, 50.
Cunningham, C. Livingston-Graham Belongs to the Million-Yard Club (Calif. Operations). Concr. Prod, v. 80, No. 3, March 1977, pp. 42-45.
Kostka, J. Former Gold Mining Site Now Producing Sand and Gravel (Concrete Aggregate Co., Golden, Colo.). Pit and Quarry, v. 69, No. 9, March 1977, pp. 70-74.
Levine, S. It's a Patrow Family Affair (Union Construction Co.) - Portable Units Work (Eau Claire) Wisconsin S and G Pits. Pit and Quarry, v. 69, No. 6, December 1977, pp. 104-106.
Pit and Quarry. Livingston-Graham Mines Sand and Gravel With Combination Shovel, Tractor-Wagon (Irwindale, Calif. Deposit). V. 69, No. 1, July 1977, pp. 48-52.
Robertson, J. L. This Glacial Esker Supplies Aggregates to Gravel-Poor Area (Straits Aggregate and Equipment Corp.'s Big Cut Operation, Millersburg, Mich.). Rock Prod., v. 80, No. 3, March 1977, pp. 76-78, 80.
Trauffer, W. E. Walt Keeler Co.'s 200-tph Plant Supplies Concrete Sand for Its Four Ready-Mix Plants in Wichita, Kansas. Pit and Quarry, v. 69, No. 12, June 1977, pp. 84-86.

[6]Evans, J. R., T. P. Anderson, M. W. Manson, R. L. Maud, W. B. Clark, and D. L. Fife. Aggregates in the Greater Los Angeles Area, California. California Division of Mines and Geology Open File Rept. 77-12A, 1977, 242 pp.
Graham, J. W. Aggregates as Construction Material in the Southeast. AIME Ann. Meeting, Atlanta, Ga., Mar. 16-18, 1977, Preprint Number 77-H-45, 5 pp.

[7]Myers, R. E. Blast Cleaning Abrasives and Their Application. Foundry Management Technol., v. 105, No. 11, November 1977, pp. 42-46.

[8]Blaha, B. Dakota Block's Territory Covers Five States (Rapid City, S.D., Producer Markets Block Through 70 Dealers). Concr. Prod., v. 80, No. 4, April 1977, pp. 34-38.
———.Wisconsin Producer "Trains" His Block (Winger Concrete Products, Inc. Runs Smooth Operation With Custom-Built Rack Tram System). Concr. Prod., v. 80, No. 4, April 1977, pp. 56-57.
Concrete Products. Ameron Produces, Installs the World's Largest Precast Pipe (Over 1,000 Sections of Record-Size Pipe Are Being Manufactured at an Onsite Plant, Near Phoenix, for the Central Arizona Project). V. 80, No. 4, April 1977, pp. 24-29.
Leverette, F. A New Mortarless Concrete Block Becomes Available to Producers (Superblock by Superblock Corp., Scottsdale, Ariz.). Mod. Concr., v. 41, No. 4, August 1977, pp. 58-60.
———.Doby Brick and Supply Co. is Early Entrant in Paver Production (Florida Block Producer Makes Concrete Interlocking Pavers in Variety of Shapes, Colors). Mod. Concr., v. 41, No. 4, August 1977, pp. 51-53.

Levine, S. Concrete Staves Provide Long-Lasting Silos (Koser Silo Works). Mod. Concr., v. 41, No. 6, October 1977, pp. 56-58.

———.Fehr Concrete Stresses Seminars for Product Promotion (Fehr Concrete Products, Inc., Eau Claire, Wis.). Mod. Concr., v. 41, No. 6, October 1977, pp. 46-48.

Herod, S. Precast/Prestressed Concrete Tanks Gaining in Various Markets (Preload Co., Garden City, N.Y.). Mod. Concr., v. 41, No. 7, November 1977, pp. 39-41.

Highway and Heavy Construction. Massive Slabs Poured Around the Clock (Blount Brothers. Corp. at Commonwealth Edison Co. is Byron Nuclear Power Plant, Rockford, Ill.). V. 120, No. 6, June 1977, pp. 33-35.

Modern Concrete. Prestressed Concrete Cylinder Pipe for Dallas Sewer Plant Project (Gifford-Hill-American Supplying 72" and 84" Pipe for Trinity River Authority). V. 41, No. 7, November 1977, pp. 42-43.

[9]Ashby, G. Minerals in the Foundry Industry. Ind. Miner., No. 124, January 1978, pp. 29-45.

Industrial Minerals. Olivine and Dunite - Blast Furnace Usage Adds New Dimension (to Foundry Sands and Other Uses). No. 116, May 1977, pp. 34-49.

Teaque, K. H. Olivine - Past, Present and Future. AIME Ann. Meeting, Atlanta, Ga., March 1977, preprint 77-H-69, 10 pp.

Wahl, E. R., and R. A. Green. Bulk Handling of Preblended Sand Additives. Foundry Management Technol., v. 105, No. 10, October 1977, pp. 136-140.

[10]The Glass Industry. Glass Container Industry Outlook - Current Developments and Future Trends. V. 58, No. 7, February 1977, pp. 17-19.

———.Glass Container Industry Outlook - Current Developments and Future Trends. V. 59, No. 2, February 1978, pp. 12-15.

———.The Flat Glass Industry Outlook. V. 58, No. 3, March 1977, pp. 24-25.

———.The Flat Glass Industry Outlook - Current Developments and Future Trends. V. 59, No. 2, February 1978, pp. 16-28.

Jones, J. Glass Fiber-Reinforced Cement. Glass Ind., v. 58, No. 6, June 1977, pp. 26-28.

[11]Highway and Heavy Construction. Freeway Paved - Both Sides At Same Time (Kennedy Highway near Baltimore, Md.). V. 120, No. 5, May 1977, p. 147.

———. Grades Work Off Stringline for Tight Grade Control (R. E. Hazard Contracting Co. near San Diego, Calif.). V. 120, No. 6, June 1977, pp. 86-87.

———. Post-Tensioned Pavement Gets Major Test (Near Phoenix, Ariz.). V. 120, No. 8, August 1977, pp. 38-40.

———. Precast Guides Save on Bridge Job (Shockey Brothers, Winchester, Va.). V. 120, No. 5, May 1977, pp. 106-107.

Modern Concrete. Concrete Overlay Reduces Pavement Restoration Cost (near Snowville, Utah). V. 41, No. 6, October 1977, pp. 23-26.

———. Precast Concrete Girder Meets Stringent Tests (Dade County's rapid transit system, Fla.). V. 41, No. 7, November 1977, p. 62.

[12]Engineering News Record. Waste Sulfur May Be Road Bonanza (Foamed Sulfur to Prevent Frost Heaves). V. 198, No. 14, Apr. 7, 1977, p. 12.

Saylak, D. and B. M. Gallaway. Beneficial Use of Sulfur in Sulfur Asphalt Pavements - A Final Report Project RF983, July 1, 1976, to November 1977. Prepared for the Bureau of Mines and the Sulfur Institute by the Texas A & M Research Foundation, 1978.

Sullivan, T. A., and W. C. McBee. Development and Testing of Superior Sulfur Concretes. Bumines RI 8160, 1976, 30 pp.

Sullivan, T. A., W. C. McBee, and K. L. Rasmussen. Studies of Sand - Sulfur - Asphalt Paving Materials. Bumines RI 8087, 1975, 19 pp.

[13]Blaha, B. Pink City: Color It Clean and Attractive (Builders Concrete, Fresno, Calif.). Concr. Prod., v. 80, No. 9, September 1977, pp. 22-26.

Highway and Heavy Construction. New Erosion Controls Work Well, Look Good (Shreveport, La.). V. 120, No. 6, June 1977, p. 56.

Leverette, F. Stop Beach, Shoreline Erosion Permanently With Concrete Block - Surgebreaker System of Concrete Block Modules Developed by Great Lakes Environmental Marine. Mod. Concr., v. 41, No. 4, August 1977, pp. 36-40.

Padan, J. W. (ed.). New England Offshore Mining Environmental Study (Project NOMES). NOAA Spec. Rept, U.S. Department of Commerce, April 1977, 140 pp.

Pit and Quarry. Michigan Sand Plant (Bridgeman Plant, Industrial Sand Div., Martin Marietta Corp.). Is Colorful Good Neighbor - Bridgeman's Program Ranges From Town Beach to Tree - Planting to Colorfully Painted Silos and Other Structures. V. 69, No. 5, November 1977, pp. 72-74.

[14]California State Mining and Geology Board. State Policy for Surface Mining and Reclamation Practice - With the Surface Mining and Reclamation Act of 1975. California Division of Mines and Geology, Spec. Pub. 51, 1977, 20 pp.

Imhoff, E. A., T. O. Friz, and J. R. LaFevers. A Guide to State Programs for the Reclamation of Surface Mined Areas. U. S. Geol. Survey Circular 731, 1976, 33 pp.

[15]Highway and Heavy Construction. Old Blacktop Recycled Without Smoke (Maplewood, Minn.). V. 120, No. 6, June 1977, pp. 104-105.

———. Recycled Slab in New Runway Base (Jacksonville International Airport). V. 120, No. 7, July 1977, pp. 30-33.

Rock Projects. Rubble Recycling Saves Time, Energy, and the Environment (Los Angeles, Calif.). V. 80, No. 5, May 1977, pp. 107-108.

[16]Appleman, B. M. Reducing and Controlling Total Delivery Costs (Ready-Mix). Mod. Concr., v. 41, No. 6, October 1977, pp. 50-55, 59.

Concrete Products. Conrock (California) Runs a King-Size Truck Mixer Fleet. V. 80, No. 1, January 1977, pp. 20-22.

Grayson, W. J., Jr. Transportation (of Aggregates): The Difference Between Profit and Loss (Customer Delivery Schedules, Transport Costs and Mode Selection). Rock Prod., v. 80, No. 6, June 1977, pp. 52-53.

Pit and Quarry. Truck Loading at Conrock's Reliance Plant (California) Takes Two Specialized Systems. V. 69, No. 3, September 1977, pp. 75-76, 87.

U.S. Department of Transportation, Federal Railroad Administration, Office of Rail Systems Analysis and Information. Carload Waybill Statistics Based on a Sampling of Waybills For Termination in 1976. Statement TD-1, July 1977, 224 pp.

[17]American Society for Testing and Materials. Concrete and Mineral Aggregates (Including Manual of Concrete Testing), 1977 Annual Book of ASTM Standards: Part 14, 1977, 772 pp.

———.Road and Paving Materials; Bituminous Materials for Highway Construction, Waterproofing and Roofing, and Pipe; Skid Resistance. 1977 Annual Book of ASTM Standards: Part 15, 1977, 1082 pp.

[18]Cleaveland, N. The Economics of High Profile Mining Dredges. World Dredging, v. 13, No. 12, December 1977, pp. 24-26.

Concrete Products. South Dakota's Largest Most Automated R/M Plant. V. 80, No. 1, January 1977, pp. 32-35.

Cooke, C. E., Jr. Fracturing With a High-Strength Proppant. J. Petrol. Tech., v. 29, October 1977, pp. 1222-1226.

Gurley, D. G., C. T. Copeland, and J. O. Hendrick. Design, Plan, and Execution of Gravel-Pack Operations for Maximum Productivity. J. Petrol. Tech., v. 29, October, 1977, pp. 1259-1266

Gutschick, K. A. Texas Producer (Colorado Rock Co., Columbus) Upgrades Gravel With Lime. Pit and Quarry, v. 69, No. 11, 1977, pp. 78-80.

Highway and Heavy Construction. Drum Mix Asphalt Plants Are Here At Last. V. 120, No. 6, June 1977, pp. 70-72.

Levine, S. Larnella Gravity Settlers Reclaim Wash Water at California Aggregate Plant (Transit Mixed Concrete Co., Azusa). Pit and Quarry, v. 69, No. 10, April 1977, pp. 104-111.

———.Las Vegas Producer Parallels Resort's Growth. Pit Quarry, v. 69, No. 1, July 1977, pp. 53-55.

———."Total Concrete Service" Is Motto of North Carolina Block/Ready Mix Combo (Concrete Service Co.). Mod. Concr., v. 41, No. 4, August 1977, pp. 48-50, 63.

Perrine, L. E. Anchor Hocking Plant Installs Advanced I.S. Machines. Glass Ind., v. 58, No. 7, July 1977, pp. 15-17.

Pit and Quarry. New Screening Technology Improves Product (Sand and Gravel) Quality and Production to Both Top and Bottom Sizes. V. 69, No. 8, February 1977, pp. 60-63.

Robertson, J. L. Company-Designed (Special Aggregates Corp., Utica, N.Y.) Portable Plant Solves Production Problems. Rock Prod., v. 80, No. 5, May 1977, pp. 64-67.

———.Floating Plant Processes and Loads Sand and Gravel at a 600-tph Rate (Dravo's Dredge No. 16, Ohio River). Rock Prod., v. 80, No. 5, May 1977, pp. 76-79.

Rock Products. Hydrocyclone System Recovers Fine Sand For California Producer (C. L. Pharris Sand and Gravel Co.). V. 80, No. 12, December 1977, pp. 77-79.

———.Land-Based Plant Processes Both River - Bottom and Dry-Bank Materials (Dravo's Georgetown, Pa. plant). V. 80, No. 5, May 1977, pp. 80-84.

Shepard, S. J. Ball Corp. Modernizes Its Asheville (N.C.) Glass Plant. Glass Ind., v. 58, No. 12, December 1977, pp. 24-26.

Stadler, L. E., and D. Cronin. Container Glass Composition. Glass Ind., v. 58, No. 12, December 1977, pp. 10-11.

Trauffer, W. E. Interstate's New 550-tph Sand and Gravel Plant (Interstate Sand and Gravel Co., near Covington, Ind.). Pit and Quarry, v. 69, No. 5, November 1977, pp. 50-56, 59.

World Dredging and Marine Construction. Special Report. 1977 Dredging Forecast: Special Section Dredge Director and Supplies. V. 13, No. 1, January 1977.

Table 2.—Sand and gravel sold or used in the United States, by geographic region

(Thousand short tons and thousand dollars)

Geographic region	Construction		Industrial		Total[1]	
	Quantity	Value	Quantity	Value	Quantity	Value
1976						
New England	44,199	74,946	147	963	44,346	75,909
Middle Atlantic	55,301	123,489	4,038	27,693	59,339	151,182
East North Central	169,305	271,291	12,521	58,569	181,826	329,859
West North Central	100,621	144,560	1,757	10,904	102,378	155,463
South Atlantic	61,440	118,218	3,841	22,942	65,281	141,160
East South Central	42,979	75,204	1,342	6,583	44,321	81,787
West South Central	92,225	181,425	3,419	23,741	95,647	205,169
Mountain	82,465	149,338	814	6,029	83,275	155,367
Pacific	206,710	465,325	2,032	12,811	208,742	478,136
Total[1]	855,242	1,603,794	29,914	170,236	885,156	1,774,030
1977						
New England	48,662	95,518	173	2,043	48,834	97,561
Middle Atlantic	54,460	117,208	3,280	22,636	57,740	139,844
East North Central	173,174	327,228	12,740	76,579	185,914	403,808
West North Central	102,313	187,804	1,845	13,526	104,158	201,330
South Atlantic	67,132	141,056	4,333	30,077	71,465	171,133
East South Central	47,949	96,920	2,329	12,602	50,277	109,523
West South Central	101,423	216,067	3,839	31,062	105,261	247,129
Mountain	94,054	191,578	848	6,068	94,901	197,646
Pacific	208,729	443,976	1,969	15,989	210,698	460,274
Total[1]	897,900	1,817,000	31,360	210,600	929,200	2,028,000

[1]Data may not add to totals shown because of independent rounding.

Table 3.—Percent of sand and gravel produced in the United States, by geographic region

Geographic region	Construction		Industrial	
	Quantity	Value	Quantity	Value
1976				
New England	5	5	1	1
Middle Atlantic	6	8	13	16
East North Central	20	17	42	34
West North Central	12	9	6	6
South Atlantic	7	7	13	13
East South Central	5	5	4	4
West South Central	11	11	11	14
Mountain	10	9	3	4
Pacific	24	29	7	8
Total	100	100	100	100
1977				
New England	5	5	1	1
Middle Atlantic	6	7	11	11
East North Central	19	18	41	37
West North Central	12	10	6	6
South Atlantic	8	8	11	13
East South Central	5	5	8	6
West South Central	11	12	12	15
Mountain	11	11	3	3
Pacific	23	24	7	8
Total	100	100	100	100

Table 4.—Sand and gravel sold or used in the United States, by State

(Thousand short tons and thousand dollars)

State	1976						1977					
	Construction		Industrial		Total[1]		Construction		Industrial		Total[1]	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Alabama	11,624	19,683	399	1,250	12,023	20,933	12,869	28,201	1,503	7,003	14,372	35,204
Alaska	74,208	204,738	--	--	74,208	204,738	66,426	134,251	--	--	66,426	134,251
Arizona	18,131	40,184	W	W	W	W	22,231	49,064	82	881	22,313	49,946
Arkansas	14,736	25,848	W	W	W	W	15,567	29,897	543	6,194	16,110	36,091
California	94,765	190,918	1,827	11,354	96,592	202,272	107,314	236,392	1,820	14,558	109,135	250,951
Colorado	20,160	32,900	W	W	W	W	23,910	50,527	W	W	W	W
Connecticut	6,414	12,978	--	--	6,414	12,978	8,543	18,316	W	W	W	W
Delaware	1,117	1,829	--	--	1,117	1,829	1,351	2,084	--	--	1,351	2,084
Florida	12,914	17,750	290	1,414	13,204	19,164	19,220	33,816	997	5,172	20,218	38,989
Georgia	4,520	6,484	315	1,903	4,835	8,387	4,809	10,496	332	2,711	5,141	13,207
Hawaii	573	1,634	--	--	573	1,634	771	2,452	--	--	771	2,452
Idaho	6,549	11,504	W	W	W	W	7,750	15,282	W	W	W	W
Illinois	34,300	61,759	4,484	25,393	33,784	87,152	33,286	68,353	4,347	32,078	37,633	101,230
Indiana	25,518	44,348	366	1,173	25,884	45,521	25,907	48,881	341	1,208	26,248	50,089
Iowa	15,206	26,277	W	W	W	W	16,600	33,290	W	W	W	W
Kansas	12,291	14,940	W	W	W	W	13,973	23,299	W	W	W	W
Kentucky	9,111	14,989	43	282	9,154	15,271	9,704	19,091	61	595	9,764	19,686
Louisiana	22,161	49,109	367	2,184	22,528	51,293	21,703	48,635	284	2,155	21,987	50,790
Maine	10,312	13,950	W	W	W	W	10,487	19,023	--	--	10,487	19,023
Maryland	12,942	31,914	--	--	12,942	31,914	11,702	29,562	--	--	11,702	29,562
Massachusetts	16,000	29,046	84	620	16,084	29,666	16,520	33,395	119	951	16,639	34,346
Michigan	42,067	58,257	5,336	20,198	47,403	78,455	40,374	72,595	6,113	28,947	46,486	101,542
Minnesota	33,486	44,503	W	W	W	W	30,030	54,297	683	5,332	30,713	59,629
Mississippi	12,033	20,394	W	W	W	W	13,353	25,375	W	W	W	W
Missouri	14,474	20,954	901	5,596	15,375	26,550	12,998	24,435	1,004	7,039	14,002	31,473
Montana	4,786	7,336	--	--	4,786	7,336	4,675	9,789	192	633	4,867	10,421
Nebraska	14,230	21,483	W	W	W	W	16,848	30,566	W	W	W	W
Nevada	9,116	16,519	555	3,587	9,671	20,106	9,904	19,542	W	W	W	W
New Hampshire	6,180	10,409	W	W	W	W	6,835	13,888	--	--	6,835	13,888
New Jersey	9,601	20,309	2,819	19,130	12,420	39,439	7,671	15,551	2,026	13,775	9,697	29,327
New Mexico	7,702	16,671	--	--	7,702	16,671	8,604	17,685	--	--	8,604	17,685
New York	27,725	55,326	156	806	27,881	56,132	29,063	56,804	134	766	29,197	57,570
North Carolina	8,309	14,344	740	3,943	9,049	18,287	8,833	17,267	857	4,003	9,690	21,270
North Dakota	5,171	8,345	--	--	5,171	8,345	5,821	12,102	--	--	5,821	12,102
Ohio	37,790	71,176	1,086	5,554	38,876	76,730	45,448	92,224	1,073	8,513	46,521	100,736

Oklahoma	8,760	11,975	1,277	7,075	10,037	19,050	10,255	18,465	1,414	8,362	11,669	26,827
Oregon	17,554	33,473	W	W	W	W	15,834	33,127	--	--	15,834	33,127
Pennsylvania	17,975	47,854	1,063	7,757	19,038	55,611	17,727	44,482	1,120	8,095	18,846	52,578
Rhode Island	2,914	4,805	W	W	W	W	2,872	5,059	--	--	2,872	5,059
South Carolina	7,110	11,802	777	5,352	7,887	17,154	6,877	12,823	888	6,458	7,766	19,281
South Dakota	5,763	8,057	--	--	5,763	8,057	6,043	9,815	--	--	6,043	9,815
Tennessee	10,211	20,138	885	4,991	11,096	25,129	12,023	24,253	750	4,945	12,773	29,197
Texas	46,571	94,496	1,277	8,721	47,848	103,217	53,898	119,069	1,597	14,351	55,495	133,420
Utah	10,547	13,442	W	W	W	W	11,895	18,622	W	W	W	W
Vermont	2,379	3,758	W	W	W	W	3,405	5,837	--	--	3,405	5,837
Virginia	10,191	23,089	W	W	W	W	10,447	24,605	W	W	W	W
Washington	19,610	34,562	203	1,455	19,813	36,017	18,356	37,693	W	W	W	W
West Virginia	4,337	11,006	W	W	W	W	3,891	10,402	W	W	W	W
Wisconsin	29,630	35,750	1,249	6,251	30,879	42,001	28,159	45,176	866	5,034	29,025	50,210
Wyoming	5,470	10,782	--	--	5,470	10,782	5,084	11,026	--	--	5,084	11,026
Total[1]	855,242	1,603,794	29,914	170,236	885,156	1,774,030	897,900	1,817,000	31,360	210,600	927,200	2,028,000

W Withheld to avoid disclosing company proprietary data; included in "Total."
[1]Data may not add to totals shown because of independent rounding.

Table 5.—Sand and gravel production by size of deposit in the United States in 1977[1]

Sales and use level	Construction				Industrial			
	Number of deposits	Percent of total	Thousand short tons	Percent of total	Number of deposits	Percent of total	Thousand short tons	Percent of total
Less than 25,000	2,489	34.5	23,118	2.6	48	26.7	434	1.4
25,000 to 49,999	1,014	14.1	35,501	4.0	30	16.6	1,086	3.5
50,000 to 99,999	1,301	18.0	87,513	9.7	31	17.2	2,224	7.1
100,000 to 199,999	1,359	18.8	185,563	20.7	29	16.1	4,075	13.0
200,000 to 299,999	412	5.7	98,689	11.0	11	6.1	2,867	9.1
300,000 to 399,999	213	3.0	72,739	8.1	6	3.3	2,161	6.9
400,000 to 499,999	119	1.7	52,072	5.8	7	3.9	3,238	10.3
500,000 to 599,999	82	1.1	44,407	4.9	4	2.2	2,278	7.3
600,000 to 699,999	57	.8	36,755	4.1	5	2.8	3,191	10.1
700,000 to 799,999	46	.6	34,336	3.8	1	.6	711	2.3
800,000 to 899,999	32	.5	26,992	3.0	2	1.1	1,784	5.7
900,000 to 999,999	20	.3	18,989	2.1	--	--	--	--
1,000,000 to 1,499,999	48	.7	57,089	6.4	5	2.8	5,778	18.4
1,500,000 to 1,999,999	17	.2	28,741	3.2	1	.6	1,530	4.9
2,000,000 to 2,499,999	6	([2])	13,481	1.5	--	--	--	--
2,500,000 and over	7	([2])	81,888	9.1	--	--	--	--
Total[3]	7,222	100.0	897,900	100.0	180	100.0	31,360	100.0

[1]An undetermined number of deposits leased from the Bureau of Land Management in Alaska are counted as one deposit.
[2]Less than 1/2 unit.
[3]Data may not add to totals shown because of independent rounding.

Table 6.—Number of sand and gravel processing plants in the United States in 1977[1]

State	Grand total of plants	Plants associated with extraction areas on land				Plants associated with dredging operations		
		Plants at site: Stationary	Plants at site: Portable	Plant not at site (stationary or portable)	Total plants	Plants on board	Plants on land	Total plants
Alabama	81	35	15	1	51	7	23	30
Alaska	25	9	12	2	23	1	1	2
Arizona	143	56	70	12	138	3	2	5
Arkansas	148	56	69	6	131	7	10	17
California	366	203	124	24	351	5	10	15
Colorado	176	40	119	7	166	1	9	10
Connecticut	88	37	48	1	86	--	2	2
Delaware	8	1	4	--	5	1	2	3
Florida	47	9	15	--	24	5	18	23
Georgia	39	14	6	3	23	1	15	16
Hawaii	4	2	1	1	4	--	--	--
Idaho	74	22	48	3	73	--	1	1
Illinois	163	54	73	1	128	7	28	35
Indiana	167	60	63	1	124	5	38	43
Iowa	192	37	110	1	148	5	39	44
Kansas	149	23	75	1	99	9	41	50
Kentucky	27	6	4	2	12	12	3	15
Louisiana	126	18	63	--	81	13	32	45
Maine	118	20	80	5	105	8	5	13
Maryland	48	21	18	3	42	--	6	6
Massachusetts	154	46	84	10	140	7	7	14
Michigan	320	74	201	4	279	7	34	41
Minnesota	335	53	254	3	310	3	22	25
Mississippi	66	7	41	--	48	4	14	18
Missouri	124	15	69	1	85	8	31	39
Montana	55	15	36	1	52	--	3	3
Nebraska	260	58	102	2	162	33	65	98
Nevada	82	26	50	2	78	1	3	4
New Hampshire	51	22	28	1	51	--	--	--
New Jersey	60	30	14	1	45	1	14	15
New Mexico	92	24	63	1	88	1	3	4
New York	409	109	289	7	405	1	3	4
North Carolina	104	17	56	4	77	4	23	27
North Dakota	60	11	44	--	55	--	5	5
Ohio	295	132	87	3	222	6	67	73
Oklahoma	111	12	60	2	74	5	32	37
Oregon	115	35	57	8	100	--	15	15
Pennsylvania	123	42	52	4	98	1	24	25
Rhode Island	27	6	16	2	24	--	3	3
South Carolina	55	12	24	3	39	2	14	16
South Dakota	103	12	57	--	69	7	27	34
Tennessee	76	17	37	3	57	6	13	19
Texas	226	80	102	2	184	13	29	42

See footnotes at end of table.

Table 6.—Number of sand and gravel processing plants in the United States in 1977[1] —Continued

State	Grand total of plants	Plants associated with extraction areas on land: Plants at site: Stationary	Plants at site: Portable	Plant not at site (stationary or portable)	Total plants	Plants associated with dredging operations: Plants on board	Plants on land	Total plants
Utah	67	8	48	--	56	5	6	11
Vermont	36	5	26	--	31	4	1	5
Virginia	74	18	34	2	54	10	10	20
Washington	134	26	80	5	111	9	14	23
West Virginia	8	3	1	--	4	3	1	4
Wisconsin	312	59	214	3	276	6	30	36
Wyoming	56	8	36	2	46	2	8	10
Total	6,179	1,705	3,279	150	5,134	239	806	1,045

[1]An undetermined number of deposits leased from the Bureau of Land Management in Alaska are included as one plant.

Table 7.—Number of sand and gravel processing plants in the United States in 1977, by geographic region[1]

Geographic region	Plants associated with extraction areas on land: Plants at site: Stationary	Plants at site: Portable	Plants not at site (stationary or portable)	Total plants	Plants associated with dredging operations: On board	On land	Total plants	Grand total of plants
New England	136	282	19	437	19	18	37	474
Middle Atlantic	181	355	12	548	3	41	44	592
East North Central	379	638	12	1,029	31	197	228	1,257
West North Central	209	711	8	928	65	230	295	1,223
South Atlantic	95	158	15	268	26	89	115	383
East South Central	65	97	6	168	29	53	82	250
West South Central	166	294	10	470	38	103	141	611
Mountain	199	470	28	697	13	35	48	745
Pacific	275	274	40	589	15	40	55	644
Total	1,705	3,279	150	5,134	239	806	1,045	6,179

[1]An undetermined number of deposits leased from the Bureau of Land Management in Alaska are included as one deposit.

Table 8.—Construction sand and gravel sold or used in the United States, by major use

(Thousand short tons and thousand dollars)

	1976 Quantity	1976 Value	1976 Value per ton	1977 Quantity	1977 Value	1977 Value per ton
Concrete aggregate (residential, nonresidential, highways, bridges, dams, waterworks, airports, etc.)	279,088	579,781	$2.08	347,447	811,866	$2.34
Concrete products (cement blocks, bricks, pipe, etc.)	78,059	164,540	2.11	53,042	129,260	2.43
Asphaltic concrete aggregate and other bituminous mixtures	127,576	251,210	1.97	132,237	284,204	2.15
Roadbase and coverings	208,563	352,970	1.69	188,843	343,666	1.82
Fill	136,854	216,463	1.58	158,691	210,805	1.33
Railroad ballast	--	--	--	1,203	2,751	2.29
Other uses	25,102	38,831	1.55	16,430	34,804	2.12
Total[1]	855,242	1,603,794	1.88	897,900	1,817,000	2.02

[1]Data may not add to totals shown because of independent rounding.

Table 9.—Sand and gravel sold or used in the United States, by geographic region and major use

(Thousand short tons and thousand dollars)

Geographic region	Concrete aggregate (residential, nonresidential, highways, bridges, dams, waterworks, airports, etc.)		Concrete products (cement blocks, bricks, pipe, etc.)		Asphaltic concrete and other aggregates, bituminous mixtures		Roadbase and coverings		Fill		Railroad ballast		Other uses		Total[1]	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1976																
New England	11,633	24,889	3,800	8,869	6,581	13,579	10,106	12,094	8,929	10,815	--	--	3,154	4,699	44,199	74,946
Middle Atlantic	19,996	53,096	8,609	20,746	7,839	21,087	8,559	13,788	7,620	10,826	--	--	2,676	3,946	55,301	123,489
East North Central	58,649	107,248	15,212	26,647	35,948	62,405	34,270	46,788	21,383	23,504	--	--	3,845	4,699	169,305	271,291
West North Central	30,870	55,968	7,218	13,273	16,396	24,215	27,034	31,998	15,571	15,230	--	--	3,525	3,876	100,621	144,560
South Atlantic	23,611	50,629	12,614	27,587	4,358	9,168	10,367	18,400	7,395	7,734	--	--	3,096	4,699	61,440	118,218
East South Central	16,164	30,196	5,693	11,153	8,015	15,793	9,837	13,497	2,861	3,804	--	--	410	767	42,979	75,204
West South Central	42,030	92,806	8,900	20,622	10,363	24,534	15,241	24,024	13,731	15,498	--	--	1,960	3,941	92,225	181,425
Mountain	25,171	57,388	3,369	8,722	13,567	26,537	28,729	41,254	8,794	11,094	--	--	2,835	4,344	82,465	149,338
Pacific	50,964	107,567	12,641	26,926	24,511	53,892	64,419	151,131	50,566	117,953	--	--	3,605	7,856	206,710	465,325
Total[1]	279,088	579,781	78,059	164,540	127,576	251,210	208,563	352,970	136,854	216,463	--	--	25,102	38,831	855,242	1,603,794
1977																
New England	15,342	36,617	3,255	8,003	6,896	14,859	11,675	20,186	8,996	11,467	48	102	2,451	4,285	48,662	95,518
Middle Atlantic	18,137	46,036	3,291	9,207	8,935	19,943	12,943	26,599	9,604	11,419	280	841	1,269	3,165	54,459	117,210
East North Central	64,406	138,362	9,188	21,152	30,614	58,310	42,347	74,232	23,424	29,630	84	219	3111	5,324	173,174	327,228
West North Central	35,657	76,657	6,990	16,081	16,352	29,924	27,250	46,020	14,398	16,525	435	739	1,230	1,857	102,313	187,804
South Atlantic	33,423	74,737	8,004	20,020	8,975	19,439	7,358	13,292	7,043	8,636	61	91	2,268	4,840	67,132	141,056
East South Central	20,828	45,825	5,561	13,705	7,292	14,986	9,340	15,892	4,396	5,304	9	17	522	1,190	47,949	96,920
West South Central	54,255	127,721	8,841	21,100	11,885	26,886	13,214	23,955	12,576	15,181	32	62	621	1,162	101,423	216,067
Mountain	30,679	74,695	2,399	5,673	14,912	33,631	31,698	56,020	11,306	14,564	42	120	3,018	6,875	94,054	191,578
Pacific	74,721	191,217	5,513	14,318	26,376	66,227	33,019	67,471	66,947	98,079	211	559	1,940	6,105	208,729	443,976
Total[1]	347,447	811,866	53,042	129,260	132,237	284,204	188,843	343,666	158,691	210,805	1,203	2,751	16,430	34,804	897,900	1,817,900

[1]Data may not add to totals shown because of independent rounding.

Table 10.—Percent of construction sand and gravel produced in the United States, by geographic region and major use

Geographic region	Concrete aggregate (residential, nonresidential, bridges, dams waterworks, airports, etc.)		Concrete products (cement blocks, bricks, pipe, etc.)		Asphaltic concrete and other aggregates, bituminous mixtures		Roadbase and coverings		Fill		Railroad ballast		Other uses		Total	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1976																
New England	4	4	5	5	5	5	5	3	7	5	--	--	13	12	5	5
Middle Atlantic	7	9	11	13	6	8	4	4	6	5	--	--	11	10	6	8
East North Central	21	18	20	16	28	25	16	13	16	11	--	--	15	12	20	17
West North Central	11	10	9	8	13	10	13	9	11	7	--	--	14	10	12	9
South Atlantic	8	9	17	17	3	4	5	5	5	4	--	--	12	12	7	7
East South Central	6	5	7	7	6	6	5	4	2	2	--	--	2	2	5	5
West South Central	16	16	11	13	8	10	7	7	10	7	--	--	8	10	11	11
Mountain	9	10	4	5	11	11	14	12	6	5	--	--	11	11	10	9
Pacific	18	19	16	16	20	21	31	43	37	54	--	--	14	21	24	29
Total	100	100	100	100	100	100	100	100	100	100	--	--	100	100	100	100
1977																
New England	4	5	6	6	5	5	6	6	6	5	4	4	15	12	5	5
Middle Atlantic	5	6	6	7	7	7	7	8	6	5	23	31	8	9	6	6
East North Central	19	17	18	16	23	21	22	22	15	14	7	8	19	16	20	18
West North Central	10	9	13	13	12	11	14	13	9	8	36	27	7	5	11	10
South Atlantic	10	9	15	16	7	7	4	4	4	4	5	3	14	14	8	8
East South Central	6	6	10	11	6	5	5	5	3	3	1	1	3	3	5	5
West South Central	16	16	17	16	9	9	7	7	8	7	3	2	4	3	11	12
Mountain	9	9	5	4	11	12	17	16	7	7	3	4	18	20	11	11
Pacific	21	23	10	11	20	23	18	19	42	47	18	20	12	18	23	25
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Table 11.—Construction sand and gravel sold or used in the United States in 1977, by State and use

(Thousand short tons and thousand dollars)

State	Concrete aggregate (residential, nonresidential, highways, bridges, dams, waterworks, airports, etc.)		Concrete products (cement blocks, bricks pipe, etc.)		Asphaltic concrete and other aggregates, bituminous mixtures		Roadbase and coverings		Fill		Railroad ballast		Other uses		Total[1]	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Alabama	7,045	16,941	1,307	3,338	1,758	4,016	1,657	2,568	1,013	1,090	--	--	89	248	12,869	28,201
Alaska	7,217	34,731	77	309	3,205	12,499	2,605	6,718	53,113	79,571	--	--	209	423	66,426	134,251
Arizona	6,736	17,543	601	1,614	3,911	10,259	6,744	12,250	3,346	4,860	--	--	894	2,539	22,231	49,064
Arkansas	6,526	13,977	651	1,462	2,287	5,068	4,627	7,614	1,174	1,331	--	--	301	445	15,567	29,897
California	57,633	134,276	3,256	8,211	16,967	38,909	20,383	39,766	7,724	10,103	157	470	1,195	4,658	107,314	236,392
Colorado	8,681	21,493	337	788	3,060	6,583	8,845	16,603	1,275	1,473	27	67	1,685	3,520	23,910	50,527
Connecticut	3,220	8,678	522	1,306	1,340	2,919	1,460	2,598	1,393	1,588	--	--	609	1,226	8,543	18,316
Delaware	205	483	78	191	108	211	803	1,039	158	160	--	--	--	--	1,351	2,084
Florida	12,344	22,260	1,922	4,010	467	1,256	2,350	3,873	1,836	1,903	--	--	301	515	19,220	33,816
Georgia	2,896	6,300	270	642	639	2,114	300	590	645	753	W	W	21	28	4,809	10,496
Hawaii	263	1,137	2	9	113	748	71	120	322	438	--	--	--	--	771	2,452
Idaho	2,208	5,309	172	466	1,156	3,015	3,224	5,265	940	1,140	--	--	49	89	7,750	15,282
Illinois	13,223	30,588	1,867	5,083	5,677	11,366	7,113	13,586	4,975	6,827	38	91	394	812	33,286	68,353
Indiana	10,595	22,675	1,504	3,145	5,883	11,641	3,786	6,391	3,642	4,171	--	--	496	857	25,907	48,881
Iowa	7,271	17,028	544	1,321	3,189	5,639	3,202	6,039	2,254	3,050	16	46	115	166	16,600	33,290
Kansas	4,732	8,929	1,150	2,549	1,698	3,020	3,388	5,296	2,302	2,443	W	W	372	566	13,973	23,299
Kentucky	4,828	10,123	908	2,362	1,756	3,497	446	741	1,715	2,209	W	W	42	142	9,704	19,091
Louisiana	11,277	29,376	1,575	3,485	2,737	6,876	2,874	5,298	3,186	3,481	W	W	54	119	21,703	48,635
Maine	1,579	3,624	779	2,085	1,509	3,026	3,553	5,967	2,289	3,259	15	24	763	1,038	10,487	19,023
Maryland	5,812	15,581	1,635	4,162	2,206	5,122	955	1,699	585	1,217	--	--	507	1,781	11,702	29,562
Massachusetts	6,654	15,754	1,046	2,620	1,414	3,437	3,368	5,894	3,467	4,444	W	W	564	1,224	16,520	33,395
Michigan	12,979	26,847	2,808	6,386	5,670	9,306	13,482	23,520	4,785	5,427	35	110	615	1,000	40,374	72,595
Minnesota	9,577	20,722	2,977	6,666	4,861	8,402	8,710	14,289	3,418	3,497	15	24	473	696	30,030	54,297
Mississippi	5,950	11,870	1,338	3,194	1,941	3,479	3,134	5,457	890	1,154	--	--	99	222	13,353	25,375
Missouri	6,514	13,263	904	2,113	1,618	3,312	2,479	4,006	1,402	1,586	W	W	69	106	12,998	24,435
Montana	1,263	3,592	86	222	403	1,172	2,380	3,978	527	806	--	--	17	19	4,675	9,789
Nebraska	4,804	9,445	984	2,282	3,331	6,459	4,955	8,975	2,606	3,123	W	W	121	212	16,848	30,566
Nevada	3,543	8,451	272	648	1,345	2,738	3,243	5,433	1,454	2,094	--	--	47	178	9,904	19,542
New Hampshire	2,436	5,540	283	714	1,450	3,053	1,503	2,877	816	1,080	W	W	331	600	6,835	13,888
New Jersey	2,814	6,061	747	1,612	556	1,319	789	1,720	2,265	3,179	W	W	303	1,027	7,671	15,551
New Mexico	8,870	9,156	488	1,078	1,698	3,385	1,929	3,296	543	616	10	40	65	115	8,604	17,685
New York	9,032	23,473	1,045	2,422	4,934	9,836	7,896	14,001	5,557	5,988	37	82	562	1,004	29,063	56,804
North Carolina	3,885	8,368	245	581	1,945	3,747	1,610	3,138	850	981	--	--	299	451	8,833	17,267

North Dakota	1,540	4,658	213	673	747	1,571	2,471	4,035	823	1,080	W	W	15	35	5,821	12,102
Ohio	20,237	43,895	2,305	5,259	8,830	18,407	6,964	14,060	6,224	8,821	W	W	884	1,864	45,448	92,224
Oklahoma	4,921	10,499	623	1,255	1,128	2,257	1,077	1,779	2,444	2,508	W	W	58	155	10,255	18,465
Oregon	4,052	9,112	1,007	2,641	2,661	6,183	5,543	11,901	2,355	2,997	18	32	196	260	15,833	33,127
Pennsylvania	6,291	16,242	1,500	5,062	3,446	8,788	4,258	10,878	1,782	2,252	45	126	405	1,135	17,727	44,482
Rhode Island	615	1,294	363	726	588	1,240	630	1,074	676	726	--	--	--	--	2,872	5,059
South Carolina	2,709	5,942	473	995	1,525	3,126	381	646	1,193	1,380	W	W	574	763	6,877	12,823
South Dakota	1,219	2,611	208	476	909	1,521	2,046	3,379	1,593	1,747	1	4	67	78	6,043	9,815
Tennessee	3,004	6,890	2,008	4,812	1,837	3,993	4,103	7,127	779	852	--	--	292	578	12,023	24,253
Texas	31,531	73,869	5,991	14,898	5,733	12,685	4,636	9,264	5,771	7,861	W	W	208	443	53,898	119,069
Utah	3,266	6,059	151	302	2,290	3,785	3,545	5,695	2,430	2,544	--	--	214	277	11,895	18,662
Vermont	837	1,728	263	552	595	1,183	1,162	1,776	355	370	W	W	184	197	3,405	5,837
Virginia	3,984	10,806	1,918	5,680	1,997	3,521	790	2,055	1,409	1,755	--	--	349	788	10,447	24,605
Washington	5,555	11,962	1,170	3,148	3,424	7,876	4,397	8,916	3,433	4,970	37	57	340	765	18,356	37,693
West Virginia	1,587	4,996	1,462	3,760	89	342	169	253	367	537	--	--	217	514	3,891	10,402
Wisconsin	7,371	14,447	703	1,279	4,555	7,589	11,002	16,675	3,798	4,383	W	W	723	791	28,159	45,176
Wyoming	1,111	3,092	293	555	1,049	2,695	1,788	3,501	792	1,032	W	W	51	150	5,084	11,026
Total[1]	347,447	811,866	53,042	129,260	132,237	284,204	188,843	343,666	158,691	210,805	1,203	2,751	16,430	34,804	897,900	1,817,000

W Withheld to avoid disclosing company proprietary data; included with "Other uses."
[1]Data may not add to totals shown because of independent rounding.

Table 12.—Industrial sand and gravel sold or used in the United States, by major use

(Thousand short tons and thousand dollars)

Use	1976			1977		
	Quantity	Value	Value per ton	Quantity	Value	Value per ton
Unground sand:						
Molding	6,896	37,264	$5.40	8,648	50,196	$5.80
Glass	11,467	65,551	5.72	10,937	65,826	6.02
Blast	1,498	9,946	6.64	1,868	13,645	7.31
Grinding and polishing	76	304	4.00	210	1,710	8.15
Fire or furnace	301	1,164	3.87	372	1,468	3.95
Engine	752	2,315	3.08	500	2,684	5.36
Filtration	183	1,060	5.79	223	1,714	7.70
Metallurgical	2,146	7,365	3.43	403	2,242	5.57
Oil (Hydrafrac)	660	4,759	7.21	894	11,184	12.51
Other	2,251	14,430	6.41	1,599	17,460	10.92
Total[1]	26,230	144,159	5.50	25,653	168,129	6.55
Ground sand:						
Filler	185	2,001	10.82	235	3,961	16.89
Chemical	40	611	15.28	129	1,386	10.79
Enamel	43	739	17.19	37	615	16.40
Abrasives	250	2,925	11.70	403	4,994	12.40
Foundry	1,741	8,455	4.86	1,660	8,089	4.87
Glass	878	6,294	7.17	1,045	8,515	8.15
Pottery, porcelain, tile	136	1,850	13.60	245	3,774	15.40
Other	168	2,094	12.46	204	2,417	11.85
Total[1]	3,440	24,968	7.26	3,958	33,750	8.53
Gravel:						
Metallurgical	134	577	4.31	1,506	7,760	5.15
Filtration	--	--	--	65	4.38	6.78
Grinding	--	--	--	--	--	--
Other	110	532	4.84	174	507	2.91
Total[1]	245	1,109	4.53	1,745	8,704	4.99
Grand total[1]	29,914	170,236	5.69	31,360	210,600	6.72

[1]Data may not add to totals shown because of independent rounding.

Table 13.—Value per ton for construction sand and gravel sold or used in the United States in 1977, by State and major use

State	Concrete aggregate[1]	Concrete products[2]	Asphaltic concrete and other bituminous mixtures	Roadbase and coverings	Fill	Railroad ballast	Other uses	Overall average for all uses
Alabama	$2.40	$2.55	$2.28	$1.55	$1.08	--	$2.79	$2.19
Alaska	4.81	4.00	3.90	2.58	1.50	--	2.02	2.02
Arizona	2.60	2.69	2.62	1.82	1.45	--	2.84	2.21
Arkansas	2.14	2.24	2.22	1.65	1.13	--	1.48	1.92
California	2.33	2.52	2.29	1.95	1.31	$3.00	3.90	2.20
Colorado	2.48	2.34	2.15	1.88	1.16	2.51	2.09	2.11
Connecticut	2.69	2.50	2.18	1.78	1.14	--	2.02	2.14
Delaware	2.36	2.46	1.96	1.29	1.01	--	--	1.54
Florida	1.80	2.09	2.69	1.65	1.04	--	1.71	1.76
Georgia	2.18	2.37	3.31	1.97	1.17	1.76	1.35	2.18
Hawaii	4.32	3.89	6.61	1.71	1.36	--	--	3.18
Idaho	2.40	2.71	2.61	1.63	1.21	--	1.80	1.97
Illinois	2.31	2.72	2.00	1.91	1.37	2.36	2.06	2.05
Indiana	2.14	2.09	1.98	1.69	1.15	--	1.73	1.89
Iowa	2.34	2.39	1.77	1.89	1.35	2.92	1.45	2.01
Kansas	1.89	2.22	1.78	1.56	1.06	1.50	1.52	1.67
Kentucky	2.10	2.60	1.99	1.66	1.29	1.96	3.41	1.97
Louisiana	2.60	2.21	2.51	1.84	1.09	--	2.20	2.24
Maine	2.30	2.68	2.01	1.68	1.42	1.64	1.36	1.81
Maryland	2.68	2.54	2.32	1.78	2.08	--	3.51	2.53
Massachusetts	2.37	2.50	2.43	1.75	1.28	2.82	2.17	2.02
Michigan	2.07	2.27	1.64	1.74	1.13	3.15	1.63	1.80
Minnesota	2.16	2.24	1.73	1.64	1.02	1.64	1.47	1.81
Mississippi	1.99	2.39	1.79	1.74	1.30	--	2.24	1.90
Missouri	2.04	2.34	2.05	1.62	1.13	3.81	1.53	1.88
Montana	2.84	2.60	2.91	1.67	1.53	--	1.08	2.09
Nebraska	1.97	2.32	1.94	1.81	1.20	1.50	1.75	1.81
Nevada	2.39	2.39	2.04	1.68	1.44	1.50	3.77	1.97
New Hampshire	2.27	2.53	2.11	1.91	1.32	1.50	1.81	2.03
New Jersey	2.15	2.16	2.37	2.18	1.40	3.20	3.39	2.03
New Mexico	2.37	2.21	1.99	1.71	1.13	4.00	1.76	2.06
New York	2.60	2.32	1.99	1.77	1.08	2.19	1.79	1.95
North Carolina	2.15	2.37	1.93	1.95	1.15	--	1.51	1.95
North Dakota	3.02	3.16	2.10	1.63	1.31	4.00	2.32	2.08
Ohio	2.16	2.28	2.08	2.02	1.42	1.93	2.11	2.03
Oklahoma	2.13	2.01	2.00	1.65	1.03	3.50	2.67	1.80
Oregon	2.25	2.62	2.32	2.15	1.27	1.81	1.32	2.09
Pennsylvania	2.58	3.38	2.55	2.55	1.26	2.76	2.80	2.50
Rhode Island	2.10	2.00	2.11	1.71	1.07	--	--	1.76
South Carolina	2.19	2.10	2.05	1.70	1.11	1.00	1.33	1.86
South Dakota	2.14	2.29	1.67	1.65	1.10	3.00	1.16	1.62
Tennessee	2.29	2.40	2.17	1.74	1.09	--	1.98	2.02
Texas	2.34	2.49	2.21	2.00	1.36	1.75	2.13	2.21
Utah	1.86	2.00	1.65	1.61	1.05	--	1.30	1.57
Vermont	2.06	2.10	1.99	1.53	1.04	3.31	1.07	1.71
Virginia	2.71	2.96	1.76	2.60	1.25	--	2.26	2.36
Washington	2.15	2.69	2.30	2.03	1.45	1.55	2.25	2.05
West Virginia	3.15	2.57	3.86	1.50	1.47	--	2.37	2.67
Wisconsin	1.96	1.82	1.67	1.52	1.15	1.63	1.09	1.60
Wyoming	2.78	1.89	2.57	1.96	1.30	2.50	2.98	2.17
Total	2.34	2.43	2.15	1.82	1.33	2.29	2.12	2.02

[1]Includes residential, nonresidential, highways, bridges, dams, waterworks, airports, etc.
[2]Includes cement blocks, bricks, pipe, etc.

Table 14.—U.S. exports of construction sand, gravel, and industrial sand

(Thousand short tons and thousand dollars)

Year and country	Construction sand		Gravel		Industrial sand		Total	
	Quantity	F.a.s.[1] value	Quantity	F.a.s.[1] value	Quantity	F.a.s.[1] value	Quantity	F.a.s.[1] value
1976								
Algeria	(2)	6	43	54	1	26	44	86
Argentina	--	--	--	--	1	39	1	39
Bahamas	3	9	2	9	(2)	15	5	33
Belgium-Luxembourg	--	--	--	--	(2)	148	(2)	148
Bermuda	--	--	(2)	1	(2)	7	(2)	8
Brazil	(2)	3	--	--	(2)	55	(2)	58
Canada	539	893	530	969	1,618	11,321	2,687	13,183
Dominican Republic	(2)	3	--	--	(2)	23	(2)	26
El Salvador	(2)	9	--	--	(2)	19	(2)	28
France	--	--	--	--	587	577	587	577
Germany, Federal Republic of	(2)	2	--	--	7	731	7	733
Guatemala	1	51	(2)	1	5	47	6	99
Jamaica	1	139	--	--	(2)	18	1	157
Japan	(2)	42	(2)	2	1	180	1	224
Mexico	12	47	4	35	313	1,922	329	2,004
Netherlands	(2)	13	--	--	1	179	1	192
Netherlands Antilles	2	13	(2)	2	3	70	5	85
Peru	--	--	--	--	4	210	4	210
Saudi Arabia	(2)	11	(2)	2	(2)	32	(2)	45
Singapore	--	--	--	--	1	57	1	57
United Kingdom	--	--	(2)	3	7	363	7	366
Other	1	96	(2)	21	5	1,041	6	1,158
Total	559	1,337	579	1,099	2,554	17,080	3,692	19,516
1977								
Algeria	(2)	9	--	--	(2)	15	(2)	24
Argentina	1	98	--	--	2	143	3	241
Bahamas	1	7	4	37	(2)	18	5	62
Belgium-Luxembourg	--	--	--	--	1	119	1	119
Bermuda	(2)	61	1	5	(2)	10	1	76
Brazil	(2)	2	(2)	2	1	67	1	71
Canada	626	1,035	591	1,048	1,124	10,695	2,341	12,778
Dominican Republic	(2)	4	(2)	4	4	93	4	101
El Salvador	(2)	1	(2)	3	1	52	1	56
France	--	--	--	--	442	1,492	442	1,492
Germany, Federal Republic of	(2)	4	(2)	1	204	884	204	889
Guatemala	(2)	17	--	--	9	111	9	128
Jamaica	1	142	(2)	3	1	66	2	211
Japan	1	74	(2)	5	1	118	2	197
Mexico	1	38	3	11	333	2,145	337	2,194
Netherlands	--	--	--	--	1	221	1	221
Netherlands Antilles	(2)	2	(2)	3	4	105	4	110
Peru	--	--	--	--	4	248	4	248
Saudi Arabia	--	--	1	62	(2)	37	1	99
Singapore	--	--	--	--	1	159	1	159
United Kingdom	(2)	25	--	--	51	459	51	484
Other	1	91	(2)	14	273	1,450	274	1,555
Total	632	1,610	600	1,198	2,457	18,707	3,689	21,515

[1]Value of material at U.S. port of export; based on transaction price, including all charges incurred in placing material alongside ship.
[2]Less than 1/2 unit.

Table 15.—U.S. imports for consumption of sand and gravel

(Thousand short tons and thousand dollars)

Year and country	Construction sand and gravel			Industrial sand			Total		
	Quantity	F.a.s.[1] value	C.i.f.[2] value	Quantity	F.a.s.[1] value	C.i.f.[2] value	Quantity	F.a.s.[1] value	C.i.f.[2] value
1976									
Australia	--	--	--	59	401	919	59	401	919
Canada	289	318	502	1	48	48	290	366	550
Germany, Federal Republic of	2	48	49	--	--	--	2	48	49
Other	1	65	73	1	40	76	2	105	149
Total	292	431	624	61	489	1,043	353	920	1,667
1977									
Australia	--	--	--	34	247	530	34	247	530
Canada	350	360	586	([3])	25	25	350	385	611
Germany, Federal Republic of	([3])	([3])	1	--	--	--	([3])	([3])	1
Other	1	32	37	1	61	99	2	93	136
Total	351	392	624	35	333	654	386	725	1,278

[1]Value at port of exportation; actual transaction value and generally includes all charges for placing material alongside ship.

[2]Value at port of entry; based on purchase price and includes all charges (except U.S. import duties) in bringing material from foreign country to alongside carrier in U.S.

[3]Less than 1/2 unit.

Silicon

Frederick J. Schottman[1]

Although overall production of silicon materials in 1977 was little changed from that in 1976, production of miscellaneous silicon alloys increased and production of metal dropped. Imports of metal increased sharply from 9% of reported consumption in 1976 to 26% in 1977. Supplies of silicon materials in the world market were abundant and prices were depressed. Domestic prices of silicon alloys were generally steady or lower during the year despite increased production costs. Domestic producers raised their prices for silicon metal early in the year, but were later forced to rescind the increase because of pressure from imports.

One new ferrosilicon furnace began operation during the year. One older plant was closed permanently, for the stated reason that it could not compete against low-cost imports.

DOMESTIC PRODUCTION

Overall, production of silicon materials was nearly the same as in 1976, but there were significant changes for particular classes of materials.

Production and shipments of the two major grades of ferrosilicon, which make up three-fourths of all silicon materials, were little changed. However, production and shipments of miscellaneous silicon alloys increased 15% and 14%, respectively. The miscellaneous silicon alloys are special purpose alloys based on ferrosilicon but with other elements added. About three-fourths of the material in this class is magnesium ferrosilicon. Among other alloys included are calcium-silicon, silicon-manganese-zirconium, and rare-earth silicides.

Production and shipments of silicon metal declined 12% and 11%, respectively, in 1977. Although demand for this material was stable, imports took a larger share of the market and domestic producers were forced to cut back production.

Producer stocks of 25% to 55% ferrosilicon and those of silicon metal increased by about one-fifth during the year. Stocks of 56% to 95% ferrosilicon declined by 11%, and stocks of miscellaneous alloys were little changed.

A new 40-megawatt ferrosilicon furnace was started at the Bridgeport, Ala., plant of the Tennessee Alloys Co. The new plant was to be operated by the TAC Alloys Division of International Minerals & Chemical Corp. (IMC) and was owned 75% by IMC and 25% by Allegheny Ludlum Steel Corp. The new furnace replaced the three small furnaces at the old plant, which had been operated as Tennessee Alloys Corp. This resulted in a 50% increase in capacity to 75,000 tons per year of 50% ferrosilicon.

Ohio Ferro-Alloys Corp. permanently closed its plant at Brilliant, Ohio. The plant had a reported capacity of 30,000 to 40,000 tons per year of 75% ferrosilicon and employed 220 workers. The closing was said to be caused by competition from low-cost imports.

After several years of active expansion and modernization programs, domestic producers announced no plans for new production facilities. Several modernization projects intended to increase efficiency and to meet air pollution control requirements had been largely completed. Moreover, slow growth in consumption combined with worldwide over-capacity, which was reflected in increased imports, made additional new capacity financially unattractive.

Table 1.—Production, shipments, and stocks of silvery pig iron, ferrosilicon, and silicon metal in 1977

(Short tons, gross weight except as noted)

Alloy	Silicon content, (percent) Range	Typical	Producers' stocks as of Dec. 31, 1976[r]	Production	Shipments	Producers' stocks as of Dec. 31, 1977
Silvery pig iron	5-24	18	W	W	W	W
Ferrosilicon (includes briquets)	25-55	48	54,301	517,282	489,042	65,312
Do	56-95	75	27,209	132,794	125,507	24,110
Silicon metal	96-99	98	18,563	124,670	116,482	22,172
Miscellaneous silicon alloys (excluding silicomanganese)	32-65	--	17,305	103,675	95,104	17,472

[r]Revised. W Withheld to avoid disclosing individual company confidential data.

Table 2.—Producers of silicon alloys and/or silicon metal in the United States in 1977

Producer	Plant location	Product
Airco, Inc., Airco Alloys Div	Calvert City, Ky	FeSi.
Do	Niagara Falls, N.Y	Do.
Alabama Alloy Co., Inc	Bessemer, Ala	Do.
Aluminum Co. of America, Northwest Alloys, Inc	Addy, Wash	FeSi,Si.
Chromasco, Ltd., Chromium Mining & Smelting Corp. Div	Woodstock, Tenn	FeSi.
Engelhard Minerals & Chemicals Corp., Philipp Bros. Div., Roane Electric Furnace Co	Rockwood, Tenn	Do.
Foote Mineral Co., Ferroalloys Div	Graham, W. Va	Do.
Do	Keokuk, Iowa	Silvery pig iron.
Hanna Mining Co.:		
Hanna Nickel Smelting Co	Riddle, Oreg	FeSi.
Silicon Division	Wenatchee, Wash	FeSi, Si.
Interlake, Inc., Globe Metallurgical Div	Beverly, Ohio	Do.
Do	Selma, Ala	Si.
International Minerals & Chemical Corp., Industry Group, TAC Alloys Div.,		
TAC Alloys	Kimball, Tenn	FeSi.
Tennessee Alloys Co	Bridgeport, Ala	Do.
Kawecki Berylco Industries, Inc., National Metallurgical Div	Springfield, Oreg	Si.
Ohio Ferro-Alloys Corp	Brilliant, Ohio	FeSi, Si.
Do	Montgomery, Ala	Si.
Do	Philo, Ohio	FeSi.
Do	Powhatan Point, Ohio	Si.
Reynolds Metals Co	Sheffield, Ala	Do.
Satralloy, Inc	Steubenville, Ohio	FeSi
Union Carbide Corp., Metals Div	Alloy, W. Va	FeSi, Si.
Do	Ashtabula, Ohio	FeSi.
Do	Marietta, Ohio	Do.
Do	Portland, Oreg	Do.
Do	Sheffield, Ala	Do.

CONSUMPTION AND USES

Overall reported consumption of silicon materials in 1977 increased 2%, based on silicon content, compared with consumption in 1976. Consumption of ferrosilicon increased while consumption of silicon metal decreased slightly.

Based on silicon content, steel and cast iron consumed 42% and 56%, respectively, of all silvery pig iron, ferrosilicon, and miscellaneous silicon alloys. Consumption of 25% to 55% and 71% to 80% grades of ferrosilicon in steel increased 10% and 5%, respectively, while consumption of ferrosilicon in cast iron was little changed.

Silicon metal consumption decreased about 1%, with a 3% decrease in its use in alloys (principally aluminum base alloys). Production of silicones, which end use consumes about two-fifths of all silicon metal, was little changed from that in 1976. During 1977, Dow Corning Corp. announced that it would build a $40 million addition to its Carrollton, Ky., silicones plant.

A relatively small tonnage of silicon metal is used as the raw materials for the production of electronic-grade silicon. Despite rapid growth of the semiconductor industry, miniaturization of components and improved production techniques, which have improved yields and reduced waste, have prevented a corresponding rapid increase in demand for silicon metal for this application.

Yearend consumer stocks were down from those at the beginning of the year for the most important consumer classes of silicon materials. Stocks for ferrosilicon were down by about 27%, while those for silicon metal and miscellaneous alloys decreased by smaller amounts.

Table 3.—Consumption, by major end use, and stocks of silicon alloys and metal in the United States in 1977

(Short tons, gross weight except as noted)

End use	Silvery pig iron	Ferrosilicon[1]				Silicon metal	Miscellaneous silicon alloys[2]	Total silicon content[3]
Silicon content (percent): Range	5-24	25-55	56-70	71-80	81-95	96-99		
Typical	18	48	65	76	85	98	58	
Steel:								
Carbon	1,454	80,207	207	28,225	767	311	9,301	66,699
Stainless and heat-resisting	(4)	16,575	(4)	16,673	108	180	231	21,029
Full alloy	2,002	29,495	591	11,062	354	1,739	1,183	25,998
High-strength low-alloy	(4)	9,854	--	1,996	(4)	16	1,003	6,845
Electric	--	(4)	(4)	30,992	--	112	--	23,664
Tool	--	1,463	90	921	(4)	26	(4)	1,486
Unspecified	3,053	12,717	2,001	4	42	--	80	8,040
Total steel	6,509	150,311	2,889	89,873	1,271	2,384	11,798	153,761
Cast irons	41,079	231,519	3,490	33,246	1,758	57	97,775	204,319
Superalloys	9	229	--	2	86	65	--	251
Alloys (excluding alloy steels and superalloys)	101	6,289	--	336	284	55,787	147	58,288
Silicones	--	--	--	--	--	41,624	--	40,792
Miscellaneous and unspecified	2,851	2,145	--	379	--	2,827	3,503	6,633
Total	50,549	390,493	6,379	123,836	3,399	102,744	113,223	464,044
Percent of 1976	100	103	61	104	108	99	106	102
Total silicon content[3]	9,099	187,435	4,148	94,115	2,888	100,689	67,670	XX
Consumers' stocks, Dec. 31, 1977	6,743	22,226	2,063	11,537	633	9,427	6,412	35,486

XX Not applicable.
[1]Includes briquets.
[2]Includes magnesium-ferrosilicon and other silicon alloys.
[3]Estimated based on typical percent content.
[4]Included with "Unspecified."

PRICES

Prices for domestic silicon materials were little changed during 1977. Despite increasing production costs, competition from imported materials restrained price increases.

In February domestic producers reduced the price of regular 50% ferrosilicon 1 cent to 33.5 cents per pound of contained silicon. The price of regular 75% ferrosilicon was unchanged through the year at 37 cents per pound. The f.o.b. warehouse price of imported 75% ferrosilicon, as quoted in Metals Week, began the year at 30 to 31.5 cents per pound and declined gradually in the second half of the year reaching 25 to 26.5 cents per pound by yearend.

Domestic producers raised the price of silicon metal 3 cents per pound in February, but rescinded that price increase in July. The end-of-year price of silicon metal with 1% maximum iron and 0.07% maximum calcium was 42.5 cents per pound. Prices for imports began the year at 40.0 to 41.0 cents per pound, rose to 44.0 to 45.0 cents per pound at midyear, and then declined to 37.5 to 38.0 cents per pound.

FOREIGN TRADE

Exports of ferrosilicon declined slightly in 1977 and were only about 9% of imports. Imports of silicon metal nearly tripled in 1977 to record high levels; imports of ferrosilicon also increased, but remained below the levels of 1974.

Exports of ferrosilicon declined 15% by weight and 19% by value in 1977. As in earlier years, most exports (62%) went to Canada. The remainder was shipped to Venezuela, Australia, Angola, the Federal Republic of Germany, Mexico, and Brazil.

Imports of ferrosilicon in 1977 compared with those of 1976 increased 17% on a gross weight basis and 12% in value. Imports of ferrosilicon with 8% to 60% silicon increased only slightly. Although shipments from Canada declined, it remained the most important source, supplying 62% of the total. Venezuela, which had not exported this material to the United States in earlier years, was the second most important source with 13% of the total. Imports of ferrosilicon with 60% to 80% silicon increased 22% by weight and 15% by value. Most of this ferrosilicon came from four countries: Norway (42%), France (15%), Canada (12%), and the Republic of South Africa (12%). Imports from each of these countries increased significantly, compared with 1976, ranging from a 188% increase for Canada to a 29% increase for Norway.

Total imports of silicon metal increased 178%, compared with those in 1976, with most of the increase coming from Canada, which went from 566 tons in 1976 to 11,011 tons in 1977. Imports also increased from the other major supplying countries (Norway, the Republic of South Africa, and Yugoslavia). The Federal Republic of Germany and Japan continued to provide most of the imported high-value semiconductor-grade silicon, which is included in the import class for silicon metal with greater than 99.7% silicon content.

During 1977, the Ferroalloys Association petitioned the Office of the Special Representative for Trade Negotiations to remove several ferroalloys, including ferrosilicon with 60% to 80% silicon, from the list of materials receiving special treatment under the Generalized System of Preferences (GSP). Under GSP specified products from designated developing countries are admitted to the United States duty free. The producers argued that the alloys were import sensitive and that the imports were causing serious injury to the domestic industry. A similar petition in 1976 was rejected.

Table 4.—U.S. exports of ferrosilicon

Year	Quantity (short tons)	Value (thousands)
1975	38,452	$15,281
1976	12,416	7,449
1977	10,548	6,035

Table 5.—U.S. imports for consumption of ferrosilicon and silicon metal, by grade and country

Grade and country	1976 Quantity (short tons) Gross weight	1976 Quantity (short tons) Silicon content	1976 Value (thousands)	1977 Quantity (short tons) Gross weight	1977 Quantity (short tons) Silicon content	1977 Value (thousands)
Ferrosilicon:						
Over 8% but not over 60% silicon:						
Brazil	--	--	--	279	128	$166
Canada	26,477	11,474	$7,201	20,148	8,477	4,877
Chile	150	70	41	33	16	8
Colombia	--	--	--	11	2	5
France	2,114	1,039	1,320	3,694	1,879	2,531
Germany, Federal Republic of	736	406	1,411	636	344	1,256
Italy	19	8	10	102	47	69
Japan	1,113	557	814	709	341	543
Mexico	--	--	--	684	112	205
Norway	966	429	571	1,231	547	752
South Africa, Republic of	--	--	--	737	407	132
United Kingdom	--	--	--	44	21	27
Venezuela	--	--	--	4,409	2,182	940
Total	31,575	13,983	11,368	32,717	14,503	11,511

See footnotes at end of table.

Table 5.—U.S. imports for consumption of ferrosilicon and silicon metal, by grade and country —Continued

Grade and country	1976 Quantity (short tons) Gross weight	1976 Quantity (short tons) Silicon content	1976 Value (thousands)	1977 Quantity (short tons) Gross weight	1977 Quantity (short tons) Silicon content	1977 Value (thousands)
Ferrosilicon: —Continued						
Over 60% but not over 80% silicon:						
Argentina	55	41	$21	716	544	$269
Australia	55	34	20	--	--	--
Belgium-Luxembourg	1,571	1,219	668	--	--	--
Brazil	5,081	3,844	1,806	2,834	2,056	1,275
Canada	3,234	2,429	1,694	9,314	7,066	4,219
Chile	997	768	328	701	541	261
France	6,266	4,311	4,065	11,867	8,450	6,498
Germany, Federal Republic of	1,689	1,214	1,422	1,061	680	1,348
India	5,703	4,163	2,070	--	--	--
Japan	2,049	1,564	863	110	84	43
Norway	26,197	19,742	10,488	33,768	24,854	11,192
Portugal	2,205	1,667	615	926	694	328
South Africa, Republic of	5,552	4,063	1,683	9,287	6,874	3,108
Spain	--	--	--	2,383	1,787	928
Sweden	--	--	--	1,764	1,330	627
Taiwan	145	110	62	217	165	91
Yugoslavia	5,406	4,069	2,209	5,743	4,350	2,119
Total	66,205	49,238	28,014	80,691	59,475	32,306
Over 80% but not over 90% silicon:						
Canada	22	19	13	150	122	51
Chile	6	5	1	--	--	--
France	--	--	--	34	29	18
Taiwan	110	89	92	--	--	--
Yugoslavia	22	19	11	--	--	--
Total	160	132	117	184	151	69
Over 90% silicon:						
Canada	77	73	50	56	55	45
Italy	--	--	--	39	37	20
Norway	23	21	15	1,101	1,033	420
South Africa, Republic of	254	234	84	--	--	--
Total	354	328	149	1,196	1,125	485
Grand total	98,294	63,681	39,648	114,788	75,254	44,371
Silicon metal:						
Over 96% but not over 99% silicon:[1]						
Canada	309	([2])	252	10,010	([2])	8,149
France	66	([2])	46	275	([2])	217
Korea, Republic of	58	([2])	29	--	--	--
Netherlands	--	--	--	([3])	([2])	1
Norway	2,825	([2])	1,966	3,785	([2])	2,634
South Africa, Republic of	2,793	([2])	1,778	3,443	([2])	2,444
Spain	--	--	--	1,308	([2])	911
Sweden	--	--	--	156	([2])	124
Switzerland	41	([2])	28	--	--	--
United Kingdom	1	([2])	13	165	([2])	151
Yugoslavia	2,164	([2])	1,421	2,923	([2])	1,863
Total	8,257	([2])	5,533	22,065	([2])	16,494
Over 99% but not over 99.7% silicon:						
Canada	238	236	196	885	878	732
France	110	109	72	--	--	--
Norway	552	545	442	1,654	1,639	1,365
South Africa, Republic of	369	365	240	1,127	1,116	793
Yugoslavia	--	--	--	664	658	485
Total	1,269	1,255	950	4,330	4,291	3,375

See footnotes at end of table.

Table 5.—U.S. imports for consumption of ferrosilicon and silicon metal, by grade and country —Continued

Grade and country	1976 Quantity (short tons) Gross weight	1976 Quantity (short tons) Silicon content	1976 Value (thousands)	1977 Quantity (short tons) Gross weight	1977 Quantity (short tons) Silicon content	1977 Value (thousands)
Silicon metal: —Continued						
Over 99.7% silicon:						
Belgium-Luxembourg	(3)	(3)	$44	(3)	(3)	$4
Canada	19	19	16	116	116	105
Denmark	1	1	407	6	6	1,297
France	--	--	--	(3)	(3)	6
Germany, Federal Republic of	65	65	3,689	43	43	3,459
Italy	(3)	(3)	17	6	6	524
Japan	19	19	1,045	15	15	720
Korea, Republic of	--	--	--	(3)	(3)	5
Netherlands	--	--	--	(3)	(3)	1
South Africa, Republic of	--	--	--	116	116	79
Spain	--	--	--	109	109	75
Switzerland	--	--	--	(3)	(3)	1
United Kingdom	(3)	(3)	2	(3)	(3)	13
Total	104	104	5,220	411	411	6,289
Grand total	9,630	(2)	11,703	26,806	(2)	26,158

[1]New category effective Jan. 1, 1976.
[2]Content data not available.
[3]Less than 1/2 unit.

WORLD REVIEW

Argentina.—Stein Ferroaleaciones of Mendoza was building a 3-megavolt-ampere furnace for calcium silicon. The company had a 3.5-megavolt-ampere furnace producing rare-earth magnesium ferrosilicon.[2]

Canada.—Chromasco, Ltd., started a new 24-megavolt-ampere ferrosilicon furnace at its Beauharnois, Quebec, plant increasing its capacity to 90,000 tons per year. A significant part of Chromasco's ferrosilicon is used internally to produce magnesium, and the company also disclosed plans to increase its magnesium capacity significantly by 1985.

Greece.—Hellenic Industrial Minerals S.A. was planning a silicon plant with an estimated capacity of 10,000 tons per year. A quartz quarry and crushing facility were being prepared.

Iceland.—Construction continued on the Icelandic Alloys Ltd. plant, partly financed by a $16 million loan from a group of European banks. The 50,000-tons-per-year ferrosilicon plant is 55% owned by the Government of Iceland and 45% owned by Elkem-Spigerverket A/S. First production is planned for 1978.

India.—The government of Orissa Province dedicated the new plant of Utkal Ferro Alloys which will produce ferrosilicon and ferromanganese.[3]

Japan.—Japanese producers of ferrosilicon and silicon metal cut back production because of low-priced imports. Silicon producers asked the Ministry of International Trade and Industry (MITI) to control imports of silicon metal by changes in tariffs. Meanwhile a committee was being formed to advise MITI concerning problems of the ferrosilicon industry.

Norway.—The Government of Norway approved a fourth furnace at the Salten Verk of Elkem-Spigerverket A/S, which will raise ferrosilicon capacity from 80,000 to 112,000 tons per year.[4] Orkla Industrier A/S is also planning a new furnace, if power is available, which will raise its capacity to 40,000 tons per year of ferrosilicon in 1979.[5] Producers in Norway were faced with present and future power shortages. Because low rainfall reduced the amount of available hydropower, noncontract power to metallurgical producers was cut off in September. The Government of Norway also set a goal for future power consumption which may limit growth of the industry.

Spain.—Hidro Nitro Española S.A. started a new 75-megavolt-ampere ferrosilicon furnace. The new furnace has a capacity of

35,000 tons per year of 75% ferrosilicon and brings the company's ferrosilicon capacity to about 55,000 tons per year. Exports are expected to account for 75% of sales.[6]

Sweden.—Airco Alloys A.B. switched a 105-megavolt-ampere furnace at Wargon from ferrosilicon to charge chrome, owing to weak demand for ferrosilicon.

TECHNOLOGY

A new furnace design was described in which the furnace shell is divided into upper and lower sections which rotate at slightly different speeds. The resulting shearing action in the charged material acts to break up crust formations and to block gas blows. The design is intended to eliminate the need for manual stoking of ferrosilicon and silicon furnaces, and thereby permit the use of closed furnaces for these materials. Closed furnaces would offer the advantages of lower costs for air pollution control and better waste energy recovery.[7]

Progress was reported on work to use silicon carbide and silicon nitride for high-temperature applications such as heat exchangers and parts for gas turbine and diesel engines. Most of the work is aimed at developing processes to fabricate these refractory materials into useful shapes. Silicon carbide is produced directly from silica, but silicon nitride is produced from silicon metal and could become an important use for this material. Many groups, including the Federal Bureau of Mines, are also investigating sialons, a class of ceramics composed of silicon, aluminum, oxygen, and nitrogen. Silicon metal is used as a starting material, either directly or through silicon nitride, for several methods of producing sialons.

The U.S. Department of Energy (DOE) supported research aimed at reducing the cost of photovoltaic power to 50 cents per peak watt by 1985. One part of this research was an effort to reduce the price of solar-grade silicon from $60 to $10 per kilogram. In this program, Westinghouse Electric Corp. was evaluating the production of high-purity silicon by the use of arc heaters to thermally decompose a silicon chemical intermediate. Dow Corning Corp. was producing semiconductor silicon on a laboratory scale using selected high-purity raw materials in an arc furnace similar to those used in the commercial production of metallurgical-grade silicon metal. Other research sponsored by DOE was intended to develop better ways to fabricate the photocells from silicon. Independently, RCA Corp. patented an amorphous silicon photocell.[8] Because of materials savings and the suitability of the production process for large-scale production, the amorphous material may facilitate the production of low-cost photocells.

---

[1]Physical scientist, Division of Ferrous Metals.
[2]Metal Bulletin. No. 6220, Aug. 26, 1977, p. 22.
[3]———. No. 6178, Mar. 25, 1977, p. 21.
[4]Work cited in footnote 2.
[5]Metal Bulletin. No. 6218, Aug. 19, 1977, p. 21.
[6]Metal Bulletin Monthly. HNE's New FeSi Unit. No. 83, November 1977, pp. 25-27.
[7]Krogsrud, H., N. E. Bugge, and K. Piene. Recent Achievements in the Development of the Modern Ferrosilicon Furnace- The Elkem Split Furnace Body. Proc. 35th Elec. Furnace Conf., ISS-AIME, Chicago, Ill., Dec. 6-9, 1977. American Institute of Mining, Metallurgical, and Petroleum Engineers, New York, pp. 15-18.
[8]Carlson, D.E. (assigned to RCA Corp.). Semiconductor Device Having a Body of Amorphous Silicon. U.S. Pat. 4,064,521, Dec. 20, 1977.

Silver

By Harold J. Drake[1]

U.S. mine production of silver rose 11% to 38.2 million ounces.[2] Imports for consumption exceeeded exports by 56.8 million ounces, and consumption declined 10% to 153.6 million ounces in 1977. The annual average price of silver recorded a 6% gain over the comparable price for 1976. The decline in consumption was attributed to the sluggish economic recovery in the United States during most of 1977. The decline was led by photographic materials, electroplated and sterling ware, jewelry, contacts and conductors, catalysts, and coins, medallions, and commemorative objects. The only uses showing increased consumption were dental and medical, brazing alloys and solders, batteries, and bearings. Coinage use was far below the level of 1976.

Refinery output fell 11% to 92.9 million ounces in 1977. Production from foreign concentrates and ores was 58% below 1976 levels whereas that from domestic sources rose 7%. Refinery output from old scrap fell 5% as a result of a 36% decline in coin melting which was enough to offset a 10% increase in silver from other kinds of scrap.

Trading of silver futures on the New York Commodity Exchange (COMEX) and the Chicago Board of Trade (CBT) rose 2% to 29.1 billion ounces while stocks on the exchanges rose 12% to 129.4 million ounces. Industrial stocks rose 17% whereas Treasury bullion stocks were only slightly below the level of 1976. The national stockpile

Table 1.—Salient silver statistics

	1973	1974	1975	1976	1977
United States:					
Mine production ---thousand troy ounces--	37,484	33,762	34,938	34,328	38,166
Value --- thousands--	$95,883	$159,018	$154,424	$149,328	$176,325
Ore (dry and siliceous) produced:					
Gold ore---thousand short tons--	3,817	2,033	2,251	1,993	3,478
Gold-silver ore --- do----	124	65	137	1,027	481
Silver ore --- do----	593	693	782	794	976
Percentage derived from:					
Dry and siliceous ores ---	30	30	35	32	43
Base-metal ores ---	70	70	65	68	57
Refinery production[1] ---thousand troy ounces--	36,494	32,368	33,073	34,359	36,729
Exports[2] --- do----	11,215	18,390	32,626	14,596	22,394
Imports for consumption[2] --- do----	96,394	94,451	66,540	72,700	79,147
Stocks Dec. 31:					
Treasury[3] --- million troy ounces--	45	44	41	40	39
Industry[4] ---thousand troy ounces--	130,111	136,543	158,299	146,423	165,343
Consumption:					
Industry and the arts --- do----	196,386	176,027	157,650	170,559	153,613
Coinage --- do----	920	1,017	2,740	1,315	91
Price[5] --- per troy ounce--	$2.558	$4.708	r$4.418	r$4.354	$4.623
World:					
Production---thousand troy ounces--	r311,874	r297,684	r303,112	r312,150	325,475
Consumption:[6]					
Industry and the arts --- do----	r477,800	r424,000	r366,000	r399,200	389,000
Coinage --- do----	29,200	r27,900	r38,800	r30,000	22,000

rRevised.
[1]From domestic ores.
[2]Excludes coinage.
[3]Excludes silver in silver dollars.
[4]Includes silver in COMEX warehouses and silver registered in Chicago Board of Trade.
[5]Average New York price - Source: Handy & Harman.
[6]Market economies only - Source: Handy & Harman.

contained 139.5 million ounces at yearend 1977.

Legislation and Government Programs.—The General Accounting Office (GAO) reported on the silver recycling operations of Federal agencies.[3] The GAO report identified scrap material containing silver and other precious metals, methods of recovery, and overall success of the Federal Government's recycling program.

The General Services Administration (GSA) sold 397,521 ounces of silver reclaimed by Government agencies. GSA also let a refinery contract on a competitive bid basis, for recovery of 85,843 ounces of silver contained in precious metal scrap.

DOMESTIC PRODUCTION

Mine production rose 11% in 1977, mainly as a result of the ending of a strike at the Sunshine mine in Idaho and the fact that two newly opened mines in Idaho operated at near capacity for most of the year. Mine and smelter labor strikes and other shutdowns moderated the advance from the 1976 level. Byproduct silver from base metal ores supplied 57% and silver ores supplied 38% of the total output. The remainder came from gold and gold-silver ores. Production in Idaho, which accounted for 40% of total production, increased 32% to 15.3 million ounces. Production in Arizona, 18% of total production, declined 10% to 6.8 million ounces whereas production in Colorado, 12% of total production, rose 14% to 4.7 million ounces. Production in Montana rose 3% to 3.4 million ounces, that in Missouri rose 4% to 2.4 million ounces, while output in Utah rose 4% to 3.3 million ounces. In the aggregate, production in these three States accounted for 24% of total production in 1977. Other States with significant production, which reported increased output, were Michigan and New Mexico; Nevada recorded a decline.

The 25 largest silver producers contributed 84% of the total output, 6 of these (1st, 2nd, 5th, 6th, 8th, and 12th) mined silver ores with the other mainly mining base metal ores. Ten of the mines produced over 1 million ounces of silver each, which in the aggregate equaled 61% of total production. Domestic mines supplied 25% of U.S. consumption in 1977.

The Sunshine mine of Sunshine Mining Co., in Idaho's Coeur d'Alene silver district, regained its place as the leading silver mine in the United States. Production in 1977 was well above the 1.1 million ounces produced in 1976 when the mine was closed for most of the year by a strike. Ore grade averaged about 24 ounces per ton. Working control of the Sunshine Mining Co. was obtained by Great Western Corp., Dallas, Tex.

ASARCO Incorporated reported production of silver at 3.7 million ounces from the Galena mine and 2.38 million ounces from the Coeur mine, both in Idaho's Coeur d'Alene silver district.[4] The company continued to evaluate the Troy project, a copper-silver deposit in western Montana. If put into operation, the mine will produce 4.2 million ounces of silver per year for about 16 years.

Hecla Mining Co., Wallace, Idaho, reported production of 3.98 million ounces of silver in 1977.[5] Hecla's Lucky Friday mine produced 2.64 million ounces, and its shares of the Sunshine mine and the Star-Morning mine totaled 1.1 million ounces and 0.2 million ounces, respectively. The grade of ore milled at the Lucky Friday mine in 1977 averaged 14.73 ounces per ton. Reserves at yearend 1977 totaled 510,000 tons compared with 475,000 tons at yearend 1976.

Day Mines Inc. (DMI), Wallace, Idaho, reported that silver production in 1977 totaled 3.09 million ounces, compared with 1.95 million ounces in 1976.[6] Production from the Sherman mine in Colorado totaled 85,066 tons with an average of 21.45 ounces per ton. DMI also shared in the production of the Coeur mine and the Galena mine in Idaho.

Earth Resources Co. (ERC) operated its DeLamar silver mine, DeLamar, Idaho, at near capacity for much of 1977 and began pouring bullion in April.[7] The geology of the deposit and the mining operation were described.[8]

The Bunker Hill Co., Kellogg, Idaho, a subsidiary of Gulf Resources & Chemical Corp., reported silver production of 7.48 million ounces, compared with 7.79 million ounces in 1976.[9] The decline in output was attributed to a strike of several months duration in the middle of the year. Company-owned mines contributed about 1.9 million ounces of silver to the total output.

Production of silver at Homestake Mining Co.'s Bulldog mine in Colorado totaled 2.0 million ounces in 1977.[10] The average grade for the 113,672 tons of ore milled in 1977 was 19.0 ounces per ton. Ore reserves of all types were 480,000 tons averaging 16.9 ounces of silver per ton.

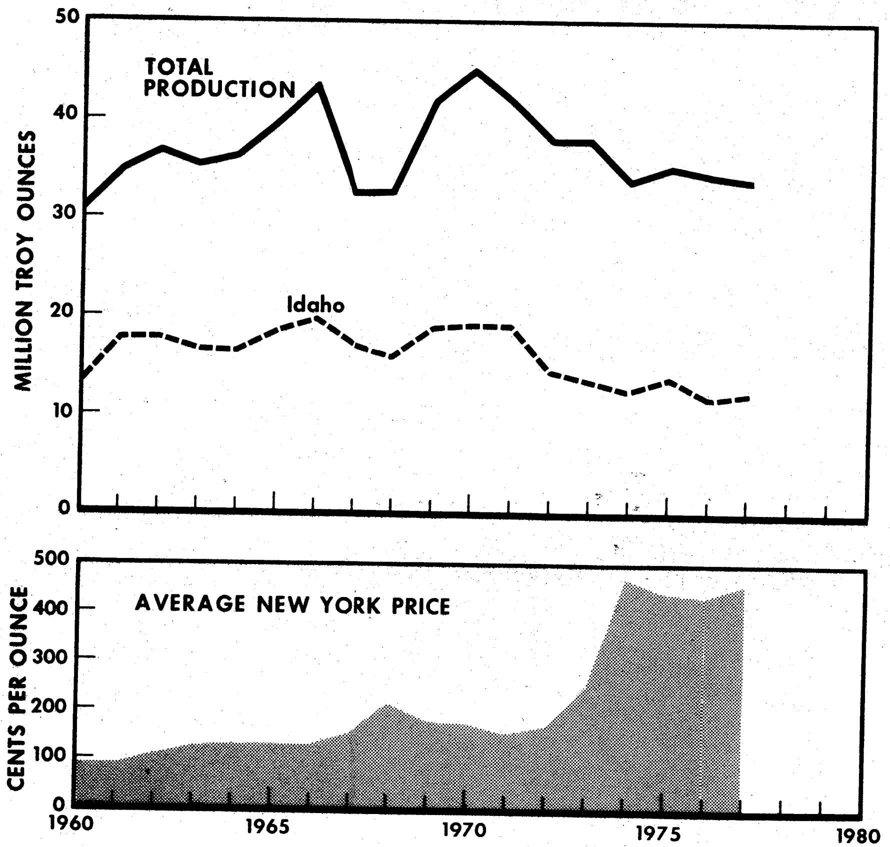


Figure 1.—Silver production in the United States and Idaho and price per ounce.

CONSUMPTION AND USES

Industrial consumption of silver fell 10% to 153.6 million ounces in 1977. An additional 91,000 ounces was used for coinage purposes. Use in photographic materials, which accounted for 35% of consumption in 1977, fell 3% to 53.7 million ounces. Use in contacts and conductors, the second largest use category, also fell 3% to 31.3 million ounces, whereas the third largest use, sterling ware, declined 16% to 16.7 million ounces. In the aggregate, these three uses accounted for 66% of total industrial consumption in 1977. Use of silver in catalysts reversed the upward trend of recent years and fell 28% to 8.9 million ounces. Use in electroplated ware declined 28% to 6.8 million ounces and use in coins, medallions, and commemorative objects was almost halved in falling to 4.3 million ounces. A decline in consumption was recorded for jewelry, down 27% to 8.1 million ounces. Use in brazing alloys and solders rose 10% to 12.4 million ounces while use in dental and medical supplies rose 15% to 2.2 million ounces. Use in batteries rose 66% to 5.8 million ounces.

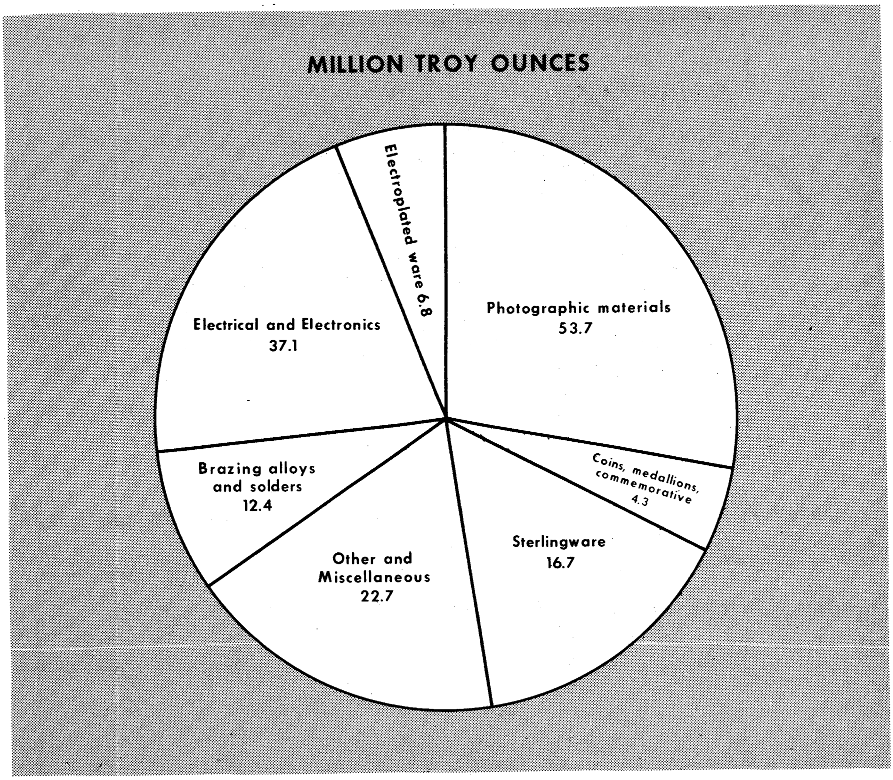


Figure 2.—Silver consumption in the United States, 1977.

STOCKS

Total accountable stocks at yearend were 350.6 million ounces. These consisted of 35.6 million ounces in industry stocks, 39.4 million ounces in Treasury stocks, 6.7 million ounces in Department of Defense stocks, 139.5 million ounces in the strategic stockpile, and 129.4 million ounces in COMEX and CBT registered vaults. COMEX warehouse stocks increased 13.6 million ounces to 68.4 million ounces while CBT stocks were virtually unchanged at 61.0 million ounces. Compared with total stocks at yearend 1976, an increase of 17.4 million ounces was registered in 1977.

PRICES

The price of silver fluctuated somewhat during 1977, rising in the first quarter then falling steadily for the next few months. The price began to rise thereafter and remained on an upward trend for the remainder of the year. The average daily price in cents per ounce of silver, as quoted by Handy & Harman, New York, began the year at 437.0, reached a high of 496.0 on March 21, a low of 432.3 on June 13, and finished the year at 478.0. The gain in the average daily price in 1977 was 41.0 cents. The average monthly price was 440.9 cents per troy ounce in January, rose to 484.2 in March, and then declined to 444.4 cents in August. An increase was then recorded in the final months to 482.8 in November and 470.6 in December. The average monthly price for the year was 462.3 cents per troy ounce compared with 435.4 cents in 1976.

Prices on the London Metal Exchange ranged from a low of 427.5 cents per ounce to a high of 497.7 cents per ounce (U.S. equivalent). The average for 1977 was 463.3 cents.

Trading volume on the COMEX was 17.7 billion ounces during 1977, a decrease of 0.8 billion ounces from 1976. The CBT trading volume was 11.4 billion ounces, a gain of 1.3 billion ounces over that in 1976.

FOREIGN TRADE

Exports of silver rose 53% to 22.4 million ounces. Refined bullion, which accounted for 40% of total exports, totaled 9.0 million ounces, a level 18% over that of 1976. Exports of waste, scrap, sweepings, doré, and precipitates totaled 13.3 million ounces which was equivalent to 59% of total exports. Ore and concentrates, the remainder of the exports, totaled 87,000 ounces. Japan, the principal foreign market in 1977 for exported material, received 35% of the total; the Federal Republic of Germany, 26%; the United Kingdom, 18%; Belgium-Luxembourg, 10%; and Canada and Switzerland, 2% each. The remainder went to about 12 countries. Bullion was shipped mainly to Japan and the United Kingdom, with significantly smaller amounts to Canada, the Federal Republic of Germany, and Mexico. Waste, scrap, and sweepings were sent to the United Kingdom, Belgium-Luxembourg, Japan, and the Federal Republic of Germany, among others.

Imports for consumption of silver totaled 79.1 million ounces and general imports totaled 90.2 million ounces. Refined bullion accounted for 88% of imports for consumption; ore and concentrates, 9%; waste and sweepings, 2%; and doré and precipitates the remainder. Imports of bullion rose 3% to 69.4 million ounces and imports of ore and concentrates rose 8% to 7.1 million ounces. Imports of waste and sweepings, at 1.6 million ounces, were one-half that of 1976. Imports of doré and precipitates decreased 14% to 1.0 million ounces.

The principal source for imported silver in 1977 was Canada, which supplied 36.9 million ounces equivalent to 47% of total imports. Mexico supplied 20.1 million ounces or 25% of imports, and Peru, 15.4 million ounces or 19%. Honduras, Japan, and Yugoslavia, in the aggregate, supplied 4.9 million ounces or 6% of total imports. The remainder was supplied by a number of countries, including Bulgaria, Chile, France, the Federal Republic of Germany, India, and Nicaragua.

Most of the bullion imported in 1977 came from Canada, Mexico, Peru, and Yugoslavia. Ore and concentrates came mainly from Canada, Honduras, Mexico, and Peru. Canada and Mexico accounted for most of the imports of waste and sweepings.

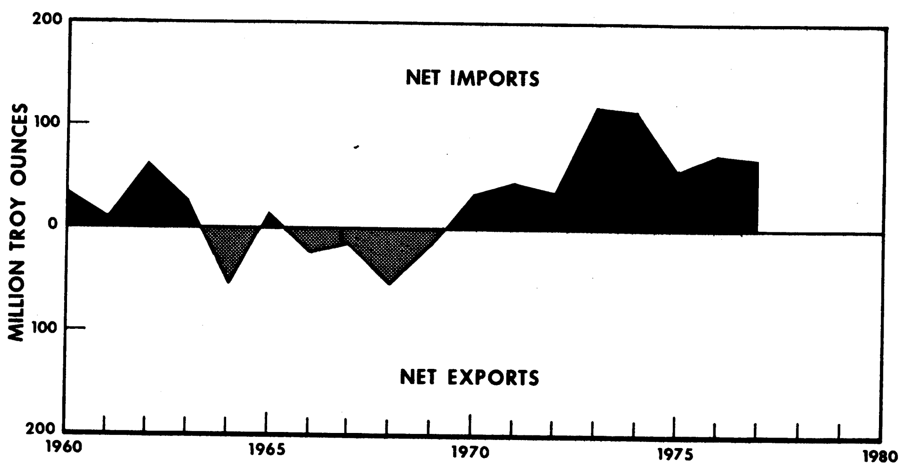


Figure 3.—Net exports or imports of silver, 1960-77.

WORLD REVIEW

World mine production of silver in 1977, including centrally planned economy countries, increased 4% to 325.5 million ounces. The United States, Canada, Mexico, and Peru accounted for 49% of world output.

World consumption of silver in 1977 for industrial and coinage uses, exclusive of centrally planned economy countries, totaled 411.0 million ounces compared with 429.2 million ounces in 1976.[11] A 3% decrease in industrial use, which accounted for 95% of total use in 1977, was accompanied by a 27% decrease in use of silver in coinage. Total consumption by market economy countries exceeded the newly mined supply by 163.0 million ounces, according to Handy & Harman estimates. Secondary production supplied 49% of the difference, outflow from Indian stocks, 27%; demonetized coin, 14%; and U.S. and foreign government stocks, the remainder. The Federal Republic of Germany was reported to have supplied an unusually high 28 million ounces of silver in 1977 reclaimed from official coins that had been retrieved by that Government.

Australia.—Production of silver rose to 27.4 million ounces. An agreement was reached between Gold Fields of South Africa Ltd. and Phelps Dodge Corp. to develop the Black Mountain lead-zinc-copper-silver deposits at Aggeneys, Namagualand. The deposit contained about 42 million tons of proven reserves containing about 120 million ounces of silver in addition to other metals. An additional 220 million tons have been indicated by diamond drilling. Production is expected to commence in 1980 with an annual output of about 4 million ounces of silver. Western Selcast (Pty.) Ltd. and MIM Holdings Ltd. continued to explore the massive sulfide zone at their Teutonic Bore property in Western Australia. Diamond drilling of the deposit has outlined at least 2.5 million tons of ore containing significant quantities of silver, copper, and zinc. Silver reserves at the Cobar, New South Wales, lead-zinc-silver deposit of EZ Industries, Ltd., totaled 30 million tons, averaging 5.3 ounces of silver per ton.

Bolivia.—Production of silver totaled 5.9 million ounces. The Government of Bolivia began accepting bids for the construction of a new lead and silver smelter to be located near Potosí in southern Bolivia. Silver capacity of the smelter was expected to be about 5.8 million ounces per year.

Canada.—Mine production of silver increased 4% to 42.8 million ounces. The Canadian silver mining industry was reviewed.[12] The review presented a detailed study of silver production, consumption, and reserves, and examined the outlook for silver in Canadian and world markets. A report on the Chappelle gold-silver deposit, British Columbia, was published which detailed exploration methods and exploitation plans for a small, high-grade deposit located in a remote area.[13] The role of the prospector was still important in the mining industry as demonstrated by the discovery and exploitation of Brandywine gold-silver property of Northair Mines Ltd., British Columbia.[14] Discovered by a weekend prospector and exploited by a small company, the mine now produces 4,500 ounces of gold and 20,000 to 25,000 ounces of silver per month in addition to substantial quantities of lead and zinc.

Production of silver at the Kidd Creek mine of Texasgulf Canada Ltd. totaled 8.9 million ounces, about 14% below that of 1976.[15] At yearend, the mine contained a 185-million-ounce silver reserve above the 2,600-foot level. Ore reserves below the 2,600-foot level totaled 31.0 million ounces. Exploration below the 2,800-foot level continued to find ore so that the ultimate depth of the deposit had not been delineated at yearend. Texasgulf Inc. continued diamond drilling its large base metal sulfide deposits at Izok Lake and Hood River, Northwest Territories.

Mine production of silver by United Keno Hill Mines, Ltd., rose 17% to 2.8 million ounces.[16] Ore reserves declined from 182,000 tons averaging 43 ounces of silver per ton to 126,000 tons averaging 40 ounces per ton. Silver production at the Sturgeon Lake mine, a joint venture between Sturgeon Lake Mines, Ltd. and Falconbridge Copper Ltd., was 2.2 million ounces, a twofold increase over that of 1976.[17] Reserves at yearend 1977 totaled 903,600 tons averaging 5.31 ounces of silver per ton.

Noranda Mines Ltd. reported that silver production from the No. 12 and No. 6 mines of Brunswick Mining & Smelting Corp., Ltd. totaled 3.5 million ounces in 1977 compared with 3.0 million ounces in 1976.[18] Reserves at both mines at yearend totaled about 100 million tons containing 300 million ounces of silver. Noranda Mines Ltd. has a 64.1%

interest in Brunswick Mining & Smelting Corp. Ltd. Mining operations at the No. 12 and No. 6 mines were described.[19] Noranda's Geco Div. reported production of 1.6 million ounces of silver in 1977 from an ore reserve which contained 39.2 million ounces at the end of the year. Production of silver by Mattagami Lake Mines Ltd. and Mattabi Mines Ltd. totaled 2.7 million ounces in 1977. Ore reserves of the two mines totaled 21.8 million ounces at the end of 1977. Noranda Mines Ltd. has operating interests in these mines.

Equity Mining Corp. was planning an open pit mine to exploit the Sam Goosley silver-gold-copper property located at Houston, British Columbia. The property was estimated to contain 43.5 million tons of ore containing 2.78 ounces of silver per ton. Production was planned at 6 million ounces of silver per year.

Dominican Republic.—Rosario Dominicana, S.A., a subsidiary of Rosario Resources Corp., operated its Pueblo Viejo gold-silver mine near capacity in 1977.[20] Production of precious metals included 1,357,290 ounces of silver and 348,473 ounces of gold. Reserves of oxide ore totaled 22.4 million tons containing 14.4 million ounces of silver and 2.6 million ounces of gold. A sulfide ore reserve contained 19.5 million ounces of silver and 2.6 million ounces of gold, but a satisfactory metallurgical process to treat the sulfide ore had not been developed.

Honduras.—Production of silver in 1977 at the El Mochito mine of Rosario Resources Corp. totaled 2.8 million ounces. Ore reserves increased during the year to 6.4 million tons containing 31.8 million ounces of silver in addition to gold, lead, zinc, and copper.

Japan.—Production, including primary and secondary, and consumption of silver in 1977 totaled 34.7 million ounces and 57.5 million ounces, respectively.[21] The supply deficiency was made up by imports of bullion and stock withdrawals. Increased consumption was reported for photography, contacts and conductors, and jewelry, while decreases were reported for fabricated products, brazing alloys, and electroplated ware.

Mexico.—Mine production of silver in 1977 totaled 47.0 million ounces. The increased output was attributed to the extensive expansion of silver mines and plants of recent years. Production is expected to increase to about 58 million ounces by yearend 1978.

Lacana Mining Corp. reported silver production at the Las Torres complex in 1977 totaled 4.9 million ounces from an ore reserve that at yearend 1977 contained 34.5 million ounces of silver.[22] When operating at full capacity, annual production at Las Torres should total 8.0 million ounces of silver. Mining operations at Las Torres were described.[23] Silver production at the Encantada mine in 1977 totaled 1.8 million ounces. At yearend, silver reserves totaled 32.7 million ounces. Annual production at the La Encantada mine is expected to be 3.2 million ounces when operated at full capacity.

Expansion of the Huautla silver-lead mine in Morelos by Rosario Mexico, S.A. de C.V. continued in 1977. The new crushing plant was completed, increasing the production rate to 300 tons per day. Silver production in 1977 totaled 600,977 ounces. At yearend, silver reserves stood at 6.6 million ounces.

Nicaragua.—Rosario Mining of Nicaragua, Inc., a subsidiary of Rosario Resources Corp., continued to explore the area around the Rosita mine and a large low-grade deposit of silver and gold in the Coco River area.[24] The Rosita mine produced 119,394 ounces of silver from an ore reserve containing 1.4 million ounces.

Spain.—Silver production in Spain totaled 3.5 million ounces. Andaluza de Piritas S.A. continued developing the base metal deposit at Aznalcóllar in southwestern Spain.[25] When completed in 1979, the open pit mine will produce 2.6 million ounces of silver in concentrates.

TECHNOLOGY

The precious metal content of some base metal ores, tailings, and concentrates are sometimes so low that the cost of their detection has sometimes precluded recovery notwithstanding their value. An analytical method using conventional assaying techniques in the determination of gold, silver, and the platinum-group metals was described which was simple, accurate, reproducible, and inexpensive.[26] The method was particularly suitable for the average-size mineral engineering research laboratories.

A light bulb that uses up to 60% less electricity than regular bulbs has been developed.[27] The glass bulb is covered with a film consisting of a layer of silver sandwiched between layers of titanium dioxide. The film allows light to pass out but not heat thus reducing the electricity required to keep the bulb's filament at optimum operating temperatume. The film is also used on glass windows of buildings to keep heat out in the summer and retain heat in the winter.

Silver and gold occuring in trace amounts in seawater or waste water can be recovered using bacteria as a concentrating agent.[28] The source water is treated with bacteria to form a sludge which is subsequently recovered and refined conventionaly to recover the precious metals. Cyanide ore leach solutions containing silver and gold can be treated in a multistep process to recover the silver and gold as metallic particles.[29] The solution is first treated with formaldehyde, then hydrogen peroxide, followed by hydrazine to produce the metallic powders. When copper is a significant impurity in electrolytic refining of silver, it can be lessened by removing the electrolyte from the cell and treating it with a 2-hydroxy benzophenoxine derivative which substantially lessens the copper content.[30] The purified electrolyte is returned to the cell for continued refining of silver. Silver-containing solutions, such as silver thiosulfate, may be electrolyzed in an open-topped tank containing a stainless steel basket including vertical cylindrical sleeves containing electrodes.[31] A voltage difference between each sleeve and electrode causes silver to plate on the basket and sleeves.

---

[1]Physical scientist, Division of Nonferrous Metals.
[2]Ounce as used throughout this chapter refers to the troy ounce.
[3]General Accounting Office. Additional Precious Metals Can Be Recovered. LCD-77-228, Dec. 28, 1977, pp. 37.
[4]ASARCO Incorporated. 1977 Annual Report. 36 pp.
[5]Hecla Mining Co. 1977 Annual Report. 24 pp.
[6]Day Mines Inc. 1977 Annual Report. 12 pp.
[7]Earth Resources Co. 1977 Annual Report. 28 pp.
[8]World Mining. DeLamar Silver Mine - Third Largest in the United States Now Pouring Bullion. V. 30, No. 12, November 1977, pp. 59-61.
[9]Gulf Resources & Chemical Corp. 1977 Annual Report. 36 pp.
[10]Homestake Mining Co. 1977 Annual Report. 32 pp.
[11]Handy & Harman. The Silver Market, 1977. 62d Annual Review, 1977, 26 pp.
[12]George, J. G. Silver in Canada in International Perspective. CIM Bull., v. 70, No. 786, October 1977, pp. 74-80.
[13]Barr, D. A. Chappelle Gold-Silver Deposit, British Columbia. CIM Bull., v. 71, No. 790, February 1978, pp. 66-79.
[14]Webster, L. Northair - Bucking the Trend in Gold. Can. Min. J., v. 98, No. 3, March 1977, pp. 48-55.
[15]Texasgulf Incorporated. 1977 Annual Report. 48 pp.
[16]Falconbridge Nickel Mines, Ltd. 1977 Annual Report. 40 pp.
[17]Page 35 of reference cited in footnote 16.
[18]Noranda Mines, Ltd. 1977 Annual Report. 32 pp.
[19]Mining Magazine. Expansion at Brunswick. V. 137, No. 3, September 1977, pp. 198-209.
[20]Rosario Resources Corp. 1977 Annual Report. 33 pp.
[21]Japan Metal Bulletin. Precious Metals. V. 8, No. 7, Feb. 13, 1978, pp. 8-9.
[22]Lacana Mining Corp. 1977 Annual Report. 21 pp.
[23]Argall, G. O. Guanajuato Group Revives Mexican Silver District, Four Mines, New Mill. World Min., v. 30, No. 10, September 1977, pp. 78-84.
[24]Pages 4 and 11 of reference cited in footnote 20.
[25]White, L. Construction is Well Along at Aznalcóllar. Eng. and Min. J., v. 178, No. 6, June 1977, pp. 130-132.
[26]Yen, W. T. A Simple, Reliable Method of Determining Precious Metal Content of Mill Products. Can. Min. J., v. 98, No. 10, October 1977, pp. 43-46.
[27]Chemical and Engineering News. Bulb-Coating Could Lighten Energy Use. V. 55, No. 34, August 1977, p. 8.
[28]Markels, M., Jr. (assigned to World Resources Co.). Process for Recovery of Selected Metal Values from Waste Waters. U.S. Pat. 4,033,763, July 5, 1977.
[29]Dietz, G. Jr., R. M. Skomoroski, and R. G. Zobbi (assigned to American Chemical & Refining Co., Inc.). Stepwise Process for Recovering Precious Metals From Solution. U.S. Pat. 4,039,327, Aug. 2, 1977.
[30]Hunter, W. (assigned to Brookside Metal Co., Inc.). Electrolytic Refining of Silverware. British Pat. 1,479,324, July 13, 1977.
[31]Kelleher, R. F. (assigned to Electrolyte Services Ltd.). Method for Electrolytic Silver Recovery. U.S. Pat. 4,039,407, Aug. 2, 1977.

Table 2.—Mine production of recoverable silver in the United States, by month

(Thousand troy ounces)

Month	1976	1977
January	2,909	2,872
February	2,948	2,866
March	3,073	3,344
April	2,831	3,178
May	2,574	3,331
June	2,913	3,506
July	2,622	2,693
August	3,039	3,109
September	2,962	3,143
October	2,828	3,362
November	2,855	3,292
December	2,775	3,470
Total	[1]34,328	38,166

[1]Data do not add to total shown because of independent rounding.

Table 3.—Twenty-five leading silver-producing mines in the United States in 1977, in order of output

Rank	Mine	County and State	Operator	Source of silver
1	Sunshine	Shoshone, Idaho	Sunshine Mining Co	Silver ore.
2	Galena	do	ASARCO Incorporated	Do.
3	Berkeley Pit	Silver Bow, Mont	The Anaconda Company	Copper ore.
4	Lucky Friday	Shoshone, Idaho	Hecla Mining Co	Lead ore.
5	Coeur	do	ASARCO Incorporated	Silver ore.
6	Bulldog Mountain	Mineral, Colo	Homestake Mining Co	Do.
7	Utah Copper	Salt Lake, Utah	Kennecott Copper Corp	Copper ore.
8	Sherman Tunnel	Lake, Colo	Day Mines, Inc	Silver ore.
9	Twin Buttes	Pima, Ariz	Anamax Mining Co	Copper ore.
10	Buick	Iron, Mo	Amax Lead Co. of Missouri	Lead ore.
11	Sierrita	Pima, Ariz	Duval Corp	Copper ore.
12	DeLamar	Owyhee, Idaho	Earth Resources Co	Silver-gold ore.
13	Bunker Hill	Shoshone, Idaho	The Bunker Hill Co	Lead-zinc ore.
14	Star Unit	do	Hecla Mining Co	Lead, lead-zinc ores.
15	Magma	Pinal, Ariz	Magma Copper Co	Copper ore.
16	Pima	Pima, Ariz	Cyprus Pima Mining Co	Do.
17	Trixie	Utah, Utah	Kennecott Copper Corp	Gold-silver ore.
18	Morenci	Greenlee, Ariz	Phelps Dodge Corp	Copper ore.
19	San Manuel	Pinal, Ariz	Magma Copper Co	Do.
20	Tyrone	Grant, N. Mex	Phelps Dodge Corp	Do.
21	Ontario	Summit, Utah	Park City Ventures	Lead-zinc ore.
22	Magmont	Iron, Mo	Cominco American, Inc	Lead ore.
23	White Pine	Ontonagon, Mich	White Pine Copper Div., Copper Range Co.	Copper ore.
24	Sunnyside	San Juan, Colo	Standard Metals Corp	Lead-zinc ore.
25	Leadville Unit	Lake, Colo	ASARCO Incorporated	Do.

Table 4.—Silver produced in the United States, in 1977, by State, type of mine, and class of ore, yielding silver, in terms of recoverable metal

State	Placer (troy ounces of silver)	Lode: Gold ore: Short tons	Lode: Gold ore: Troy ounces of silver	Lode: Gold-silver ore: Short tons	Lode: Gold-silver ore: Troy ounces of silver	Lode: Silver ore: Short tons	Lode: Silver ore: Troy ounces of silver
Alaska	1,670	W	W	--	--	--	--
Arizona	--	--	--	--	--	18,336	117,467
California	202	W	W	4,000	26,093	--	--
Colorado	--	--	--	--	--	276,862	3,681,587
Idaho	--	W	W	W	W	571,879	10,243,084
Michigan	--	--	--	--	--	--	--
Missouri	--	--	--	--	--	--	--
Montana	--	3,658	1,518	3,059	20,098	61,178	264,052
Nevada	75	1,848,362	201,292	--	--	22,032	3,073
New Mexico	--	W	W	--	--	2,680	19,474
New York	--	--	--	--	--	--	--
Oregon	--	2,978	6,313	--	--	49	808
South Dakota	--	1,578,413	68,717	--	--	--	--
Tennessee	--	--	--	--	--	--	--
Washington	--	39,750	113,232	--	--	W	W
Other States[1]	--	4,434	16,413	473,726	1,405,318	23,029	197,412
Total	1,947	3,477,595	407,485	480,785	1,451,509	976,045	14,526,957
Percent of total silver	([2])	--	1	--	4	--	38

State	Lode: Copper ore: Short tons	Lode: Copper ore: Troy ounces of silver	Lode: Lead ore: Short tons	Lode: Lead ore: Troy ounces of silver	Lode: Zinc ore: Short tons	Lode: Zinc ore: Troy ounces of silver
Alaska	W	W	--	--	--	--
Arizona	151,664,491	6,680,543	--	--	--	--
California	--	--	--	--	--	--
Colorado	--	--	1,229	2,822	159,861	96,658
Idaho	150,000	58,282	185,872	2,600,383	9,680	2,229
Michigan	3,509,571	335,479	--	--	--	--
Missouri	--	--	8,925,602	2,362,752	--	--
Montana	15,475,605	3,081,451	2,012	323	--	--
Nevada	6,145,492	387,248	100	536	300	7,267
New Mexico	24,266,264	757,793	150	503	W	W
New York	--	--	--	--	1,071,226	56,353
Oregon	32	13	--	--	--	--
South Dakota	--	--	--	--	--	--
Tennessee	--	--	--	--	--	--
Washington	--	--	--	--	--	--
Other States[1]	32,582,783	1,884,335	--	--	680,030	131,426
Total	233,794,238	13,185,144	9,114,965	4,967,319	1,921,097	293,933
Percent of total silver	--	34	--	13	--	1

See footnotes at end of table.

Table 4.—Silver produced in the United States, in 1977, by State, type of mine, and class of ore, yielding silver, in terms of recoverable metal-Continued

State	Lode: Copper-lead, lead-zinc, copper-zinc, and copper-lead-zinc ores		Lode: Old tailings, etc.		Total[3]	
	Short tons	Troy ounces of silver	Short tons	Troy ounces of silver	Short tons	Troy ounces of silver
Alaska	--	--	--	--	8	1,725
Arizona	40,710	15,872	39,741	14,263	151,763,278	6,828,145
California	--	--	W	W	4,511	57,891
Colorado	783,687	882,358	1	71	1,221,640	4,663,496
Idaho	764,033	1,567,838	--	--	2,077,700	15,291,964
Michigan	--	--	--	--	3,509,571	335,479
Missouri	--	--	--	--	8,925,602	2,362,752
Montana	--	--	--	--	15,545,512	3,367,442
Nevada	104,679	138,911	--	--	8,120,965	738,402
New Mexico	--	--	--	--	24,411,047	918,155
New York	--	--	--	--	1,071,226	56,353
Oregon	--	--	--	--	3,059	7,134
South Dakota	--	--	--	--	1,578,413	68,717
Tennessee	1,250,130	60,246	--	--	1,250,130	60,246
Washington	W	W	--	--	193,575	120,582
Other States[1]	493,233	623,738	--	[4]28,112	33,564,702	3,287,220
Total	3,436,472	3,288,963	39,742	42,446	253,240,939	38,165,703
Percent of total silver	--	9	--	([2])	--	100

W Withheld to avoid disclosing company proprietary data; included in "Other States."
[1]Includes Illinois, Utah, Virginia, and States indicated by symbol W.
[2]Less than 1/2 unit.
[3]Data may not add to State totals because of items withheld to avoid disclosing company proprietary data.
[4]Includes byproduct silver recovered from tungsten ore in California and fluorspar in Illinois.

Table 5.—Mine production of recoverable silver in the United States, by State

(Troy ounces)

	1973	1974	1975	1976	1977
Alaska	828	547	W	3,265	1,725
Arizona	7,199,251	6,355,528	6,285,854	7,615,112	6,828,145
California	55,897	41,894	79,757	57,265	57,891
Colorado	3,598,209	2,783,978	3,366,000	4,083,171	4,663,496
Idaho	13,619,824	12,435,701	13,868,133	11,561,421	15,291,964
Michigan	850,273	642,944	632,336	310,837	335,479
Missouri	2,057,732	2,387,250	2,525,042	2,277,013	2,362,752
Montana	4,349,869	3,512,161	2,616,626	3,278,629	3,367,442
Nevada	623,660	872,243	1,608,735	783,892	738,402
New Mexico	1,111,269	1,194,800	792,050	891,932	918,155
New York	54,345	64,463	56,047	49,199	56,353
Oregon	1,282	8,925	W	--	7,134
South Dakota	71,939	62,474	67,669	58,117	68,717
Tennessee	73,104	20,053	53,752	77,890	60,246
Utah	3,619,038	3,207,923	2,821,730	3,134,021	3,283,323
Washington	W	W	W	W	120,582
Other States	197,050	170,990	163,851	146,466	3,897
Total	37,483,570	33,761,874	34,937,582	34,328,230	38,165,703

W Withheld to avoid disclosing company proprietary data; included in "Other States."

Table 6.—Silver produced in the United States from ore, old tailings, etc., in 1977, by State and method of recovery, in terms of recoverable metal

State	Total ore, old tailings, etc. treated[1 2] (thousand short tons)	Ore and old tailings to mills					Crude ore, old tailings, etc., to smelters[1]	
		Thousand short tons[1 2]	Recoverable in bullion		Concentrates smelted and recoverable metal			
			Amalgamation (troy ounces)	Cyanidation (troy ounces)	Concentrates (short tons)	Troy ounces	Thousand short tons	Troy ounces
Alaska	([3])	--	--	--	--	--	([3])	55
Arizona	[4]182,993	[4]182,686	--	77,000	8,377,614	6,695,008	307	56,137
California	5	5	295	16	2,144	52,297	([3])	5,081
Colorado	[5]1,222	[5]1,217	16,418	140,628	127,268	4,364,623	5	141,827
Idaho	2,078	2,075	--	820,106	139,928	14,454,355	3	17,503
Michigan	3,510	3,510	--	--	146,872	335,479	--	--
Missouri	8,926	8,926	--	--	879,060	2,362,752	--	--
Montana	15,562	15,485	7	--	325,271	3,090,673	77	276,762
Nevada	[4]18,451	[4]18,390	--	201,742	293,065	531,116	61	5,469
New Mexico	24,440	24,360	--	--	768,734	887,658	80	30,497
New York	1,195	1,195	--	--	134,335	56,353	--	--
Oregon	3	--	--	--	--	--	3	7,134
South Dakota	1,578	1,578	--	68,717	--	--	--	--
Tennessee	4,995	4,995	--	--	205,462	60,246	--	--
Utah	33,054	32,910	--	--	739,252	2,501,293	144	782,030
Washington	194	194	--	--	12,242	118,982	([3])	1,600
Other States[6]	542	542	--	--	34,941	3,897	--	--
Total	298,748	298,068	16,720	1,308,209	12,186,188	35,514,732	680	1,324,095

[1]Includes some nonsilver-bearing ore not separable.
[2]Excludes tonnages of fluorspar and tungsten ores from which silver was recovered as a byproduct.
[3]Less than 1/2 unit.
[4]Includes ore from which silver was recovered by heap leaching.
[5]Includes ore from which silver was recovered by vat leaching.
[6]Includes Illinois and Virginia.

Table 7.—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)		Silver recoverable from all sources (percent)			
	Amalgamation	Cyanidation	Amalgamation	Cyanidation	Smelting[1]	Placers
1973	3,536	260,846	0.01	0.70	99.29	([2])
1974	2,467	335,909	.01	.99	99.00	([2])
1975	2,293	420,077	.01	1.20	98.79	([2])
1976	1,862	407,375	([2])	1.19	98.80	0.01
1977	16,720	1,308,209	.04	3.43	96.52	.01

[1]Crude ores and concentrates.
[2]Less than 0.005 percent.

Table 8.—Silver produced at refineries in the United States, by source

(Thousand troy ounces)

Source	1976	1977
Concentrates and ores:		
Domestic	34,359	36,729
Foreign	19,994	8,315
Total	54,353	45,044
Old scrap:		
Coins	15,945	10,173
Other	34,280	37,686
Total	50,225	47,859
Total net production	104,578	92,903
New scrap	53,084	51,747
Grand total	157,662	144,650

Table 9.—U.S. consumption of silver, by end use

(Thousand troy ounces)

Final use[1]	1976	1977
Electroplated ware	9,534	6,844
Sterling ware	19,815	16,690
Jewelry	10,995	8,059
Photographic materials	55,530	53,679
Dental and medical supplies	1,942	2,232
Mirrors	4,622	2,131
Brazing alloys and solders	11,198	12,362
Electrical and electronic products:		
Batteries	3,490	5,783
Contacts and conductors	32,329	31,316
Bearings	273	523
Catalysts	12,267	8,883
Coins, medallions, commemorative objects	8,240	4,252
Miscellaneous[2]	324	859
Total net industrial consumption	170,559	153,613
Coinage	1,315	91
Total consumption	171,874	153,704

[1]End use as reported by converters of refined silver.
[2]Includes silver-bearing copper, silver-bearing lead anodes, ceramics, paints, etc.

Table 10.—Value of silver exported from and imported into the United States

(Thousand dollars)

Year	Exports	Imports[1]
1975	147,567	330,556
1976	61,435	328,784
1977	84,645	355,953

[1]Revised to reflect imports for consumption rather than general imports. Values for general imports for the years covered by this table are as follows (in thousands): 1975—$394,536; 1976—$378,061; 1977—$406,639.

Table 11.—U.S. exports of silver in 1977, by country

(Thousand troy ounces and thousand dollars)

Country	Ore and concentrates		Waste and sweepings		Refined bullion	
	Quantity	Value	Quantity	Value	Quantity	Value
Argentina	--	--	--	--	63	304
Belgium-Luxembourg	27	100	2,123	9,516	--	--
Canada	24	83	204	935	278	1,327
Colombia	--	--	--	--	161	792
France	19	84	26	126	--	--
Germany, Federal Republic of	8	36	5,153	11,121	626	900
India	--	--	10	27	--	--
Japan	--	--	1,550	6,788	6,335	28,992
Korea, Republic of	--	--	--	--	18	89
Mexico	--	--	5	13	411	1,727
Netherlands	--	--	108	476	1	2
Spain	5	9	285	1,198	2	10
Sweden	--	--	256	1,042	42	187
Switzerland	(1)	1	496	2,282	14	72
United Kingdom	4	11	3,089	11,613	1,032	4,711
Venezuela	--	--	--	--	5	24
Other	--	--	8	19	6	28
Total	87	324	13,313	45,156	8,994	39,165

[1]Less than 1/2 unit.

Table 12.—U.S. imports for consumption[1] of silver in 1977, by country

(Thousand troy ounces and thousand dollars)

Country	Ore and concentrates		Waste and sweepings		Doré and precipitates		Refined bullion	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Argentina	--	--	--	--	--	--	19	25
Australia	--	--	1	2	--	--	2	14
Bolivia	65	96	--	--	--	--	--	--
Bulgaria	--	--	--	--	--	--	273	1,198
Brazil	77	299	21	80	--	--	--	--
Canada	758	3,226	747	2,936	164	936	35,240	159,350
Chile	53	275	--	--	129	593	338	1,543
Colombia	50	238	--	--	--	--	--	--
Costa Rica	--	--	8	33	(2)	1	13	62
France	--	--	170	308	--	--	--	--
Germany, Federal Republic of	146	670	27	106	--	--	--	--
Greece	--	--	26	36	--	--	--	--
Honduras	1,832	7,505	--	--	--	--	73	217
Hong Kong	--	--	10	46	--	--	--	--
India	--	--	80	144	--	--	77	336
Italy	(2)	(2)	4	14	--	--	2	10
Japan	--	--	6	29	--	--	807	3,577
Mexico	941	4,205	461	1,336	--	--	18,724	87,268
Netherlands	--	--	3	13	--	--	--	--
Nicaragua	52	243	--	--	3	14	86	372
Panama	3	14	--	--	--	--	--	--
Peru	3,047	13,479	--	--	482	2,231	11,898	52,364
Philippines	46	208	11	45	--	--	--	--
Trinidad and Tobago	--	--	1	2	--	--	--	--
United Kingdom	--	--	1	4	(2)	(2)	--	--
Yugoslavia	--	--	--	--	258	1,191	1,898	9,006
Other	1	2	13	50	--	--	(2)	1
Total	7,071	30,460	1,590	5,184	1,036	4,966	69,450	315,343

[1]General imports were as follows, in thousand troy ounces and thousand dollars: Ores and concentrates, 18,097 ($81,176) and waste and sweepings, 1,586 ($5,154). Imports for consumption and general imports were the same for doré and precipitates and for refined bullion.

[2]Less than 1/2 unit.

Table 13.—Silver: World production[1] by country

(Thousand troy ounces)

Country[2]	1975	1976	1977[p]
North and Central America:			
Canada	39,695	41,199	42,758
Costa Rica[e]	3	2	1
Dominican Republic	109	907	1,357
El Salvador	176	166	112
Haiti[e]	(3)	(3)	--
Honduras	3,802	2,964	3,210
Mexico	38,029	42,640	47,029
Nicaragua	324	204	153
United States	34,938	34,328	38,166
South America:			
Argentina	2,283	1,750	[e]1,800
Bolivia	[4]5,470	5,091	5,887
Brazil	235	[r e 5]240	[e]240
Chile	6,263	7,287	[e]7,650
Colombia[6]	88	106	100
Ecuador	37	52	43
Peru	37,527	35,579	30,100
Europe:			
Bulgaria[e]	800	[r]900	800
Czechoslovakia[e]	[r]1,190	[r]1,190	1,190
Finland	744	773	813
France	1,502	2,806	[e]3,100
German Democratic Republic[e]	[r]1,800	1,600	1,600
Germany, Federal Republic of	1,079	1,026	[e]970
Greece[6]	480	477	374
Greenland[e]	380	375	517
Hungary	[r]32	32	39
Ireland[e]	1,384	925	936
Italy[6]	1,157	1,556	1,207
Poland[e 7]	[r]13,200	[r]16,100	17,700
Portugal	25	27	25
Romania[e]	1,500	1,300	1,250
Spain	3,447	3,107	[e]3,540
Sweden	4,515	4,617	[e]4,820
U.S.S.R.[e 6]	43,000	44,000	45,000
Yugoslavia[6]	5,412	4,631	4,694
Africa:			
Algeria[e]	[r]120	150	200
Kenya	[r e]20	[r e]19	19
Mauritania	[e]26	32	[e 8]26
Morocco	[r]3,041	2,054	2,244
Rhodesia, Southern	[r]169	117	114
South Africa, Republic of	3,084	2,821	3,130
South-West Africa, Territory of[e]	[r]1,400	[r]1,100	1,300
Tanzania	(9)	(9)	[e](9)
Tunisia	292	252	236
Zaire	2,291	2,472	2,730
Zambia[10]	[e]1,000	1,065	[e]1,000
Asia:			
Burma	[r]749	705	791
China, People's Republic of[e]	[r]965	[r]965	965
India	83	102	425
Indonesia	1,033	1,086	790
Japan	8,733	9,299	9,646
Korea, North[e]	1,600	1,600	1,600
Korea, Republic of	1,494	1,838	2,040
Philippines	1,620	1,481	1,622
Taiwan	6	100	68
Oceania:			
Australia	[r]23,348	25,073	27,424
Fiji	26	20	15
New Zealand	[e]2	1	3
Papua New Guinea	1,384	1,841	[e]1,906
Total	[r]303,112	312,150	325,475

[e]Estimate. [p]Preliminary. [r]Revised.

[1]Recoverable content of ores and concentrates produced unless otherwise noted.

[2]In addition to the countries listed Ghana, Thailand, and Turkey produce silver, but information is inadequate to make reliable estimates of output levels.

[3]Revised to none.

[4]Includes production by the State mining company (COMIBOL) plus the exports of medium and small (private sector) mines.

[5]Estimate includes 20,000 ounces of silver recovered from gold ores plus an estimated 220,000 ounces of silver recovered as a byproduct from lead.

[6]Smelter and/or refinery production.

[7]Series revised. Revised figures for years prior to those shown are as follows, in thousand troy ounces: 1967—640; 1968—1,300; 1969—2,600; 1970—3,900; 1971—4,500; 1972—7,700; 1973—8,700; and 1974—11,300.

[8]Estimate based on declining output of copper ore.

[9]Less than 1/2 unit.

[10]Refined silver and silver contained in blister copper and refinery muds.

Slag-Iron and Steel

By James R. Evans[1]

Combined sales and usage of iron and steel slag in 1977 was 32.4 million tons, slightly under the 32.6 million tons of 1976. Total sales value, however, showed a 3% increase from that of 1976 to $82 million, the highest total sales value ever recorded. Average value per ton of all slags was $2.54. Total sales and use of all slags have remained nearly constant from 1975 through 1977, but the total value has increased 13% (table 1, figure 1).

DOMESTIC PRODUCTION

Iron slags sold or used in 1977 totaled 25.7 million tons, a slight decrease from 26.0 million tons in 1976, and very near the level of 1970 (table 1). The total sales value was $71.3 million, 2% above the level of 1976, and the highest ever recorded. The average value per ton of all iron slags was $2.77.

Steel slags sold or used in 1977 totaled 6.7 million tons, slightly above the 1976 level, but significantly below the levels from 1970 to 1975. Total sales value in 1977 was $10.9 million, a 12% increase over that of 1976.

Iron slags were processed at 70 plants in 14 States. Ohio, Pennsylvania, and Indiana, in that order, were the leading States, and accounted for 57% of the national total. Steel slags were processed at 38 plants in 14 States. Because of proprietary reasons, individual State totals for steel slag cannot be given. The geographic distribution of slag plants is shown in figure 2.

About 80% of iron and steel slag products in the United States were shipped to markets by truck, 13% by rail, and 4% by waterway.

CONSUMPTION AND USES

Because there were no known imports or exports of iron or steel slags in 1977, production or processing is assumed to equal consumption in the United States. As normal, most of the slags consumed in the United States were in the construction industry.

Most salable iron slag banks in the United States have been exhausted, and the availability of iron slag in 1977 was largely dependent on newly produced blast-furnace iron from iron and steel plants. An extensive but undetermined tonnage of steel slag banks exist because only a part of the production of steel slag is sold or used each year. These banks will grow larger with time unless new markets or an increase in existing markets develops. Part of both the iron and steel slags are high in metallic iron content and are unsuitable for sale into the construction industry. However, because they do contain abundant iron they can be returned to the blast furnaces of the iron and steel plants as part of the new charge.

Air-cooled iron blast-furnace slag continued to be the most important slag product in terms of both tons processed and in the number of different types of uses. Locally, iron slag is competitive with sand and gravel and crushed stone, principally for use in aggregates. Air-cooled iron slag shows excellent bonding characteristics when mixed with portland cement to make concrete. It also shows high stability when

Table 1.—Iron and steel slags sold or used in the United States, by type[1]

(Thousand short tons and thousand dollars)

Year	Iron blast-furnace slag								Steel slag		Total slag	
	Air-cooled		Granulated		Expanded		Total iron slag					
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1970	22,252	42,135	1,936	2,134	1,959	6,570	26,147	50,839	7,539	8,832	33,686	59,671
1971	21,444	42,352	1,787	2,445	1,581	4,887	24,812	49,684	8,488	9,719	33,300	59,403
1972	21,878	44,787	1,657	3,059	1,518	5,529	25,053	53,375	10,162	11,023	35,215	64,398
1973	24,971	52,249	1,999	3,667	1,852	6,936	28,822	62,852	9,739	10,765	38,561	73,617
1974	26,226	57,227	2,081	4,442	1,573	6,461	29,880	68,130	8,862	11,195	38,742	79,325
1975	22,242	53,386	1,780	4,335	1,302	5,934	25,324	63,655	7,302	8,965	32,626	72,620
1976	22,899	59,813	1,618	3,529	1,492	6,610	26,009	69,952	6,588	9,728	32,597	79,680
1977	22,753	61,270	1,488	3,579	1,475	6,414	25,716	[2]71,262	6,668	10,850	32,384	82,112

[1]Value based on selling price at plant.
[2]Data do not add to total shown because of independent rounding.

Source: National Slag Association (1970-76).

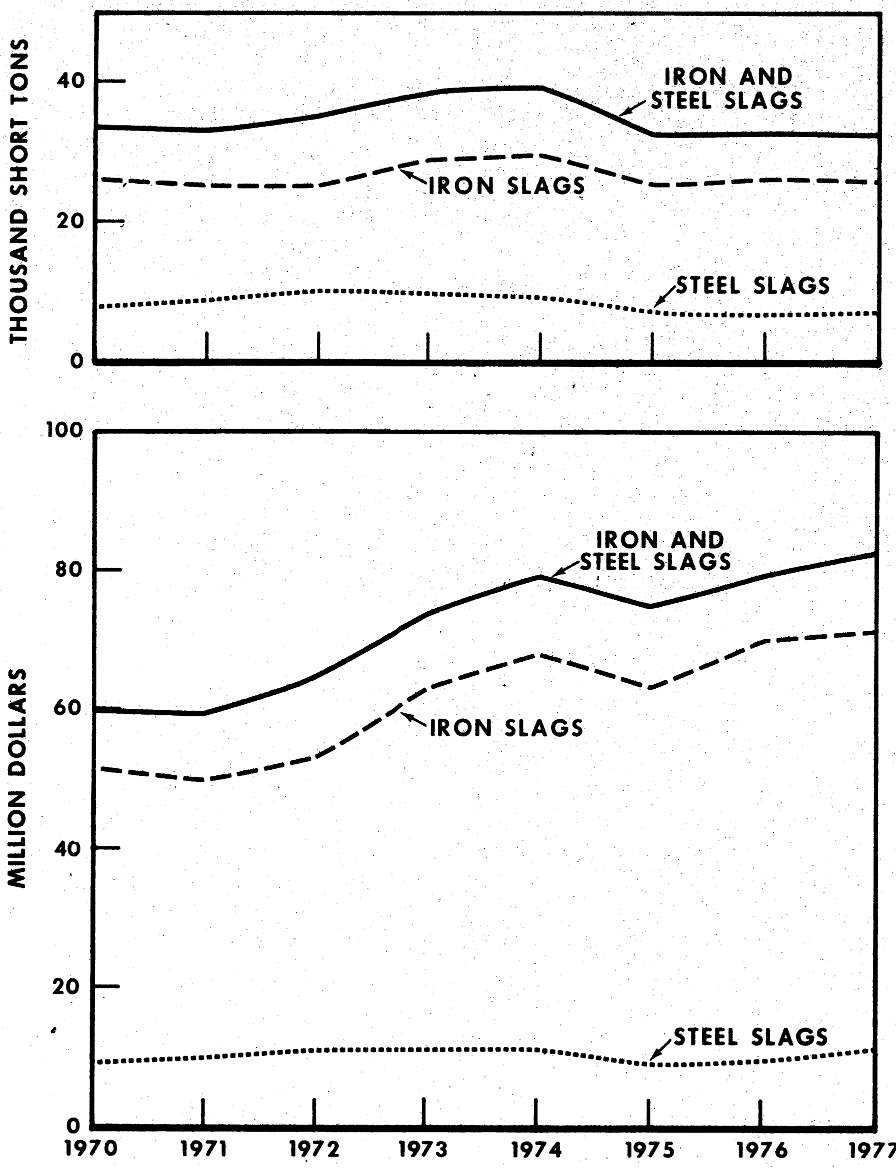


Figure 1.—Quantity and value of iron and steel slags sold or used in the United States.

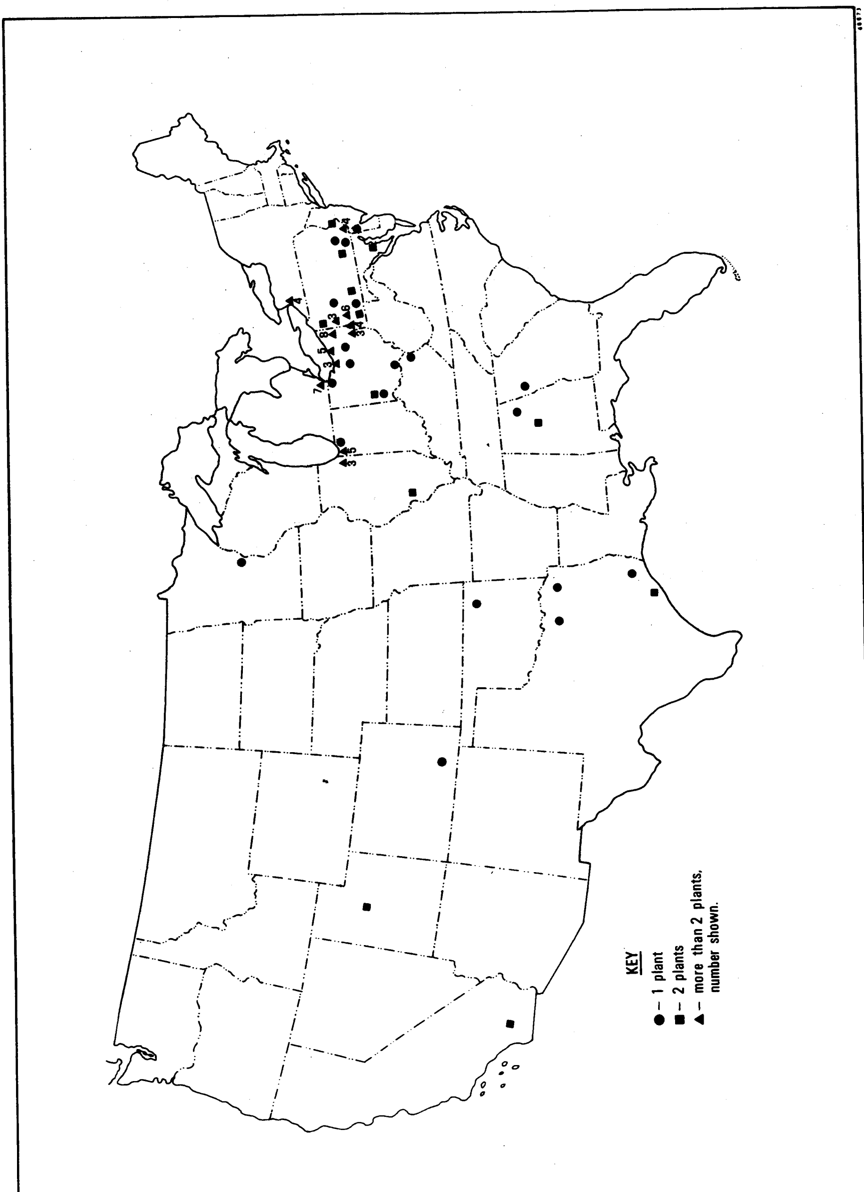


Figure 2.—Location and number of major iron and steel furnace slag plants in the United States.

Table 2.—Value per ton at the plant for iron and steel slags sold or used in the United States, by type

Year	Iron blast-furnace slag				Steel slag	Total slag
	Air-cooled	Granulated	Expanded	Total iron slag		
1970	$1.89	$1.10	$3.35	$1.94	$1.17	$1.77
1971	1.98	1.37	3.09	2.00	1.15	1.78
1972	2.05	1.85	3.64	2.13	1.08	1.83
1973	2.09	1.83	3.75	2.18	1.11	1.91
1974	2.18	2.13	4.11	2.28	1.26	2.05
1975	2.40	2.44	4.56	2.51	1.23	2.23
1976	2.61	2.18	4.43	2.69	1.48	2.44
1977	2.69	2.41	4.35	2.77	1.63	2.54

used in asphaltic concretes and high skid resistance when used in bituminous road surfacing. Consumption of concrete aggregate showed a marked increase in both quantity (32%) and value (31%), as did concrete products for use in bridges, blocks, and pipes; 148% and 159%, respectively. Asphaltic concrete aggregate and railroad ballast were near the 1976 level, but roadbases showed a 32% drop in tonnage used.

Consumption of granulated iron blast-furnace slag was down 8% below that of 1976 to 1.5 million tons (table 7). The major use of granulated slag was in roadbases for highway construction; 72% of the total. The reason for this is that granulated slag has natural hydraulic properties imparting to it the ability, on damp compaction, to slowly set into a hard, dense mass and insure little overall settlement for pavements or other overlays. Uses other than in roadbases were minor but do show that consumption in 1977 was down from that of 1976.

About 97% of expanded iron blast-furnace slag goes into aggregate or is used for concrete products such as blocks, brick, and pipe. This slag is lightweight and shows high fire resistance and low shrinkage properties, which makes it desirable for lightweight concrete products. Consumption for these uses was up 1% from that of 1976. An upward trend should continue as long as this type of slag is available because the rising cost of energy necessary to expand other lightweight aggregates, such as shale, is making the expanded (pelletized) slag more competitive. In 1977, 509,000 tons of expanded slag was marketed as concrete aggregate and 916,000 tons as concrete products. Use in cement manufacture was down to 50,000 tons in 1977 from 85,000 tons in 1976.

Steel slags are used mainly in roadbases and fills. Uses for steel slag are limited because steel slags may exhibit uncontrolled expansion, a result of hydration of free lime and marked variations in chemical composition and physical properties. Aging in the open air for at least 3 months has proven useful in controlling expansion. Uses for roadbases and fills made up 79% of the total uses. Other uses for steel slag were in asphaltic concrete aggregate, railroad ballast, soil conditioning, and fire protection. Total use of steel slags was up 1% from that of 1976.

Table 3.—Iron blast-furnace slags sold or used in the United States, by State[1]

(Thousand short tons and thousand dollars)

Year and State	Air-cooled screened		Total all types	
	Quantity	Value	Quantity	Value
1976				
Ohio	5,052	13,967	5,792	16,526
Pennsylvania	5,083	14,905	6,075	17,862
Illinois, Indiana, Michigan	5,171	13,979	6,157	17,321
Other States[2]	7,006	16,106	7,985	18,243
Total	22,312	58,957	26,009	69,952
	Air-cooled screened and unscreened		Total all types	
	Quantity	Value	Quantity	Value
1977				
Alabama	1,232	3,814	1,232	3,814
California	547	991	547	991
Illinois	1,131	3,128	1,131	3,128
Ohio	5,039	15,210	6,030	17,753
Pennsylvania	4,481	14,784	5,314	17,325
Colorado, Texas, Utah	1,707	3,877	1,707	3,877
Other States[3]	8,616	19,466	9,755	24,374
Total	22,753	61,270	25,716	71,262

[1]Value based on selling price at plant.
[2]Includes Alabama, California, Colorado, Kentucky, Maryland, New York, Texas, Utah, and West Virginia.
[3]Includes Indiana, Kentucky, Maryland, Michigan, New York, and West Virginia.

Source: National Slag Association (1976).

Table 4.—Iron and steel furnace slag plants and sources in the United States[1]

State and City	Company	Iron slag: Air-cooled	Iron slag: Expanded	Iron slag: Granulated	Steel slag	Method of steel slag processing: Open hearth	Method of steel slag processing: Basic oxygen process	Method of steel slag processing: Electric
Alabama:								
Alabama City	Vulcan Materials Co	1	--	--	--	--	--	--
Ensley	do	1	--	--	--	--	--	--
Fairfield	do	1	--	--	--	--	--	--
Total		3	--	--	--	--	--	--
California: Fontana	Heckett Co	1	--	--	1	--	X	--
Colorado: Pueblo	Fountain Sand and Gravel Co	1	--	--	--	--	--	--
Delaware: Claymont	International Mill Service	--	--	--	1	--	--	X
Georgia: Atlanta	do	--	--	--	1	--	--	X
Illinois:								
Chicago	Illinois Slag & Ballast Co	1	--	--	1	--	X	--
Do	Spang and Co.	--	--	--	1	--	X	X
Granite City	International Mill Service	--	--	--	1	--	X	--
Do	St. Louis Slag Products, Co., Inc	1	--	--	--	--	--	--
Peoria	International Mill Service	--	--	--	1	--	--	X
Total		2	--	--	4	--	3	2
Indiana:								
Burns Harbor	The Levy Co	1	--	--	1	--	X	--
Gary	United States Steel Corp	1	1	--	1	--	X	--
Indiana Harbor	Vulcan Materials Co	1	--	--	--	--	--	--
Total		3	1	--	2	--	2	--
Kentucky: Ashland	Standard Slag Co	1	--	--	--	--	--	--
Maryland:								
Baltimore	Maryland Slag Co	1	1	--	--	--	--	--
Easton	do	S	S	--	--	--	--	--
Pocomoke	do	S	S	--	--	--	--	--
Salisbury	do	S	S	--	--	--	--	--
Total		4	4	--	--	--	--	--

See footnotes at end of table.

Table 4.—Iron and steel furnace slag plants and sources in the United States[1] —Continued

State and City	Company	Iron slag: Air-cooled	Iron slag: Expanded	Iron slag: Granulated	Steel slag	Method of steel slag processing: Open hearth	Method of steel slag processing: Basic oxygen process	Method of steel slag processing: Electric
Michigan:								
Detroit	E. C. Levy Co	1	1	1	1	--	X	--
Ecorse	do	--	--	--	1	--	X	--
Trenton	do	1	--	--	1	--	X	--
Total		2	1	1	3	--	3	--
Minnesota: Newport	International Mill Service	--	--	--	1	--	--	X
New York:								
Buffalo	Buffalo Slag Co	2	1	--	--	--	--	--
Do	Heckett Co	--	--	--	1	--	X	--
Total		2	1	--	1	--	1	--
Ohio:								
Canton	Heckett Co	--	--	--	1	--	--	X
Cleveland	Stein, Inc	--	--	--	1	--	X	X
Do	Standard Slag Co	1	--	--	1	--	X	--
Do	do	1	1	--	--	--	--	--
Hamilton	American Materials Corp	1	--	--	--	--	--	--
Lorain	Spang and Co	--	--	--	1	--	X	--
Do	United States Steel Corp	1	--	--	1	--	X	--
Lordstown	Standard Slag Co	1	--	1	1	X	--	--
Mansfield	International Mill Service	--	--	--	1	--	--	X
McDonald	United States Steel Corp	1	--	--	--	--	--	--
Middletown	American Materials Corp	1	--	--	--	--	--	--
Do	McGraw Construction Co	1	--	--	--	--	--	--
Mingo Junction	International Mill Service	--	--	--	1	X	--	--
Do	Standard Slag Co	2	--	--	--	--	--	--
New Boston	do	1	--	--	--	--	--	--
Struthers	do	--	--	1	--	--	--	--
Toledo	France Stone Co	1	--	--	--	--	--	--
Warren	Heckett Co	--	--	--	1	--	--	X
Do	Standard Slag Co	1	--	--	--	--	--	--
Youngstown	do	1	--	--	--	--	--	--
Total		14	1	2	9	2	4	4
Oklahoma: Sand Springs	International Mill Service	--	--	--	1	--	--	X

Pennsylvania:								
Belle Vernon	Duquesne Slag Products Co	1	--	1	--	--	--	--
Bethlehem	Bethlehem Mines Corp	1	--	--	--	--	--	--
Do	Sheridan Slag Co	--	1	--	--	--	--	--
Birdsboro	Birdsboro Slag Products	1	--	--	--	--	--	--
Butler	Spang and Co	--	--	--	1	--	--	X
Coatesville	International Mill Service	--	--	--	1	--	X	--
Dunbar	Vanderbilt Slag Co	--	--	1	--	--	--	--
Duquesne	United States Steel Corp	--	--	1	--	--	--	--
Lebanon	Sheridan Corp	1	--	--	--	--	--	--
Midland	International Mill Service	1	--	--	1	--	--	X
Morrisville	Warner Co	1	--	--	--	--	--	--
Park Hill	Standard Slag Co	1	--	--	1	X	--	--
Penn Hills	United States Steel Corp	--	--	--	1	X	--	--
Phoenixville	International Mill Service	--	--	--	1	X	--	--
Pittsburgh	Duquesne Slag Products Co	1	--	--	--	--	--	--
Rankin	United States Steel Corp	--	--	1	--	--	--	--
Steelton	Hempt Bros	1	--	--	1	X	--	--
Swedeland	Sheridan Slag Corp	--	1	--	--	--	--	--
West Aliquippa	Duquesne Slag Products Co	1	--	--	--	--	--	--
West Mifflin	do	1	--	--	1	--	X	--
Wheatland	Dunbar Slag Co	1	--	--	1	--	X	--
Total		12	2	4	9	4	3	2
Texas:								
Beaumont	International Mill Service	--	--	--	1	--	--	X
Houston	Houston Slag Materials Co	1	--	--	1	--	--	X
Lone Star	Gifford-Hill Co	1	--	--	--	--	--	--
Midlothian	International Mill Service	--	--	--	1	--	--	X
Total		2	--	--	3	--	--	3
Utah: Provo	United States Steel Corp	1	--	--	1	X	--	--
Virginia: Virginia Beach	Maryland Slag Co	S	S	--	--	--	--	--
West Virginia:								
Weirton	International Mill Service	--	--	--	1	--	X	--
Do	Standard Slag Co	3	--	--	--	--	--	--
Total		3	--	--	1	--	1	--
Grand total		52	11	7	38	7	18	14

[1]X-represents method of steel processing; S-represents sources.

Table 5.—Shipments of iron and steel slag in the United States in 1977, by method of transportation

Method of transportation	Quantity (thousand short tons)	Percent of total
Rail	4,105	13
Truck	26,047	80
Waterway	1,329	4
Used at plant site	903	3
Total	32,384	100

Table 6.—Air-cooled iron blast-furnace slag sold or used in the United States, by use[1]

(Thousand short tons and thousand dollars)

Use	1976		1977	
	Quantity	Value	Quantity	Value
Concrete aggregate	1,928	5,733	2,553	7,535
Concrete products	298	921	738	2,383
Cement manufacture	NA	NA	146	351
Asphaltic concrete aggregate	4,060	11,388	4,024	12,798
Roadbases	10,684	28,142	7,289	19,157
Fill	NA	NA	3,097	6,894
Railroad ballast	3,790	7,715	3,400	7,191
Mineral wool	758	2,236	525	1,457
Roofing, built-up and shingles	221	798	255	816
Sewage treatment	12	66	46	88
Soil conditioning	61	203	2	5
Glass manufacture	NA	NA	217	1,399
Ice control	NA	NA	27	76
Other uses	1,087	2,611	433	1,119
Total[2]	22,899	59,813	22,753	61,270

NA Not available.
[1]Value based on selling price at plant.
[2]Data may not add to totals shown because of independent rounding.

Source: National Slag Association (1976).

Table 7.—Granulated and expanded iron blast-furnace slags sold or used in the United States, by use[1]

(Thousand short tons and thousand dollars)

Use	1976				1977			
	Granulated		Expanded		Granulated		Expanded	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Lightweight concrete aggregate	--	--	9	47	--	--	509	2,265
Concrete products	125	454	1,398	6,382	119	447	916	4,047
Cement manufacture	87	334	--	--	60	211	50	101
Roadbases	1,199	2,332	--	--	1,064	2,264	--	--
Fill	NA	NA	--	--	151	404	--	--
Soil conditioning	59	168	--	--	45	115	--	--
Ice control	NA	NA	--	--	8	31	--	--
Other uses	148	241	85	181	40	107	--	--
Total[2]	1,618	3,529	1,492	6,610	1,488	3,579	1,475	6,414

NA Not available.
[1]Value based on selling price at plant.
[2]Data may not add to totals shown because of independent rounding.

Source: National Slag Association (1976).

Table 8.—Steel slag sold or used in the United States, by use[1] [2]

(Thousand short tons and thousand dollars)

Use	1976		1977	
	Quantity	Value	Quantity	Value
Asphaltic concrete aggregate	353	510	396	776
Roadbases	4,089	6,121	2,929	5,207
Fill	1,412	2,081	2,330	3,072
Railroad ballast	465	640	354	569
Soil conditioning	--	--	44	114
Fire protection	--	--	35	76
Other uses	269	376	580	1,036
Total	6,588	9,728	6,668	10,850

[1]Excludes tonnage returned to furnace for charge material.
[2]Value based on selling price at plant.

Source: National Slag Association (1976).

PRICES

The data in table 9 for average selling prices were derived from weighted averages from the range of reported prices. Ranges of prices reflect the highest and lowest reported selling prices of material that went into the use categories. Extreme higher prices in the use categories indicate that some users required demanding specification, which required more than normal processing. In some geographic areas overall construction as well as other costs are higher, resulting in higher prices for processed materials.

Table 9.—Average selling price and range of selling prices at the plant for iron and steel slags in the United States, by use, 1977

(Per short ton)

Use	Iron blast-furnace slag						Steel slag	
	Air-cooled		Granulated		Expanded			
	Average	Range	Average	Range	Average	Range	Average	Range
Concrete aggregate	$2.95	$1.05-$5.00	--	--	--	--	--	--
Lightweight concrete aggregate	--	--	--	--	$4.45	$1.40-$4.49	--	--
Concrete products	3.23	.80-4.00	$3.77	$3.74-$3.77	4.42	2.73-6.25	--	--
Cement manufacture	2.40	.46-3.31	3.50	2.64-5.00	2.02	--	--	--
Asphaltic concrete aggregate	3.18	1.55-7.50	--	--	--	--	$1.96	$1.00-$2.87
Road bases	2.63	.96-4.44	2.13	1.60-3.45	--	--	1.78	.54-4.00
Fill	2.23	1.00-3.45	2.67	1.45-3.02	--	--	1.32	.50-2.50
Railroad ballast	2.12	1.05-4.00	--	--	--	--	1.61	.70-2.26
Mineral wool	2.78	1.05-5.00	--	--	--	--	--	--
Roofing, built-up and shingles	3.20	1.81-5.00	--	--	--	--	--	--
Sewage treatment	1.91	1.81-3.31	--	--	--	--	--	--
Soil conditioning	2.65	--	2.54	2.53-2.65	--	--	2.60	--
Glass manufacture	6.44	2.65-10.96	--	--	--	--	--	--
Fire protection	--	--	--	--	--	--	2.19	2.10-2.30
Ice control	2.80	--	3.75	--	--	--	--	--
Other uses	2.59	1.00-3.50	2.68	2.65-2.75	--	--	1.78	1.53-2.80

FOREIGN TRADE

There were no known imports or exports of iron or steel slags in 1977.

WORLD REVIEW

Data on production of slag in other countries were not available for 1977, nor were data on resources (the amount available as newly made slag plus old stockpiles). However, resources and usage are known to be significant in countries such as Japan, the Federal Republic of Germany, France, and the United Kingdom where there are large iron and steel industries.

[1]Physical scientist, (formerly with Division of Nonmetallic Minerals, now with U. S. Geological Survey).

Sodium and Sodium Compounds

By Russell J. Foster[1]

Strong demand for flat and fibrous glass, plus increased exports, prompted record domestic production of soda ash in 1977. Production of natural ash increased 19%, which more than offset a 23% decline in the manufacture of synthetic material. Soda ash exports amounted to 9% of production. Additional natural soda ash capacity came onstream in Wyoming, and a California producer was expanding both natural soda ash and sodium sulfate capacities. Total production of sodium sulfate was down slightly, as domestic consumption declined because of curtailed use in kraft pulping. Net imports of sodium sulfate were 13% of apparent consumption. The quantity of metallic sodium produced increased 9% compared with that of 1976.

DOMESTIC PRODUCTION

Total U.S. production of soda ash increased 6% in 1977 to a new high of 8,040,000 tons. Production of natural soda ash derived from trona or brine was up 19%, but the synthetic product declined 23%. Natural ash claimed a 77% share of total production. Table 2 illustrates the trend away from synthetic, and toward natural soda ash.

PPG Industries, Inc., announced the closing of its Solvay plant at Corpus Christi, Tex., effective March 31, 1978, citing increased costs of energy, raw materials, maintenance of equipment, and compliance with antipollution regulations.[2] Only two other synthetic soda ash plants continued to operate in the United States—Allied Chemical Corp. at Syracuse, N.Y., and BASF-Wyandotte Corp., at Wyandotte, Mich. Stauffer Chemical Co. brought an additional 200,000 tons per year of natural soda ash capacity onstream at Green River,

Table 1.—Manufactured and natural sodium carbonates produced in the United States

(Thousand short tons and thousand dollars)

Year	Manufactured soda ash (ammonia-soda process)[1] [2]	Natural sodium carbonates[3]		Total quantity
	Quantity	Quantity	Value	
1973	3,813	3,722	94,385	7,535
1974	3,507	4,059	137,486	7,566
1975	2,802	4,328	182,620	7,130
1976	2,344	5,216	259,253	7,560
1977	1,812	6,228	337,516	8,040

[1]Current Industrial Reports, Inorganic Chemicals, U.S. Bureau of the Census.
[2]Includes quantities used to manufacture caustic soda, sodium bicarbonate, and finished light and dense soda ash.
[3]Soda ash and trona (sesquicarbonate).

Table 2.—Source of U.S. soda ash by process, 1968-77

(Thousand short tons)

Year	Solvay		Natural	
	Production	Percent of total	Production	Percent of total
1968	4,596	69.2	2,043	30.8
1969	4,540	64.5	2,495	35.5
1970	4,393	62.1	2,678	37.9
1971	4,298	60.0	2,865	40.0
1972	4,305	57.2	3,218	42.8
1973	3,813	50.6	3,722	49.4
1974	3,507	46.4	4,059	53.6
1975	2,802	39.3	4,328	60.7
1976	2,344	31.0	5,216	69.0
1977	1,812	22.5	6,228	77.5

Table 3.—Manufactured and natural sodium sulfate produced in the United States[1]

(Thousand short tons and thousand dollars)

Year	Manufactured and natural[2]			Natural only	
	Lower purity[3] (99% or less)	High purity	Total	Quantity	Value
1973	530	908	1,438	672	11,597
1974	565	783	1,348	684	16,411
1975	431	796	1,227	667	27,667
1976	466	766	1,232	663	32,655
1977	458	741	1,199	636	29,313

[1]All quantities converted to 100% Na_2SO_4 basis.
[2]Current Industrial Reports, Inorganic Chemicals, U.S. Bureau of the Census.
[3]Includes Glauber's salt.

Wyo.[3] Construction proceeded on Kerr-McGee Chemical Corp.'s new 1.3-million-ton-per-year natural soda ash plant, which will replace the existing facilities at Trona, Calif. The company will continue production at its Westend, Calif., plant.[4]

The total quantity of sodium sulfate produced in the United States in 1977 was 1,199,000 tons, a decrease of 3%. Production of byproduct material declined 1%, and output of natural sodium sulfate declined 4%. About 53% of the total was the natural compound. Kerr-McGee Chemical Corp. was in the process of expanding natural sodium sulfate capacity by 150,000 tons per year at Trona, Calif.[5]

Table 4.—Production and price of metallic sodium in the United States, 1968-77

Year	Production (short tons)	Price (cents per pound)
1968	156,391	15.47
1969	164,685	15.84
1970	171,251	15.94
1971	153,075	16.26
1972	160,504	16.98
1973	176,903	17.43
1974	173,174	17.89
1975	144,133	20.70
1976	145,863	[e]24.60
1977	158,752	28.82

[e]Estimate.

Metallic sodium production increased 9% to 158,752 tons. Table 4 shows production and price trends for metallic sodium during the past 10 years. A list of U.S. producers of natural sodium compounds and metallic sodium follows:

Product and company	Plant location	Source of sodium
Soda ash:		
Kerr-McGee Chemical Corp	Trona, Calif	Dry lake brine.
Do	Westend, Calif	Do.
Allied Chemical Corp	Green River, Wyo	Underground trona.
FMC Corp	do	Do.
Stauffer Chemical Co	do	Do.
Texasgulf, Inc	Granger, Wyo	Do.
Sodium sulfate:		
Kerr-McGee Chemical Corp	Trona, Calif	Dry lake brine.
Do	Westend, Calif	Do.
Ozark-Mahoning Co	Brownfield, Tex	Subterranean brine.
Do	Seagraves, Tex	Do.
Great Salt Lake Minerals & Chemicals Corp.	Ogden, Utah	Salt lake brine.
Metallic sodium:		
E. I. du Pont de Nemours & Co	Niagara Falls, N. Y	Salt.
Do	Memphis, Tenn	Do.
Ethyl Corp	Baton Rouge, La	Do.
Do	Houston, Tex	Do.
R. M. I., Inc	Ashtabula, Ohio	Do.

CONSUMPTION AND USES

Estimated distribution of soda ash and sodium sulfate is listed below:[6]

Industry	Percent of demand	
	Soda ash	Sodium sulfate
Pulp and paper	7	65
Glass	47	([1])
Detergents	6	25
Chemicals	25	--
Water treatment	3	--
Other and exports	12	10

[1]Included with other.

Domestic consumption of soda ash increased in 1977 mainly because of growth in the flat- and fibrous-glass sectors of the glass industry. Use of soda ash in the production of other chemicals was nearly the same as in 1976.

Demand for sodium sulfate, however, was down. Although detergents have been reformulated to contain more sodium sulfate because of the reduced phosphate content required by antipollution regulations, tightening of operations by paper manufacturers has cut back the consumption of sodium sulfate in kraft pulping. In addition, production of pulp, paper, and board products rose less than 1% in 1977.

Despite a slight decrease in demand for gasoline antiknock additives, production of metallic sodium was up 9%.

STOCKS

Yearend stocks of natural sodium compounds, as reported by producers, were as follows:

	Thousand short tons	
	1976	1977
Natural soda ash	102	101
Natural sodium sulfate	56	93

PRICES

The prices of natural soda ash and natural sodium sulfate, f.o.b. mine or plant, as reported by producers, were as follows:

	Value, dollars per short ton		Change, percent
	1976	1977	
Bulk soda ash	49.70	54.19	+9
Bulk sodium sulfate	49.25	46.09	-6

Quoted prices of sodium compounds and metallic sodium at yearend 1977 follow:

		Price
Sodium carbonate (soda ash):		
Light, paper bags, carlots, works	per ton	$57.00-$71.00
Light, bulk, carlots, works	do	57.00-64.00
Dense, paper bags, carlots, works	do	57.00-71.00
Dense, bulk, carlots, works	do	55.00
Sodium sulfate (100% Na_2SO_4):		
Technical detergent, rayon-grade, bags, carlots	do	70.00-72.00
Technical detergent, rayon-grade, bulk, works	do	55.00
Domestic salt cake, bulk, works[1]	do	60.00
National Formulary (N.F. XII), drums	per pound	.235
Metallic sodium:		
Bricks, carlots, works	do	.60
Fused, lots 18,000 pounds and more, works	do	.54
Bulk, tank, works	do	.37

[1]East of Mississippi River.

Source: Chemical Marketing Reporter. Current Prices of Chemicals and Related Materials. V. 213, No. 26, Dec. 26, 1977, p. 34.

All producers of natural and synthetic soda ash had raised list prices 5% to 8% by mid-April 1977. However, Texasgulf, Inc., stated that its new price of $55 per ton for bulk ash would remain effective through yearend 1978.[7] In December, FMC Corp. announced price increases of 7% to 9% for bagged soda ash and sodium sesquicarbonate in bulk and in bags effective at the beginning of 1978.[8]

FOREIGN TRADE

In 1977, exports of sodium carbonate from the United States increased 18% to 759,000 tons. The quantity was 9% of total production. Nearly 44% of exported soda ash was shipped to other countries in North America; 27% to South America; 20% to Asia and Oceania; and 9% to Africa. Sodium carbonate imports were negligible.

Imported sodium sulfate declined 29% to 223,000 tons. More than 54% of the imports entered from Canada and 35% came from Belgium. Sodium sulfate exports were down 25% to 43,000 tons. The primary destination for exported sodium sulfate was Oceania (60%). Net imports of sodium sulfate represented 13% of apparent consumption.

Table 5.—U.S. exports of sodium carbonate and sodium sulfate

(Thousand short tons and thousand dollars)

Year	Sodium carbonate		Sodium sulfate	
	Quantity	Value	Quantity	Value
1975	529	45,822	77	6,144
1976	645	r47,004	57	3,636
1977	759	52,943	43	2,801

rRevised.

Table 6.—U.S. imports for consumption of sodium sulfate

(Thousand short tons and thousand dollars)

Year	Crude (salt cake)[1]		Anhydrous		Total[1]	
	Quantity	Value	Quantity	Value	Quantity	Value
1975	203	8,305	82	4,319	285	12,624
1976	214	10,360	102	5,751	316	16,111
1977	121	5,702	102	5,528	223	11,230

[1]No Glauber's salt was imported in the years 1975 through 1977.

Table 7.—U.S. imports for consumption of sodium carbonate and bicarbonate in 1977

(Thousand short tons and thousand dollars)

	Quantity	Value
Soda ash	1	145
Sodium bicarbonate	4	449
Total	5	594

WORLD REVIEW

Tables 8 and 9 list world production, by country, of sodium carbonate and sodium sulfate. Natural sources contributed 23% of the world's soda ash supply, and the United States produced 98% of that amount. The top five soda ash producing nations in the world were the United States, the U.S.S.R., the United Kingdom, France, and the Federal Republic of Germany.

Natural sodium sulfate provided 42% of the world's production. The United States and Canada together produced 54% of the natural material. The five top-ranking nations in the production of sodium sulfate were the United States, the U.S.S.R., Canada, Japan, and Spain.

Algeria.—A consortium of Italian companies headed by Italconsult formed a joint venture with Industrial Export of Romania for the construction of a 165,000-ton-per-year soda ash plant in Algeria.[9]

Argentina.—Alcalis de la Patagonia received government approval to construct a 220,000-ton-per-year soda ash plant at San Antonio Oeste, Río Negro Province. The facility is due onstream in 1979, and will eliminate the country's need for sodium carbonate imports. Limestone will be obtained from quarries at Bustamante Bay, and salt from a nearby salt field.[10]

Belgium.—Industry voiced its opposition to a 9% rise in soda ash prices requested by Solvay et Cie. Although prices of Belgian soda ash have been among the highest in Europe, the company stated that raw material and labor costs in Belgium have necessitated the increase.[11]

Brazil.—The capacity of Companhia Nacional de Alcali's soda ash plant at Cabo Frio will be enlarged to 742 tons per day. The expansion of the facility, built in 1953, can be accomplished without interrupting operation.[12]

Pakistan.—A contract was awarded for the modernization and expansion of Sind Alkalis' soda ash unit at Karachi. The increase in capacity to 55,000 tons per year was scheduled for completion by 1979.[13]

Thailand.—Aided by a technical assistance grant from the Asian Development Bank, the Government of Thailand has undertaken a feasibility study of a rock salt and soda ash project proposed by the Association of Southeast Asian Nations. Large quantities of high-purity rock salt exist in the northeastern part of the country, and the soda ash plant could insure the region's glass manufacturers a constant supply of raw materials at predictable prices.[14]

United Kingdom.—At yearend, the United Kingdom Price Commission notified Imperial Chemical Industries, Ltd., of its intention to investigate proposed soda ash price increases because of possible repercussions on other products, especially glass. In 1976, the company authorized expenditures for the modernization of its Cheshire plant, which should increase capacity by 88,000 tons per year.[15]

Table 8.—Sodium carbonate: World production by country

(Thousand short tons)

Country[1]	1975	1976	1977[p]
Natural:			
Chad	6	[e]6	[e]12
Kenya	101	127	[e]132
United States	4,328	5,216	6,228
Total	4,435	5,349	6,372
Manufactured:			
Albania[e]	23	23	25
Australia[e]	165	170	175
Austria[e]	175	185	185
Belgium	386	[e]430	[e]450
Brazil[e]	140	150	160
Bulgaria	1,090	1,130	[e]1,200
Chile[e]	9	10	11
Colombia[e]	45	55	55
Czechoslovakia	133	131	[e]140
Denmark[2]	1	1	[e]1
France	1,409	1,451	1,505
German Democratic Republic	902	914	[e]925
Germany, Federal Republic of	1,377	1,503	[e]1,500
Greece[e]	1	1	1
India	594	622	[e]655
Italy[e]	[r]713	[r]741	783
Japan	1,239	1,197	[e]1,240
Korea, Republic of	[r]107	140	188
Mexico	450	430	[e]460
Netherlands	244	299	[e]287
Norway	21	[e]23	[e]25
Pakistan	87	70	[e]80
Poland	[r]789	800	[e]805
Portugal	127	126	[e]143
Romania	764	897	[e]920
Spain	[r]523	[e]570	[e]330
Sweden[e]	1	1	1
Switzerland[e]	40	45	45
Taiwan	74	82	[e]85
Turkey[e]	55	60	65
U.S.S.R	5,172	5,337	[e]5,590
United Kingdom[e]	1,500	1,540	1,650
United States	2,802	2,344	1,812
Yugoslavia	162	151	173
Total	[r]21,320	21,629	21,670

[e]Estimate. [p]Preliminary. [r]Revised.

[1]In addition to the countries listed, a number of nations are either known or believed to have produced sodium carbonate, but production is unreported, and available general information is inadequate for the formulation of reliable estimates of output levels. Notable among the producing countries not listed are Canada and the People's Republic of China.

[2]Production for sale only; excludes output consumed by producers.

Table 9.—Sodium sulfate: World production by country

(Thousand short tons)

Country[1]	1975	1976	1977[p]
Natural:			
Argentina	43	39	[e]39
Canada	521	507	459
Chile[2]	13	14	[e]15
Iran	28	28	28
Mexico	331	251	[e]240
Spain	152	[e]154	[e]154
Turkey	89	97	[e]100
U.S.S.R.[e 3]	330	340	350
United States	667	663	636
Total	2,174	2,093	2,021
Manufactured:			
Austria[e]	50	55	60
Belgium[e]	330	340	280
Chile[4]	25	31	[e]35
Finland[e]	80	70	70
France	162	143	131
German Democratic Republic	[r]184	164	[e]165
Germany, Federal Republic of	283	283	[e]285
Greece[e]	7	7	8
Hungary[e]	11	11	11
Italy[e]	110	117	120
Japan	324	345	360
Netherlands[e]	50	55	55
Portugal	57	54	[e]53
Spain[5]	154	[e]183	[e]194
Sweden	107	113	115
U.S.S.R.[e 3]	230	240	250
United States[6]	560	569	563
Total	[r]2,724	2,780	2,755

[e]Estimate. [p]Preliminary. [r]Revised.
[1]In addition to the countries listed, the People's Republic of China, Norway, Poland, Romania, Switzerland, and the United Kingdom are assumed to have produced manufactured sodium sulfate, and other unlisted countries may have produced this commodity, but production figures are not reported and available general information is inadequate for the formulation of reliable estimates of output levels.
[2]Natural mine output, excluding byproduct output from the nitrate industry, which is reported separately under manufactured.
[3]Conjectural estimates based on 1968 information on natural sodium sulfate and general economic conditions.
[4]Byproduct of nitrate industry.
[5]Quantities of manufactured sodium sulfate credited to Spain are reported in official sources in such a way as to indicate that they are in addition to the quantities reported as mined (reported in this table under natural), but some duplication may exist.
[6]Derived figure; data presented are the difference between reported total sodium sulfate production (natural and manufactured, undifferentiated) and reported natural sodium sulfate production (reported under natural in this table).

TECHNOLOGY

UOP, Inc., was awarded contracts by Pacific Power & Light Co. and Idaho Power Co. for the design, engineering, and construction of a flue-gas desulfurization system utilizing wet-sodium process technology. The system will be installed on a new unit of the coal-fired Jim Bridger electric power generating station near Rock Springs, Wyo. Byproduct sodium carbonate solution from FMC Corp.'s soda ash plant will be used as the reagent to remove sulfur dioxide. The 500-megawatt addition to the powerplant has been scheduled for completion in 1979.[16]

The Atomics International Division of Rockwell International has developed a system using a combination melt of 90% sodium carbonate and 10% sodium sulfate for the clean destruction of pesticides and other hazardous materials. Gases formed during the combustion of the wastes are combined with air and continuously introduced beneath the surface of the melt. At the normal operating temperature of 800° to 1,000° C, carbon dioxide, steam, and sodium salts are formed. After the off-gas has been cleaned of particulates, it can be vented to the atmosphere without further treatment.[17]

In laboratory-scale experiments partly sponsored by the U.S. Department of Energy, General Electric Co. scientists have used

Glauber's salt as a heat sink in a solar energy heating system. When placed in a slowly revolving drum, this form of sodium sulfate becomes noncrystalline as it absorbs energy, and recrystallizes when the energy is released. The compound is a better retainer of heat than the same volume of water or rocks.[18]

Research at Ford Motor Co. conducted under a National Science Foundation grant, led to the development of practical prototype sodium-sulfur battery cells with reasonable power. Molten sodium and sulfur serve as the electrodes and a beta-aluminum tube is the electrolyte. Economic mass production of the tubes and cell reproducibility are key problems.[19]

---

[1]Physical scientist, Division of Nonmetallic Minerals.

[2]Chemical Marketing Reporter. PPG Closing Solvay Process in Texas. V. 212, No. 19, Nov. 7, 1977, p. 3.

[3]Chemical Week. In Alkali Battle, Five Bet on the Underdog. V. 119, No. 18, Nov. 3, 1976, pp. 14-15.

[4]———. Plant Plumbs Dry Lake's Chemicals. V. 121, No. 11, Sept. 14, 1977, p. 47.

Engineering and Mining Journal. Kerr-McGee Expands Soda Ash Output Nine-Fold from Searles Lake Brines. V. 178, No. 10, October 1977, pp. 71-75.

[5]Chemical Week. The Pieces of Cake Are Changing in Size. V. 120, No. 9, Mar. 2, 1977, pp. 37-38.

[6]Chemical Marketing Reporter. Soda Ash. V. 208, No. 8, Aug. 25, 1975, p. 9.

———. Sodium Sulfate. V. 213, No. 5, Jan. 30, 1978, p. 9.

[7]———. More Natural Ash Lists Rise; FMC Sets '77 Contract Prices. V. 211, No. 9, Feb. 28, 1977, p. 16.

———. Texasgulf Guarantees Soda Ash Price in Move to Attract Larger Market Share. V. 212, No. 7, Aug. 15, 1977, pp. 5, 32.

[8]Chemical Week. Prices of Soda Ash and Other Inorganics Up. V. 121, No. 24, Dec. 14, 1977, p. 38.

[9]Industrial Minerals. Company News & Mineral Notes. No. 119, August 1977, p. 57.

[10]Chemical Marketing Reporter. Argentina Eyes Carbonate Unit. V. 212, No. 9, Aug. 29, 1977, p. 7.

[11]European Chemical News. Solvay Faces Stiff Opposition to Soda Ash Price Rise. V. 31, No. 793, July 1, 1977, p. 14.

[12]———. Krebs Soda Ash Order. V. 31, No. 809, Oct. 28, 1977, p. 45.

[13]Industrial Minerals. Company News & Mineral Notes. No. 115, April 1977, p. 51.

[14]———. ADB Finance for Soda Ash Project. No. 115, April 1977, p. 14.

[15]European Chemical News. ICI Soda Ash Price Rises Under Price Commission Investigation. V. 31, No. 816, Dec. 16-23, 1977, p. 12.

[16]Chemical Marketing Reporter. UOP is Awarded Millions in Contracts for Sulfur Dioxide Removal Equipment. V. 211, No. 9, Feb. 28, 1977, pp. 5, 12.

[17]Chemical & Engineering News. Molten Salt Decomposes Pesticide Wastes. V. 55, No. 37, Sept. 12, 1977, p. 44.

[18]Wall Street Journal. GE Invents Method for Storing Energy of Sun with a Salt. V. 190, No. 121, Dec. 21, 1977, p. 11.

[19]Chemical Week. Progress in Sodium-Sulfur Battery Research. V. 121, No. 1, July 6, 1977, p. 31.

Stone

By Avery H. Reed[1]

Quantity of all stone produced in 1977 increased 6% over the 1976 total. Output of dimension stone was 1.42 million tons valued at $103.9 million, a quantity slightly above 1976 production but 26% below that of 1974. Output of crushed stone was 954 million tons valued at $2.35 billion, 6% in quantity above 1976 but 10% below the 1973 record. Value of total stone produced rose to a record high, increasing $235.9 million, or 11%.

Stone was produced in every State except Delaware and North Dakota. Leading States were Texas, Pennsylvania, and Illinois. There were over 2,100 companies, operating about 5,500 quarries. Average output per company was 455,000 tons. Average output per quarry was 174,000 tons. More than half the stone was produced at quarries producing more than 500,000 tons each. Most of the stone was hauled by truck.

Leading stone producers were Vulcan Materials Co., 86 quarries; Martin Marietta Corp., 111 quarries; Lone Star Industries Inc., 26 quarries; United States Steel Corp., 12 quarries; Koppers Co., Inc., 47 quarries; Medusa Corp., 59 quarries; Ashland Oil Inc., 37 quarries; General Dynamics Corp., 8 quarries; U.S. Forest Service, 535 quarries; and The Flintkote Co., 18 quarries. These 10 producers operated 939 quarries and produced 26% of the total stone output.

Classification.—The Bureau of Mines classifies stone into two categories (crushed and dimension) and into nine kinds (granite, limestone, marble, marl, sandstone, shell, slate, traprock, and miscellaneous). The category classifications are not exact; some crushed stone may be in large pieces, such as riprap, and some dimension stone may be in small pieces, such as art objects or carvings. The dimension stone industry is concerned with cutting or shaping stone to a certain size, and waste or scrap from processing dimension stone may be a part of the crushed stone industry.

Classification by kind is also difficult. Granite may include metamorphic gneisses or syenites. Limestone may be pure calcium carbonate, or may be bituminous, dolomitic, or siliceous. Marble may include any calcareous rock that will polish. Marl may range from low to high in shale or clay content. Sandstone may be calcareous, quartz or quartzite, silt, or conglomerate. Miscellaneous stone includes aa, lava, schist, and any other stone not included in the aforementioned categories.

The Bureau of Mines generally accepts the classification reported by producers.

Table 1.—Salient stone statistics in the United States

(Thousand short tons and thousand dollars)

	1973	1974	1975	1976	1977
Sold or used by producers:					
Dimension stone	1,582	1,915	1,403	1,400	1,416
Value	$85,999	$100,318	$98,586	$104,400	$103,920
Crushed stone	1,058,541	1,041,600	899,990	900,260	953,960
Value	$1,904,464	$2,085,800	$2,021,700	$2,116,600	$2,353,000
Total stone[1]	1,060,124	1,043,515	901,390	901,660	955,370
Total value[1]	$1,990,463	$2,186,118	$2,120,300	$2,221,000	$2,456,920
Exports (value)	$13,063	$18,159	$22,125	$23,965	$22,620
Imports for consumption (value)	$48,678	$51,631	$46,137	$46,211	$48,580

[1]Data may not add to totals shown because of independent rounding.

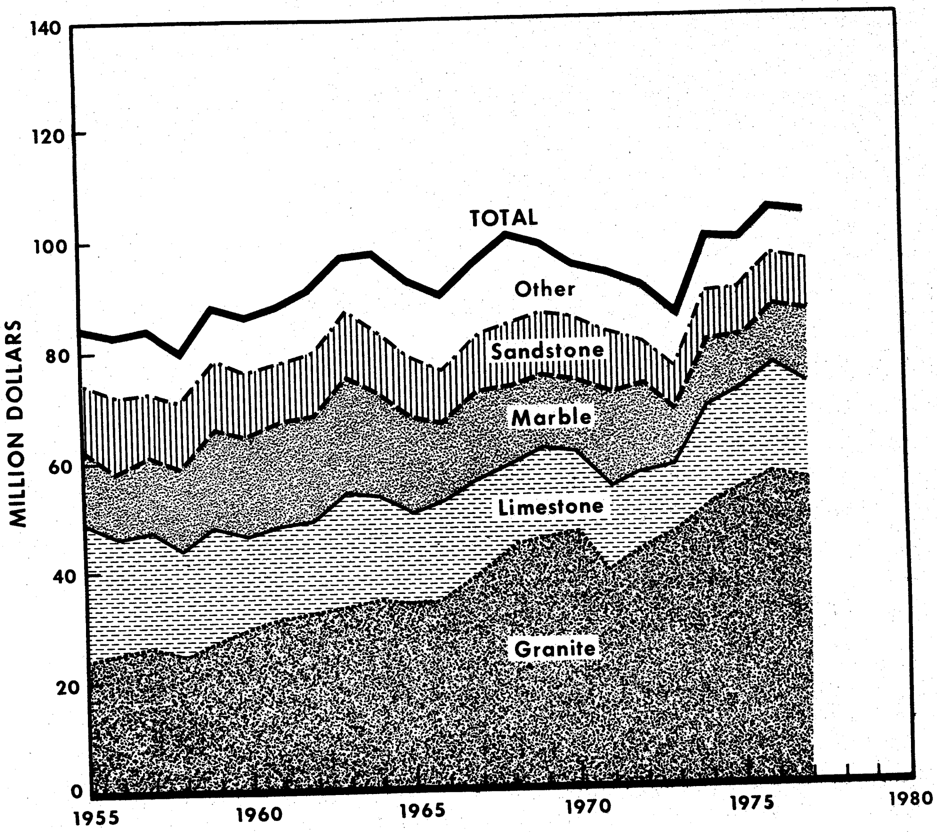


Figure 1.—Value of dimension stone sold or used by producers in the United States, by kind.

Deposits of unconsolidated materials, including beach sands, are generally classified as sand and gravel, regardless of chemical content. However, many deposits of stone are relatively soft and may be mined without blasting. Natural sand deposits are classified as sand and gravel, but manufactured sand (stone sand) is classified as stone.

The Bureau of Mines canvass of dimension stone does not include processors of purchased rough stone. All producers are covered; if the producer sells rough stone to a processor, it is tabulated as rough stone; if the producer processes finished stone, only the finished stone is tabulated, and the rough stone is deducted.

Capacity figures and stocks are not available. Inventories on hand at quarries and plants are estimated at about 1 month's supply, or 100 million tons.

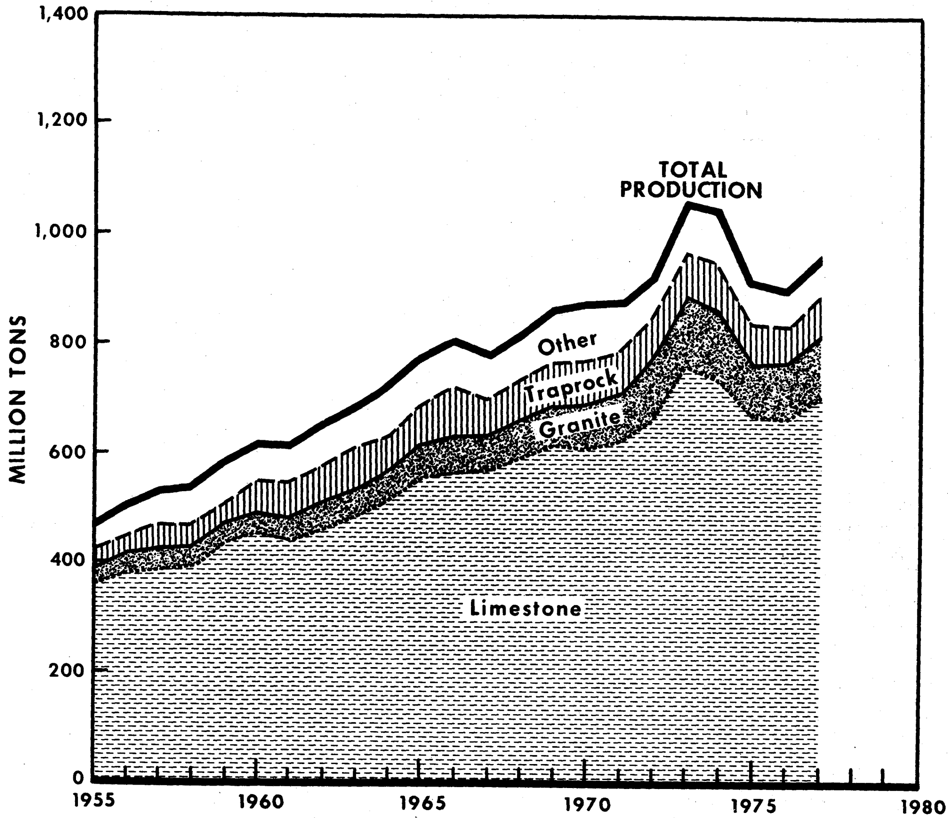


Figure 2.—Crushed stone sold or used by producers in the United States, by kind.

DOMESTIC PRODUCTION

Dimension Stone.—Dimension stone was produced by 292 companies at 430 quarries in 42 States. Leading States were Indiana, Georgia, Ohio, Vermont, and Wisconsin; these five States accounted for 58% of the total output. Of the total production, 39% was granite, 31% was limestone, 17% was sandstone, 7% was marble, 4% was slate, and the remainder was miscellaneous stone. Leading companies were Coggins Granite Industries, Inc., Rock of Ages Corp., and Oolitic Limestone Co. Average output per company was 4,850 tons valued at $356,000. Total output of dimension stone increased 1% to 1.42 million tons valued at $103.9 million, 26% less than in 1974.

Crushed Stone.—Crushed stone was produced by 1,894 companies at 5,177 quarries, in every State except Delaware and North Dakota. Leading States were Texas, Pennsylvania, Illinois, Missouri, and Florida; these five States accounted for 30% of the total output. Of the total production, 74% was limestone, 11% was granite, 8% was traprock, 3% was sandstone, and the remainder, other types of stone. Average output per company was 504,000 tons valued at $1.2 million. Total output increased 6% to 954 million tons valued at $2.3 billion, but was 10% below the record high of 1973. Leading producers were Vulcan Materials Co., Martin Marietta Corp., Lone Star Industries, and United States Steel Corp.

Table 2.—Dimension stone sold or used by producers in the United States, by State

State	1976			1977		
	Short tons	Cubic feet (thousands)	Value (thousands)	Short tons	Cubic feet (thousands)	Value (thousands)
Alabama	17,267	221	$2,234	13,992	171	$1,715
Alaska	--	--	--	85	1	1
Arkansas	5,423	68	95	7,574	103	128
Arizona	W	W	W	13,354	167	368
California	12,626	151	804	25,654	307	996
Colorado	5,904	75	198	4,896	62	181
Connecticut	9,143	109	215	9,101	108	240
Georgia	224,680	2,372	13,411	240,460	2,511	13,637
Hawaii	W	W	W	592	7	4
Illinois	4,108	48	103	2,545	30	109
Indiana	263,240	3,594	12,787	244,270	3,317	11,804
Maine	264	3	13	--	--	--
Maryland	25,560	324	669	29,510	369	909
Massachusetts	81,865	984	5,352	62,619	753	4,856
Michigan	7,559	93	129	8,015	100	147
Minnesota	36,997	441	9,819	33,376	395	8,133
Missouri	4,084	50	915	2,892	36	597
Montana	4,374	52	152	2,994	35	114
New Hampshire	62,600	710	5,273	72,996	850	4,650
New Mexico	13,699	175	105	17,500	240	106
New York	27,492	291	2,211	25,053	295	2,272
North Carolina	37,606	432	3,830	40,425	498	3,041
Ohio	87,286	1,182	2,936	147,490	1,915	3,557
Oklahoma	9,635	111	709	8,873	100	634
Oregon	1,376	16	97	W	W	W
Pennsylvania	65,112	780	4,639	65,879	794	5,362
South Carolina	16,858	204	900	13,162	145	627
South Dakota	36,569	409	10,653	34,900	396	11,404
Tennessee	19,474	233	2,328	13,409	162	941
Texas	14,609	203	1,836	27,298	358	3,922
Utah	6,699	86	328	6,073	78	238
Vermont	121,240	1,280	11,481	120,560	1,276	14,561
Virginia	10,547	120	1,758	9,931	113	1,864
Washington	5,208	65	477	4,529	56	440
Wisconsin	71,764	866	4,591	73,141	889	4,821
Wyoming	2,174	26	63	W	W	W
Other States[1]	87,337	1,101	3,288	33,019	426	1,544
Total[2]	1,400,400	16,950	104,400	1,416,200	17,065	103,920
Puerto Rico	157,240	2,095	1,515	143,670	1,916	1,633

W Withheld to avoid disclosing company proprietary data; included with "Other States."
[1]Includes Florida, Idaho, Iowa, Kansas, Nevada (1976), New Jersey, Rhode Island, West Virginia, and States indicated by symbol W.
[2]Data may not add to totals shown because of independent rounding.

Table 3.—Crushed stone sold or used by producers in the United States, by State

(Thousand short tons and thousand dollars)

State	1976 Quantity	1976 Value	1977 Quantity	1977 Value
Alabama	23,815	63,195	25,248	72,649
Alaska	6,727	20,092	4,008	17,493
Arizona	4,142	13,826	5,359	16,367
Arkansas	17,701	39,713	18,310	45,448
California	32,364	74,548	34,011	80,146
Colorado	5,293	12,357	5,597	14,169
Connecticut	6,007	17,383	6,980	20,319
Florida	38,606	74,412	48,558	101,440
Georgia	31,630	85,395	37,864	106,220
Hawaii	6,092	21,193	5,758	19,876
Idaho	3,462	9,122	3,077	8,005
Illinois	61,858	141,440	57,074	135,960
Indiana	28,187	59,418	26,740	61,392
Iowa	30,272	75,921	29,183	76,964
Kansas	16,348	38,228	17,229	41,807
Kentucky	33,378	77,060	36,096	88,941
Louisiana	9,685	28,127	9,710	26,920
Maine	1,443	4,596	1,312	4,110
Maryland	15,683	47,000	16,736	49,772
Massachusetts	7,855	28,150	8,030	30,501
Michigan	41,477	82,202	40,517	84,971
Minnesota	7,530	15,948	7,831	16,991
Mississippi	1,762	2,968	2,176	3,933
Missouri	47,542	97,412	49,612	104,700
Montana	3,464	7,842	3,680	7,923
Nebraska	4,101	11,054	4,128	12,974
Nevada	1,904	5,975	1,668	5,506
New Hampshire	679	1,759	719	2,036
New Jersey	11,234	39,012	12,993	46,621
New Mexico	1,921	4,289	1,950	4,786
New York	28,109	72,829	29,922	88,509
North Carolina	30,839	78,632	32,810	87,254
Ohio	42,612	104,060	44,853	116,410
Oklahoma	19,625	36,630	23,323	46,809
Oregon	20,348	42,589	17,600	39,400
Pennsylvania	63,542	161,250	63,522	163,650
Rhode Island	305	1,295	274	1,238
South Carolina	13,010	29,790	14,772	36,043
South Dakota	3,204	6,587	3,377	7,477
Tennessee	37,581	83,828	41,897	99,196
Texas	54,841	99,816	65,446	122,780
Utah	2,744	6,681	2,765	7,072
Vermont	1,857	10,962	2,123	12,635
Virginia	36,121	89,965	41,707	109,740
Washington	10,218	23,614	12,239	28,156
West Virginia	9,717	24,133	10,495	28,022
Wisconsin	20,667	36,747	22,241	42,097
Wyoming	2,755	7,567	2,434	7,585
Total[1]	900,260	2,116,600	953,960	2,353,000
American Samoa	30	156	6	31
Guam	457	1,438	577	1,897
Puerto Rico	13,247	45,609	12,043	42,648
Virgin Islands	279	2,050	262	2,076

[1]Data may not add to totals shown because of independent rounding.

Table 4.—Crushed stone sold or used by producers in the United States, by size of operation

(Thousand short tons)

Size range	1976 Number of operations	1976 Quantity	1976 Percent	1977 Number of operations	1977 Quantity	1977 Percent
0 to 25	2,030	14,583	2	2,045	14,508	2
25 to 50	705	25,184	3	587	21,919	2
50 to 75	320	19,747	2	343	20,806	2
75 to 100	253	21,894	2	220	18,965	2
100 to 200	668	93,613	10	617	87,898	9
200 to 300	368	89,579	10	375	91,129	10
300 to 400	215	73,701	8	216	74,590	8
400 to 500	177	78,165	9	171	76,759	8
500 to 600	109	59,908	7	114	61,939	7
600 to 700	92	59,348	7	89	57,340	6
700 to 800	65	48,807	5	68	50,581	5
800 to 900	43	36,425	4	58	48,959	5
900 plus	169	278,950	31	197	328,230	34
Total[1]	5,214	900,260	100	5,101	953,960	100

[1]Data may not add to totals shown because of independent rounding.

Table 5.—Crushed stone sold or used by producers in the United States, by method of transportation

(Thousand short tons)

Method	1976 Quantity	1976 Percent	1977 Quantity	1977 Percent
Truck	722,220	80	771,030	81
Rail	76,209	9	82,264	8
Water	63,243	7	63,441	7
Other	38,585	4	37,216	4
Total[1]	900,260	100	953,960	100

[1]Data may not add to totals shown because of independent rounding.

LIMESTONE

Limestone includes dolomite, coquina, bituminous limestone, and aragonite, but excludes marl, shell, and marble.

Dimension.—Dimension limestone was produced by 68 companies at 98 quarries in 21 States. Leading States were Indiana, Wisconsin, Ohio, New Mexico, and Kansas; these five States accounted for 88% of the total output of dimension limestone. Leading companies were Victor Oolitic Stone Co., Blazer Materials Corp., and Indiana Limestone Co. Total output of dimension limestone increased 7% to 442,700 tons valued at $18.8 million. Average production per company was 6,500 tons valued at $277,000. Limestone represented 31% of the total dimension stone produced.

Crushed.—Crushed limestone was produced by 1,289 companies at 3,089 quarries in 46 States. Leading States were Texas, Illinois, Florida, Missouri, and Pennsylvania; these five States accounted for 37% of the total output of crushed limestone. Leading companies were Vulcan Materials Co. and United States Steel Corp. Total output of crushed limestone increased 7% to 707 million tons valued at $1.7 billion. Average production per company was 550,000 tons valued at $1.3 million. Limestone represented 74% of the total crushed stone produced.

Table 6.—Dimension limestone sold or used by producers in the United States, by State

State	1976			1977		
	Short tons	Cubic feet (thousands)	Value (thousands)	Short tons	Cubic feet (thousands)	Value (thousands)
Alaska	--	--	--	85	1	$1
California	3,410	43	$70	5,178	65	124
Illinois	4,108	48	103	2,545	30	109
Indiana	258,930	3,530	W	240,240	3,256	11,647
Michigan	W	W	W	611	7	23
Minnesota	14,374	178	2,205	13,399	166	2,038
New York	--	--	--	234	4	4
Texas	8,261	127	155	W	W	W
Utah	161	2	6	--	--	--
Virginia	611	7	18	835	10	53
Washington	1,773	22	61	1,712	21	61
Wisconsin	63,815	796	1,750	67,028	836	2,164
Other States[1]	58,334	748	15,414	110,820	1,418	2,607
Total[2]	413,770	5,500	19,782	442,690	5,816	18,832
Puerto Rico	W	W	W	143,670	1,916	1,633

W Withheld to avoid disclosing company proprietary data; included with "Other States."
[1]Includes Alabama, Arizona (1976), Colorado, Florida, Iowa, Kansas, Missouri (1976), New Mexico, Ohio, Oklahoma, Rhode Island, and States indicated by symbol W.
[2]Data may not add to totals shown because of independent rounding.

Table 7.—Crushed limestone sold or used by producers in the United States, by State

(Thousand short tons and thousand dollars)

State	1976		1977	
	Quantity	Value	Quantity	Value
Alabama	21,615	49,718	23,341	58,190
Alaska	1,950	8,859	2,772	12,557
Arizona	3,318	10,903	4,633	13,671
Arkansas	7,189	18,126	7,013	19,256
California	14,800	33,298	17,239	39,641
Colorado	3,988	9,482	3,980	10,214
Connecticut	170	1,290	169	885
Florida	38,047	73,276	48,097	100,510
Georgia	4,094	10,293	4,478	11,162
Hawaii	1,115	3,832	1,097	3,800
Idaho	353	807	580	983
Illinois	61,858	141,440	57,074	135,960
Indiana	28,163	59,378	26,724	61,366
Iowa	30,272	75,921	29,183	76,964
Kansas	15,734	36,331	16,761	40,325
Kentucky	33,340	76,870	36,068	88,782
Maine	900	2,623	881	2,509
Maryland	10,699	31,689	11,852	35,565
Massachusetts	W	W	709	8,289
Michigan	40,214	77,296	39,489	80,725
Minnesota	5,499	11,608	5,469	11,330
Mississippi	W	W	1,797	3,376
Missouri	45,911	93,733	47,708	101,130
Montana	1,776	3,939	2,064	4,243
Nebraska	4,101	11,054	4,128	12,974
Nevada	1,688	5,567	1,499	5,137
New Mexico	1,449	3,187	1,441	3,684
New York	25,296	63,795	27,500	80,141
North Carolina	4,120	10,801	5,094	14,168
Ohio	41,229	95,063	43,355	106,450
Oklahoma	18,750	34,743	22,787	45,359
Oregon	W	W	449	1,372
Pennsylvania	48,796	124,080	47,548	123,410
South Carolina	W	W	3,604	8,698
South Dakota	2,228	3,788	2,276	4,249
Tennessee	W	W	41,893	99,053
Texas	51,653	91,724	61,369	112,050
Utah	2,074	5,550	2,325	6,336
Vermont	1,051	9,170	1,067	10,090
Virginia	17,788	43,684	19,797	51,963
Washington	1,009	1,979	1,003	2,251
West Virginia	8,894	21,782	9,749	25,740
Wisconsin	17,705	29,768	18,160	32,718
Wyoming	1,616	4,093	1,588	4,378
Other States[1]	42,453	105,720	713	7,419
Total[2]	662,880	1,496,200	706,520	1,679,100
American Samoa	30	156	6	31
Guam	457	1,438	577	1,897
Puerto Rico	11,951	42,191	10,666	39,030

W Withheld to avoid disclosing company proprietary data; included with "Other States."
[1]Includes New Jersey, Rhode Island, and States indicated by symbol W.
[2]Data may not add to totals shown because of independent rounding.

GRANITE

Granite includes all acidic intrusives, gneisses, and syenites, but excludes basic intrusives and extrusives and traprock.

Dimension.—Dimension granite was produced by 82 companies at 120 quarries in 18 States. Leading States were Georgia, Vermont, New Hampshire, Massachusetts, and South Dakota; these five States accounted for 80% of the total output of dimension granite. Leading companies were Coggins Granite Industries, Rock of Ages Corp., and Kitledge Granite Corp. Total output of dimension granite decreased 5% to 547,000 tons valued at $54.6 million. Average output per company was 6,700 tons valued at $670,000. Granite represented 39% of the total crushed stone produced.

Crushed.—Crushed granite was produced by 146 companies at 736 quarries in 31 States. Leading States were Georgia, North Carolina, Virginia, South Carolina, and Arkansas; these five States accounted for 80% of the total output of crushed granite. Leading producers were Vulcan Materials Co., Martin Marietta Corp., and Lone Star Industries, Inc. Total output of crushed granite increased 10% to 109 million tons valued at $276 million. Average output per company was 740,000 tons valued at $1.9 million. Granite represented 11% of the total crushed stone produced.

Table 8.—Dimension granite sold or used by producers in the United States, by State

State	1976			1977		
	Short tons	Cubic feet (thousands)	Value (thousands)	Short tons	Cubic feet (thousands)	Value (thousands)
California	5,240	64	$589	3,356	41	$365
Connecticut	5,424	61	154	4,906	55	155
Georgia	r195,690	2,017	8,241	185,590	1,881	7,405
Maine	264	3	13	--	--	--
Massachusetts	81,865	984	5,352	62,619	753	4,856
Minnesota	W	W	W	18,514	211	6,071
Missouri	1,519	18	288	992	12	268
New Hampshire	62,600	710	5,273	72,996	850	4,650
North Carolina	30,521	380	3,186	31,899	400	2,206
South Carolina	16,858	204	900	13,162	145	627
South Dakota	36,569	409	10,653	34,900	396	11,404
Texas	6,348	76	1,681	13,064	156	3,533
Vermont	W	W	W	82,623	857	8,771
Washington	30	(1)	2	--	--	--
Wisconsin	7,421	64	2,820	W	W	W
Other States[2]	123,880	1,333	16,774	22,796	244	4,339
Total[3]	574,230	6,325	55,924	547,420	6,001	54,650

rRevised. W Withheld to avoid disclosing company proprietary data; included with "Other States."
[1]Less than 1/2 unit.
[2]Includes Colorado, Nevada (1976), New York, Oklahoma, Pennsylvania, Virginia, and States indicated by symbol W.
[3]Data may not add to totals shown because of independent rounding.

Table 9.—Crushed granite sold or used by producers in the United States, by State

(Thousand short tons and thousand dollars)

State	1976		1977	
	Quantity	Value	Quantity	Value
Alaska	1,074	2,708	1,164	4,703
Arizona	149	520	W	W
Arkansas	6,786	13,186	6,614	14,680
California	5,146	13,214	4,728	12,576
Colorado	1,134	2,489	1,173	2,702
Georgia	26,838	66,930	30,781	80,392
Idaho	1	3	1	2
Massachusetts	1,266	3,989	1,036	3,268
Minnesota	1,605	3,365	1,962	4,437
Montana	13	21	20	34
Nevada	194	351	W	W
North Carolina	22,980	57,764	24,237	62,753
Oregon	90	185	80	138
Pennsylvania	494	1,357	W	W
South Carolina	8,600	21,243	9,752	25,336
South Dakota	--	--	77	77
Texas	8	93	W	W
Utah	W	W	60	119
Vermont	2	5	200	630
Virginia	12,487	29,987	14,929	37,937
Washington	1,199	2,171	1,599	2,878
Wisconsin	886	1,193	1,384	1,839
Wyoming	W	W	685	1,499
Other States[1]	7,394	18,978	8,074	20,414
Total[2]	98,328	239,670	108,550	276,410
Puerto Rico	W	W	W	W

W Withheld to avoid disclosing company proprietary data; included with "Other States."
[1]Includes Connecticut, Maine, Maryland, Missouri, New Hampshire, New Jersey, New Mexico, Rhode Island, and States indicated by symbol W.
[2]Data may not add to totals shown because of independent rounding.

TRAPROCK

Traprock includes basalt, andesite, and other basic volcanics.

Dimension.—Dimension traprock was produced in Hawaii by J. W. Glover Ltd. and in Washington by Heatherstone Inc., Mount Adams Flagstone Co., and Island Frontier Landscaping Construction Co. Output declined 34% to 770 tons valued at $20,000. Average production per company was only 200 tons valued at $5,000.

Crushed.—Crushed traprock was produced by 289 companies at 717 quarries in 23 States. Leading States were Oregon (21%), New Jersey (12%), Washington (11%), Connecticut (8%), and Massachusetts. Leading producers were the U.S. Forest Service, Ashland Oil Inc., and Trap Rock Industries, Inc. Total output increased 3% to 77.4 million tons valued at $208 million. Average production per company was 268,000 tons valued at $719,000. Granite represented 8% of the total crushed stone produced.

Table 10.—Crushed traprock sold or used by producers in the United States, by State

(Thousand short tons and thousand dollars)

State	1976		1977	
	Quantity	Value	Quantity	Value
Alaska	2,402	4,802	W	W
California	3,967	9,165	5,448	12,952
Colorado	--	--	307	808
Connecticut	5,651	15,130	6,471	18,303
Hawaii	4,809	16,781	W	W
Idaho	2,137	4,293	1,654	3,748
Maryland	2,546	7,665	2,251	7,106
Massachusetts	5,793	15,892	W	W
Montana	1,482	3,302	1,190	2,640
New Jersey	8,259	27,244	9,070	30,582
New Mexico	190	444	132	315
New York	1,662	5,623	1,440	5,184
North Carolina	1,734	4,857	2,949	8,735
Oregon	18,735	38,603	16,225	35,658
Pennsylvania	3,412	8,074	4,257	9,804
South Dakota	29	28	--	--
Texas	W	W	49	212
Vermont	51	150	--	--
Virginia	4,146	10,208	4,746	11,632
Washington	6,279	14,739	8,649	19,265
Wisconsin	1,118	3,792	1,285	4,558
Other States[1]	801	2,084	11,284	36,170
Total[2]	75,202	192,880	77,407	207,670
Puerto Rico	W	W	860	2,069
Virgin Islands	279	2,050	262	2,076

W Withheld to avoid disclosing company proprietary data; included with "Other States."
[1]Includes Arizona (1976), Maine, Michigan, Minnesota, New Hampshire, and States indicated by symbol W.
[2]Data may not add to totals shown because of independent rounding.

SANDSTONE

Sandstone includes quartz, quartzite, and conglomerate but excludes unconsolidated sand and gravel.

Dimension.—Dimension sandstone was produced by 84 companies at 125 quarries in 26 States. Leading States were Ohio, Pennsylvania, New York, Maryland, and Georgia; these five States accounted for 73% of the total output of dimension sandstone. Leading producers were Standard Slag Co., Briar Hill Stone Co., and Waller Brothers Stone Co. Output decreased 9% to 247,000 tons valued at $9.1 million. Average production was 2,900 tons valued at $109,000. Sandstone represented 17% of the total dimension stone produced.

Crushed.—Crushed sandstone was produced by 195 companies at 403 quarries in 32 States. Leading States were Pennsylvania, Arkansas, California, Georgia, and Ohio; these five States accounted for 55% of the total output of crushed sandstone. Leading producers were Martin Marietta Corp., Concrete Materials Co., and Raleigh Stone Co. Output expanded 13% to 30.2 million tons valued at $91.2 million. Average production per company was 155,000 tons valued at $468,000. Sandstone represented 3% of the total crushed stone produced.

Table 11.—Dimension sandstone sold or used by producers in the United States, by State

State	1976			1977		
	Short tons	Cubic feet (thousands)	Value (thousands)	Short tons	Cubic feet (thousands)	Value (thousands)
Arizona	1,579	23	$34	3,079	50	$48
Arkansas	W	W	W	13,354	167	368
California	662	9	18	311	4	10
Colorado	5,277	68	132	4,353	56	115
Connecticut	3,719	48	61	4,195	53	85
Indiana	4,308	65	W	4,029	60	W
Maryland	12,597	162	365	16,118	201	561
Missouri	580	9	27	W	W	W
New York	20,649	252	1,566	16,555	198	1,371
Pennsylvania	30,630	393	894	35,004	449	956
Tennessee	9,476	121	582	W	W	W
Virginia	W	W	W	1,844	23	35
Washington	3,059	38	393	2,497	31	359
Wisconsin	528	7	21	W	W	W
Wyoming	223	3	4	108	1	2
Other States[1]	178,900	2,336	6,093	145,110	1,901	5,218
Total[2]	272,190	3,532	10,192	246,550	3,195	9,129
Puerto Rico	W	W	W	--	--	--

W Withheld to avoid disclosing company proprietary data; included with "Other States."
[1]Includes Alabama, Georgia, Idaho (1976), Michigan, Minnesota, Montana, New Jersey, New Mexico, North Carolina, Ohio, Utah, West Virginia, and States indicated by symbol W.
[2]Data may not add to totals shown because of independent rounding.

Table 12.—Crushed sandstone sold or used by producers in the United States, by State

(Thousand short tons and thousand dollars)

State	1976		1977	
	Quantity	Value	Quantity	Value
Alaska	336	596	--	--
Arizona	509	1,603	542	1,833
Arkansas	3,603	7,481	4,572	9,878
California	3,413	7,429	2,600	5,406
Colorado	W	W	137	445
Georgia	W	W	1,875	5,503
Idaho	819	3,737	820	3,242
Kansas	W	W	468	1,481
Kentucky	38	190	27	159
Maine	399	1,420	W	W
Maryland	214	1,121	213	1,293
Montana	191	575	370	923
New Mexico	234	437	345	664
New York	1,126	3,324	973	3,126
North Carolina	107	547	197	800
Ohio	1,384	8,995	1,498	9,962
Oregon	W	W	634	1,848
Pennsylvania	5,323	14,535	6,024	17,265
South Dakota	948	2,771	1,024	3,151
Tennessee	3	8	--	--
Texas	689	1,941	1,316	3,774
Vermont	10	28	W	W
Virginia	862	2,298	1,411	4,088
Washington	875	2,544	532	2,298
West Virginia	823	2,351	746	2,281
Wisconsin	W	W	1,404	2,956
Other States[1]	4,818	14,574	2,456	8,830
Total[2]	26,723	78,506	30,187	91,210

W Withheld to avoid disclosing company proprietary data; included with "Other States."
[1]Includes Alabama, Connecticut, Louisiana (1977), Michigan, Minnesota, Missouri, Oklahoma, Utah, and States indicated by symbol W.
[2]Data may not add to totals shown because of independent rounding.

MARBLE

Marble includes both crystalline and limestone marble, verde antique, and any other calcareous stone that will take a polish.

Dimension.—Dimension marble was produced by 16 companies at 29 quarries in 13 States. Leading States were Georgia, Vermont, California, Alabama, and Texas; these five States accounted for 85% of the total output of dimension marble. Leading producers were Georgia Marble Co., Vermont Marble Co., and V & M Quarry Co. Output expanded 73% to 96,700 tons valued at $12.2 million. Average output per company was 6,000 tons valued at $760,000. Marble represented 7% of the total dimension stone produced.

The marble for the National Gallery of Art East Building, Washington, D.C., came from quarries near Knoxville, Tenn. The stone for the original National Gallery came from the same area in 1941.

Crushed.—Crushed marble was produced by 17 companies at 35 quarries in 13 States. Leading States were Alabama, Georgia, North Carolina, Wyoming, and Texas; these five States accounted for 91% of the total production of crushed marble. Leading producers were Georgia Marble Co., Moretti-Harrah Marble Co., and Texas Quarries Inc. Output increased 6% to 1.5 million tons valued at $23.9 million. Average production per company was 91,000 tons valued at $1.4 million.

Table 13.—Dimension marble sold or used by producers in the United States, by State

State	1976			1977		
	Short tons	Cubic feet (thousands)	Value (thousands)	Short tons	Cubic feet (thousands)	Value (thousands)
Idaho	893	10	$90	W	W	W
Tennessee	9,998	112	1,746	W	W	W
Wyoming	1,951	23	59	W	W	W
Other States[1]	43,135	492	8,423	96,654	1,113	$12,148
Total	55,977	[2]638	10,318	96,654	1,113	12,148

W Withheld to avoid disclosing company proprietary data; included with "Other States."
[1]Includes Alabama, Arizona, California (1977), Georgia, Missouri, Montana, New Mexico, North Carolina, Texas (1977), Vermont, Washington (1976), and States indicated by symbol W.
[2]Data do not add to total shown because of independent rounding.

Table 14.—Crushed marble sold or used by producers in the United States, by State

(Thousand short tons and thousand dollars)

State	1976		1977	
	Quantity	Value	Quantity	Value
Alabama	649	9,964	653	12,764
Arizona	43	564	40	532
Missouri	W	W	4	216
Texas	68	684	W	W
Vermont	2	6	--	--
Wyoming	63	1,574	W	W
Other States[1]	632	7,794	843	10,435
Total	[2]1,456	20,586	1,540	23,947
Puerto Rico	97	518	W	W

W Withheld to avoid disclosing company proprietary data; included with "Other States."
[1]Includes California, Georgia, Nevada, North Carolina, Tennessee, Utah (1977), Virginia, Washington, and States indicated by symbol W.
[2]Data may not add to total shown because of independent rounding.

CALCAREOUS MARL

Marl includes stone that is both calcareous and aluminous, mainly clays and shells. The lime content may range from low to high. Crushed marl was produced by 22 companies at 26 quarries in 8 States. Leading States were South Carolina (56%), Texas, and Mississippi. Leading producers were Giant Portland Cement Co., Gifford-Hill & Co., Inc., and Capitol Cement Co. Output was 2.5 million tons valued at $3.74 million. Average production per company was 114,000 tons valued at $170,000.

Table 15.—Crushed calcareous marl sold or used by producers in the United States, by State

(Thousand short tons and thousand dollars)

State	1976		1977	
	Quantity	Value	Quantity	Value
Indiana	24	40	17	26
Michigan	66	156	22	67
North Carolina	173	321	213	478
South Carolina	2,384	2,978	1,416	2,009
Virginia	5	9	6	13
Other States[1]	719	943	843	1,148
Total[2]	3,371	4,446	2,517	3,740

[1]Includes Maine, Mississippi, and Texas.
[2]Data may not add to totals shown because of independent rounding.

SLATE

Slate is a unique metamorphic stone with perfect cleavage.

Dimension.—Dimension slate was produced by 32 companies at 39 quarries in Pennsylvania (42%), Vermont, Virginia, North Carolina, New York, and California. Leading companies were A. Dalley & Sons, Inc., Stoddard Slate Co., Inc., and J. G. Hadeka. Output was 57,000 tons valued at $8.2 million. Average production per company was only 1,790 tons valued at $258,000. Slate represented 4% of the total output of dimension stone.

Crushed.—Crushed slate was produced by eight companies at eight quarries in Virginia (66%), Georgia, Arkansas, and New York. Leading producers were Ashland Oil Inc., Solite Corp., and Arvonia-Buckingham Slate Co. Output increased 2% to 894,000 tons valued at $7.7 million. Average production per company was 112,000 tons valued at $959,000.

SHELL

Shell is mainly fossil reefs of oyster shell. Crushed shell was produced by 13 companies at 23 locations in Louisiana, Texas, Alabama, Florida, Maryland, California, and Virginia. Leading producers were Radcliff Materials Inc., Parker Brothers & Co., Inc., and Pontchartrain Dredging Corp. Output decreased 2% to 13.5 million tons valued at $33.5 million. Average production per company was 1 million tons valued at $2.6 million.

MISCELLANEOUS STONE

Miscellaneous stone includes mica shist, lava, soapstone, aa, or other stone.

Dimension.—Other kinds of dimension stone were produced by 14 companies at 16 quarries in 9 States. Leading States were Maryland (54%), California, Pennsylvania, Arizona, and New Mexico. Other States were Virginia, North Carolina, Washington, and Utah. Leading producers were Stoneyhurst Quarries, Tosalma Stone Quarry, and Vic Williams Stone Co. Output was 24,800 tons valued at $903.000. Average production per company was only 1,800 tons valued at $64,000.

Crushed.—Other kinds of crushed stone were produced by 61 companies at 341 quarries in 24 States. Leading States were Pennsylvania, California, Vermont, Washington, and Maryland; these five States accounted for 86% of the total output of other crushed stone. Leading producers were the U.S. Forest Service, Eureka Stone Quarry, Inc., and Lone Star Industries. Output declined 27% to 12.8 million tons valued at $29.8 million. Average production per company was 211,000 tons valued at $489,000. The problems of asbestos fibers in crushed stone continued to depress the market for miscellaneous stone.

Table 16.—Crushed miscellaneous stone sold or used by producers in the United States, by State

(Thousand short tons and thousand dollars)

State	1976		1977	
	Quantity	Value	Quantity	Value
Alaska	966	3,127	W	W
Arizona	W	W	40	154
California	5,021	11,107	3,976	9,148
Hawaii	169	580	W	W
Idaho	152	282	22	30
Maryland	470	1,219	429	1,149
Montana	1	4	35	83
North Carolina	1,642	4,079	W	W
Oklahoma	253	276	W	W
Oregon	276	484	212	383
Pennsylvania	5,519	13,200	W	W
Rhode Island	16	56	11	38
Vermont	742	1,602	W	W
Virginia	214	432	W	W
Washington	840	1,752	W	W
Wisconsin	W	W	9	26
Other States[1]	1,383	2,866	8,109	18,796
Total[2]	17,664	41,099	12,843	29,806

W Withheld to avoid disclosing company proprietary data; included with "Other States."
[1]Includes Arkansas, Colorado (1976), Kansas (1976), Louisiana, Massachusetts, Missouri (1976), Nevada, New Mexico, New York (1977), Utah, Wyoming, and States indicated by symbol W.
[2]Data may not add to totals shown because of independent rounding.

CONSUMPTION AND USES

Stone was consumed in every State. Dimension stone was marketed over wide areas to meet specific requirements. Crushed stone was generally marketed in a limited area, usually in the State where produced. Although large stockpiles may exist, output during the year is considered to equal consumption.

Dimension.—Dimension stone was used for building stone (62%), monuments (23%), and other uses. Output of rough monumental stone was 271,800 tons valued at $16.8 million. Production of rough blocks decreased 14% to 234,800 tons valued at $6.9 million. Output of rubble was 179,900 tons valued at $2.4 million. Output of cut building stone increased 7% to 129,400 tons valued at $21.9 million. These four uses accounted for 58% of the total production of dimension stone.

Crushed.—Crushed stone was used for roadstone (57%), concrete (13%), cement (11%), and many other uses. Output of roadbase aggregate increased 15% to 220.6 million tons valued at $494.1 million. Production of other aggregate and roadstone increased 19% to 156.3 million tons valued at $367.4 million. Output of concrete aggregate increased 7% to 124.5 million tons valued at $322.4 million. Stone used in cement increased 5% to 103.9 million tons valued at $190.3 million. Output of bituminous aggregate increased 8% to 93.9 million tons valued at $252.7 million. These five uses accounted for 73% of the total production of crushed stone.

Table 17.—Dimension stone sold or used by producers in the United States, by use

Use	1976			1977		
	Short tons	Cubic feet (thousands)	Value (thousands)	Short tons	Cubic feet (thousands)	Value (thousands)
Rough monumental	271,460	2,829	$15,223	271,840	2,803	$16,820
Rough blocks	r271,450	3,478	9,108	234,750	3,037	6,885
Rubble	113,220	1,426	1,339	179,930	2,252	2,360
Cut building stone	120,780	1,550	23,978	129,380	1,648	21,908
Rough construction	119,050	1,493	3,197	126,240	1,533	2,973
Curbing	118,470	1,396	8,048	103,190	1,227	7,487
House stone veneer	84,997	1,114	3,961	101,620	1,291	4,683
Sawed building stone	91,387	1,214	5,306	90,257	1,186	6,737
Dressed monumental	65,804	738	22,031	56,175	638	21,371
Rough flagging	38,158	486	1,574	34,804	443	1,649
Dressed flagging	38,687	441	1,730	33,789	388	1,669
Structural shapes	10,275	117	2,588	11,629	128	3,298
Dressed construction	25,563	312	2,078	11,019	134	940
Roofing slate	9,960	113	2,045	9,934	109	2,338
Flooring slate	6,205	66	1,046	6,349	70	955
Billiard tables	1,772	20	405	2,090	23	451
Blackboards	193	2	101	134	1	107
Other rough stone	6,159	76	r163	3,326	42	64
Other dressed stone	4,675	53	264	--	--	--
Other uses[1]	2,082	25	210	9,712	112	1,229
Total[2]	1,400,400	16,950	104,400	1,416,200	17,065	103,920

rRevised.
[1]Includes paving blocks, electrical fixtures, and other uses.
[2]Data may not add to totals shown because of independent rounding.

Table 18.—Crushed stone sold or used by producers in the United States, by use

(Thousand short tons and thousand dollars)

Use	1976		1977	
	Quantity	Value	Quantity	Value
Roadbase aggregate	191,160	401,710	220,590	494,150
Other aggregate and roadstone	131,170	299,880	156,250	367,370
Concrete aggregate	116,000	270,610	124,510	322,370
Cement	99,208	177,080	103,890	190,260
Bituminous aggregate	86,639	225,330	93,864	252,680
Surface treatment aggregate	54,708	131,670	44,920	111,630
Lime[1]	37,756	88,474	36,363	89,065
Aglime	39,995	107,440	31,986	95,679
Railroad ballast	23,204	50,354	25,484	57,447
Macadam aggregate	27,556	61,356	25,307	56,384
Flux stone	23,767	57,621	23,067	59,049
Riprap	27,075	61,043	21,114	50,339
Stone sand	4,824	14,192	11,801	32,611
Roofing granules	4,394	11,798	5,099	14,702
Fill	4,933	8,656	4,608	6,649
Other fillers	2,908	30,769	3,012	36,227
Glass	3,199	18,772	2,698	16,683
Mineral food	2,437	13,881	2,369	12,860
Filter stone	928	2,510	2,079	5,515
Rock dust for coal mines	1,377	8,026	1,337	8,463
Asphalt filler	832	4,478	1,131	5,234
Refractory stone	775	5,045	844	5,679
Whiting	976	19,726	833	21,711
Sulfur dioxide removal	655	1,496	807	1,962
Terrazzo	614	7,069	625	7,846
Other chemicals	1,095	1,877	615	1,048
Agmarl	469	1,468	559	1,903
Lightweight aggregate	523	4,385	492	5,404
Ferrosilicon	1,007	2,814	339	1,402
Acid neutralization	27	173	295	1,071
Abrasives	99	706	157	1,048
Paper	136	656	116	412
Building products	122	282	62	131
Bedding material	135	391	61	238
Drain fields	323	448	30	63
Waste products	303	378	W	W
Other uses[2]	8,929	24,049	6,645	17,727
Total[3]	900,260	2,116,600	953,960	2,353,000

W Withheld to avoid disclosing company proprietary data; included with "Other uses."
[1]Includes dead-burned lime, alkalies, and sugar.
[2]Includes magnesium metal, slate flour, porcelain, stucco, disinfectant, and uses indicated by symbol W.
[3]Data may not add to totals shown because of independent rounding.

LIMESTONE

Dimension.—Dimension limestone was used for building stone (96%) and other uses. Output of rough blocks increased 8% to 148,200 tons valued at $4.2 million. Production of rubble was 99,680 tons valued at $1.1 million. Output of house stone veneer decreased 7% to 53,790 tons valued at $2.4 million. Production of cut building stone declined 15% to 49,850 tons valued at $7.34 million. Output of sawed building stone declined 19% to 38,630 tons valued at $2.7 million. These five uses accounted for 88% of the total production of dimension limestone.

Crushed.—Crushed limestone was used for roadstone (52%), cement (14%), concrete (14%), and many other uses. Output of roadbase aggregate increased 11% to 151.5 million tons valued at $319 million. Production of stone for cement increased 6% to 99 million tons valued at $181.4 million. Output of other aggregate and roadstone was 98.96 million tons valued at $226.4 million. Production of concrete aggregate increased 8% to 97.5 million tons valued at $245.5 million. Output of bituminous aggregate expanded 16% to 60.2 million tons valued at $156.1 million. These five uses accounted for 72% of the total production of crushed limestone.

Table 19.—Dimension limestone sold or used by producers in the United States, by use

Use	1976			1977		
	Short tons	Cubic feet (thousands)	Value (thousands)	Short tons	Cubic feet (thousands)	Value (thousands)
Rough blocks	137,580	1,865	$3,713	148,160	2,001	$4,215
Rubble	55,420	714	614	99,685	1,252	1,090
House stone veneer	57,756	764	2,331	53,787	703	2,445
Cut building stone	58,669	782	8,693	49,851	668	7,342
Sawed building stone	47,830	654	3,109	38,629	527	2,672
Rough construction	23,599	306	601	29,489	367	435
Rough flagging	18,384	238	336	15,371	201	338
Dressed construction	11,768	144	297	3,926	49	99
Dressed flagging	2,386	31	82	2,900	37	132
Curbing	257	3	4	W	W	W
Other rough stone	114	1	2	W	W	W
Other uses[1]	3	([2])	1	898	12	64
Total[3]	413,770	5,500	19,782	442,690	5,816	18,832

W Withheld to avoid disclosing company proprietary data; included with "Other uses."
[1]Includes other uses and uses indicated by symbol W.
[2]Less than 1/2 unit.
[3]Data may not add to totals shown because of independent rounding.

Table 20.—Crushed limestone sold or used by producers in the United States, by use

(Thousand short tons and thousand dollars)

Use	1976		1977	
	Quantity	Value	Quantity	Value
Roadbase aggregate	136,520	272,100	151,470	319,050
Cement	93,407	166,260	99,049	181,440
Other aggregate and roadstone	80,491	175,910	98,965	226,360
Concrete aggregate	90,575	203,140	97,465	245,490
Bituminous aggregate	51,972	127,230	60,205	156,090
Surface treatment aggregate	38,476	94,222	35,945	89,244
Lime[1]	36,918	86,583	35,561	87,804
Aglime	39,825	106,670	31,863	95,282
Macadam aggregate	23,837	51,457	21,819	47,218
Flux stone	22,508	51,936	21,628	53,024
Riprap	15,174	35,173	13,450	31,597
Railroad ballast	9,671	19,729	10,825	24,037
Stone sand	3,494	9,621	8,990	23,867
Fill	1,448	2,433	2,503	3,059
Other filler	1,845	14,536	1,987	20,043
Mineral food	1,979	12,321	1,958	11,749
Glass	2,119	11,961	1,783	10,580
Filter stone	422	1,043	1,365	3,348
Rock dust for coal mines	1,377	8,026	1,337	8,463
Asphalt filler	576	2,976	851	4,166
Sulfur dioxide removal	654	1,494	807	1,962
Whiting	897	18,333	696	17,120
Other chemicals	1,095	1,877	615	1,048
Soil conditioning	321	1,056	361	1,435
Terrazzo	204	1,847	349	3,119
Roofing granules	393	1,315	300	1,489
Acid neutralization	27	173	295	1,071
Waste products	303	378	274	321
Paper	136	656	116	411
Abrasives	18	168	60	360
Refractories	33	89	35	80
Building products	W	W	29	65
Drain fields	300	392	28	58
Bedding material	44	87	16	37
Ferrosilicon	914	2,254	W	W
Other uses[2]	5,178	12,792	3,523	8,581
Total[3]	662,880	1,496,200	706,520	1,679,100

W Withheld to avoid disclosing company proprietary data; included with "Other uses."
[1]Includes dead-burned dolomite, alkalies, and sugar.
[2]Includes magnesium metal, stucco, porcelain (1977), disinfectant, other uses, and uses indicated by symbol W.
[3]Data may not add to totals shown because of independent rounding.

Table 21.—Crushed limestone sold or used by producers in the United States in 1977, by State and use

(Thousand short tons and thousand dollars)

State	Aggregates		Cement		Lime[1]		Aglime		Flux stone	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Alabama	W	W	3,836	8,701	1,813	8,314	1,595	4,819	1,577	3,809
Alaska	2,726	12,465	--	--	--	--	--	--	--	--
Arizona	724	1,454	W	W	812	3,330	--	--	402	1,540
Arkansas	3,297	11,651	W	W	W	W	568	1,618	W	W
California	W	W	12,478	22,749	727	2,204	29	159	50	113
Colorado	W	W	2,665	6,583	W	W	W	W	W	W
Connecticut	W	W	--	--	W	W	W	W	--	--
Florida	41,343	87,828	2,554	3,173	W	W	1,019	3,529	--	--
Georgia	2,863	6,802	W	W	--	--	111	341	--	--
Hawaii	327	1,866	734	1,777	W	W	22	90	--	--
Idaho	206	412	W	W	--	--	--	--	--	--
Illinois	45,978	105,380	3,065	5,510	W	W	4,337	11,233	W	W
Indiana	20,338	47,902	3,159	5,019	--	--	2,090	4,908	W	W
Iowa	20,778	55,862	3,787	7,044	W	W	2,816	9,225	W	W
Kansas	12,468	31,923	3,292	6,136	--	--	430	897	--	--
Kentucky	26,806	66,463	1,045	1,796	1,242	2,505	2,295	5,650	72	213
Maine	W	W	W	W	--	--	W	W	--	--
Maryland	9,158	25,334	2,062	2,581	27	68	W	W	--	--
Massachusetts	W	W	--	--	W	W	134	996	W	W
Michigan	W	W	8,314	15,162	10,625	21,815	430	923	9,423	21,488
Minnesota	W	W	--	--	--	--	431	1,034	--	--
Mississippi	W	W	W	W	--	--	478	1,036	--	--
Missouri	30,044	66,081	6,016	10,335	3,205	5,380	3,571	8,342	W	W
Montana	31	66	W	W	651	1,408	--	--	W	W
Nebraska	W	W	W	W	--	--	196	509	W	W
Nevada	240	378	W	W	W	W	--	--	W	W
New Jersey	W	W	--	--	W	W	W	W	W	W
New Mexico	602	1,125	W	W	W	W	--	--	W	W
New York	19,977	63,752	5,283	8,131	W	W	334	1,752	W	W
North Carolina	4,042	11,617	W	W	--	--	W	W	--	--
Ohio	28,496	66,679	2,921	8,237	3,949	7,349	1,693	5,370	3,346	7,768
Oklahoma	W	W	2,425	3,790	W	W	458	946	--	--
Oregon	W	W	W	W	W	W	W	W	--	--
Pennsylvania	29,571	71,715	8,006	15,419	3,377	9,569	1,550	7,541	2,306	8,026
South Carolina	W	W	W	W	--	--	487	2,138	--	--
South Dakota	1,236	2,460	612	971	265	475	W	W	--	--
Tennessee	34,655	79,209	1,841	4,692	W	W	2,878	7,399	--	--
Texas	W	W	7,887	10,500	2,221	4,415	371	564	825	1,581
Utah	W	W	1,030	2,844	W	W	W	W	W	W
Vermont	W	W	--	--	--	--	W	W	--	--
Virginia	13,765	34,698	1,584	2,979	1,566	2,975	1,660	6,880	207	435
Washington	W	W	W	W	W	W	W	W	--	--

See footnotes at end of table.

Table 21.—Crushed limestone sold or used by producers in the United States in 1977, by State and use —Continued

(Thousand short tons and thousand dollars)

State	Aggregates		Cement		Lime[1]		Aglime		Flux stone	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
West Virginia	6,186	17,448	W	W	W	W	126	487	W	W
Wisconsin	16,245	27,732	--	--	W	W	1,229	3,200	15	24
Wyoming	62	131	W	W	W	W	--	--	--	--
Other States[2]	102,670	208,870	14,455	27,311	5,081	17,997	525	3,696	3,405	8,027
Total[3]	474,860	1,107,300	99,049	181,440	35,561	87,804	31,863	95,282	21,628	53,024
American Samoa	4	19	2	12	--	--	--	--	--	--
Guam	W	W	--	--	W	W	--	--	--	--
Puerto Rico	7,884	34,154	W	W	W	W	--	--	--	--

State	Riprap		Railroad ballast		Other uses[4]		Total[3]	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Alabama	402	1,036	108	232	14,010	31,279	23,341	58,190
Alaska	1	2	45	90	--	--	2,772	12,557
Arizona	--	--	W	W	2,695	7,347	4,633	13,671
Arkansas	81	183	87	180	2,980	5,624	7,013	19,256
California	89	302	--	--	3,866	14,114	17,239	39,641
Colorado	W	W	--	--	1,315	3,631	3,980	10,214
Connecticut	--	--	--	--	169	885	169	885
Florida	61	291	W	W	3,120	5,689	48,097	100,510
Georgia	28	61	W	W	1,476	3,958	4,478	11,162
Hawaii	W	W	--	--	14	67	1,097	3,800
Idaho	W	W	--	--	374	571	580	983
Illinois	542	1,259	640	1,358	2,512	11,220	57,074	135,960
Indiana	301	903	248	485	588	2,149	26,724	61,366
Iowa	190	562	893	2,162	719	2,109	29,183	76,964
Kansas	145	397	107	233	319	739	16,761	40,325
Kentucky	3,961	9,494	121	308	526	2,353	36,068	88,782
Maine	W	W	W	W	881	2,509	881	2,509
Maryland	133	496	86	186	386	6,900	11,852	35,565
Massachusetts	W	W	--	--	575	7,293	709	8,289
Michigan	371	722	266	533	10,060	20,082	39,489	80,725
Minnesota	101	187	W	W	4,937	10,109	5,469	11,330
Mississippi	W	W	W	W	1,319	2,340	1,797	3,376
Missouri	3,180	5,660	172	408	1,520	4,924	47,708	101,130
Montana	8	22	W	W	1,374	2,747	2,064	4,243
Nebraska	68	195	W	W	3,864	12,270	4,128	12,974
Nevada	--	--	--	--	1,259	4,759	1,499	5,137
New Jersey	--	--	--	--	687	6,966	687	6,966
New Mexico	W	W	W	W	839	2,559	1,441	3,684

New York	463	1,476	249	657	1,194	4,373	27,500	80,141
North Carolina	W	W	W	W	1,052	2,551	5,094	14,168
Ohio	694	2,002	974	2,052	1,282	6,993	43,355	106,450
Oklahoma	511	1,125	1,400	2,756	17,993	36,742	22,787	45,359
Oregon	--	--	--	--	449	1,372	449	1,372
Pennsylvania	469	1,126	889	2,657	1,380	7,357	47,548	123,410
South Carolina	W	W	W	W	3,117	6,560	3,604	8,698
South Dakota	6	7	139	280	18	56	2,276	4,249
Tennessee	483	962	266	505	1,770	6,286	41,893	99,053
Texas	547	1,249	1,105	2,128	48,413	91,613	61,369	112,050
Utah	4	9	W	W	1,291	4,774	2,325	6,336
Vermont	28	60	W	W	1,044	10,030	1,067	10,090
Virginia	83	249	66	164	866	3,583	19,797	51,963
Washington	W	W	--	--	1,003	2,251	1,003	2,251
West Virginia	36	123	592	1,137	2,809	6,545	9,749	25,740
Wisconsin	173	678	W	W	498	1,084	18,160	32,718
Wyoming	W	W	W	W	1,526	4,247	1,588	4,378
Other States[2]	296	759	2,372	5,526	[5]19,284	[5]98,616	[6]W	[6]W
Total[3]	13,450	31,597	10,825	24,037	19,284	98,616	706,520	1,679,100
American Samoa	--	--	--	--	--	--	6	31
Guam	--	--	--	--	577	1,897	577	1,897
Puerto Rico	--	--	--	--	2,782	4,876	10,666	39,030

W Withheld to avoid disclosing company proprietary data; included with "Other States" and with "Other uses."
[1]Includes dead-burned dolomite, alkalies, and sugar.
[2]Includes Rhode Island and States indicated by symbol W.
[3]Data may not add to totals shown because of independent rounding.
[4]Includes concealed uses and other uses.
[5]Includes other uses only: Stone sand, fill, other filler, mineral food, glass, filter stone, rock dust for coal mines, asphalt filler, sulfur dioxide removal, whiting, other chemicals, soil conditioning, terrazzo, roofing granules, acid neutralization, waste products, paper, abrasives, refractories, building products, drain fields, bedding material, ferrosilicon, magnesium metal, stucco, porcelain, disinfectant, and other uses.
[6]Concealed States only.

GRANITE

Dimension.—Dimension granite was used for monuments (57%), building stone (23%), curbing (19%), and other uses. Output of rough monumental stone increased 2% to 270,700 tons valued at $16.7 million. Production of curbing declined 13% to 102,800 tons valued at $7.5 million. Output of cut building stone was 48,000 tons valued at $10.9 million. Production of dressed monumental stone was 42,620 tons valued at $16.2 million. Output of rough blocks increased 5% to 33,130 tons valued at $1.4 million. These five uses accounted for 91% of the total production of dimension granite.

Crushed.—Crushed granite was used for roadstone (66%), concrete (17%), railroad ballast (9%), and other uses. Output of roadbase aggregate was 33.8 million tons valued at $84.7 million. Production of bituminous aggregate increased 5% to 17 million tons valued at $46.6 million. Output of other aggregate and roadstone decreased 11% to 15.9 million tons valued at $39.9 million. Production of railroad ballast was 9.6 million tons valued at $20.9 million. Output of surface treatment aggregates was 3.2 million tons valued at $8.2 million. These five uses accounted for 73% of the total production of crushed granite.

Table 22.—Dimension granite sold or used by producers in the United States, by use

Use	1976			1977		
	Short tons	Cubic feet (thousands)	Value (thousands)	Short tons	Cubic feet (thousands)	Value (thousands)
Rough monumental	266,480	2,770	$14,925	270,730	2,791	$16,748
Curbing	117,930	1,389	8,015	102,800	1,222	7,465
Cut building stone	29,318	355	10,300	48,037	581	10,885
Dressed monumental	54,726	608	18,143	42,623	482	16,154
Rough blocks	31,492	334	1,082	33,131	347	1,419
Rubble	20,924	233	171	23,444	267	219
Rough construction	27,510	330	1,016	10,094	114	329
Dressed construction	10,794	132	1,662	6,168	74	800
House stone veneer	1,875	22	107	3,970	48	130
Sawed building stone	7,776	93	217	3,106	37	124
Other rough stone	2,791	28	94	316	3	7
Other dressed stone	69	1	7	W	W	W
Rough flagging	207	3	9	W	W	W
Other uses[1]	2,345	28	176	2,993	36	370
Total[2]	574,230	6,325	55,924	547,420	6,001	54,650

W Withheld to avoid disclosing company proprietary data; included with "Other uses."
[1]Includes paving blocks, dressed flagging, and uses indicated by symbol W.
[2]Data may not add to totals shown because of independent rounding.

Table 23.—Crushed granite sold or used by producers in the United States, by use

(Thousand short tons and thousand dollars)

Use	1976		1977	
	Quantity	Value	Quantity	Value
Roadbase aggregate	22,828	52,969	33,842	84,699
Concrete aggregate	17,198	43,317	18,427	50,913
Bituminous aggregate	16,225	42,759	17,048	46,598
Other aggregates and roadstone	17,775	43,769	15,859	39,935
Railroad ballast	9,096	20,574	9,653	20,888
Surface treatment aggregate	3,430	7,842	3,168	8,215
Riprap	4,283	9,989	2,163	5,220
Roofing granules	1,683	3,038	1,973	3,773
Macadam aggregate	1,685	3,937	1,682	4,212
Stone sand	723	1,764	1,306	3,069
Fill	154	210	824	1,164
Filter stone	180	584	99	301
Terrazzo	181	826	58	439
Mineral food	168	757	25	298
Bedding material	60	215	W	W
Other uses[1]	2,660	7,120	2,428	6,689
Total[2]	98,328	239,670	108,550	276,410

W Withheld to avoid disclosing company proprietary data; included with "Other uses."
[1]Includes asphalt filler, other uses, and uses indicated by symbol W.
[2]Data may not add to totals shown because of independent rounding.

TRAPROCK

Dimension.—Dimension traprock was used for rubble, rough blocks, rough flagging, and house stone veneer.

Crushed.—Crushed traprock was used for roadstone (80%) and other uses. Output of other aggregate and roadstone was 27 million tons valued at $69 million. Production of roadbase aggregate increased 7% to 17.5 million tons valued at $43.81 million. Output of bituminous aggregate decreased 2% to 11.5 million tons valued at $34.9 million. These three uses accounted for 72% of the total production of crushed traprock.

Table 24.—Crushed traprock sold or used by producers in the United States, by use

(Thousand short tons and thousand dollars)

Use	1976		1977	
	Quantity	Value	Quantity	Value
Other aggregate and roadstone	18,462	48,879	26,997	68,998
Roadbase aggregate	16,340	38,729	17,515	43,808
Bituminous aggregate	11,762	33,897	11,518	34,856
Concrete aggregate	5,143	15,360	5,211	16,020
Surface treatment aggregate	9,623	21,798	4,286	10,232
Railroad ballast	2,998	6,975	3,355	8,422
Riprap	4,410	8,949	3,167	8,392
Roofing granules	1,763	5,185	1,928	5,758
Macadam aggregate	1,573	5,050	1,542	4,380
Stone sand	158	863	758	3,051
Fill	2,137	4,270	391	802
Filter stone	233	623	327	1,016
Bedding material	26	81	21	93
Drain fields	20	46	W	W
Building products	1	1	W	W
Other uses[1]	553	2,170	387	1,842
Total[2]	75,202	192,880	77,407	207,670

W Withheld to avoid disclosing company proprietary data; included with "Other uses."
[1]Includes asphalt filler, terrazzo (1977), other uses, and uses indicated by symbol W.
[2]Data may not add to totals shown because of independent rounding.

SANDSTONE

Dimension.—Dimension sandstone was used for building stone (90%) and other uses. Output of rough construction stone expanded 16% to 58,037 tons valued at $1.3 million. Production of rubble was 45,632 tons valued at $770,600. Output of sawed sandstone expanded 15% to 39,908 tons valued at $1.9 million. Production of rough blocks increased 10% to 35,677 tons valued at $619,200. Output of cut sandstone was 24,816 tons valued at $2.1 million. These five uses accounted for 83% of the total production of dimension sandstone.

Crushed.—Crushed sandstone was used for roadstone (59%) and other uses. Output of roadbase aggregate increased 3% to 7 million tons valued at $16.8 million. Production of other aggregate and roadstone expanded 17% to 5.7 million tons valued at $12.8 million. Output of bituminous aggregate was 3.95 million tons valued at $11.6 million. These three uses accounted for 55% of the total production of crushed sandstone.

Table 25.—Dimension sandstone sold or used by producers in the United States, by use

Use	1976			1977		
	Short tons	Cubic feet (thousands)	Value (thousands)	Short tons	Cubic feet (thousands)	Value (thousands)
Rough construction	50,124	642	$1,103	58,037	713	$1,315
Rubble	28,324	377	367	45,632	602	771
Sawed building stone	34,688	456	1,725	39,908	526	1,891
Rough blocks	32,473	447	553	35,677	485	619
Cut building stone	24,827	320	2,039	24,816	321	2,116
Rough flagging	19,512	244	1,227	17,715	222	1,230
House stone veneer	21,781	288	882	14,876	200	572
Dressed flagging	10,040	127	476	6,787	85	336
Other rough stone	48,263	603	1,563	2,383	30	49
Other dressed stone	582	7	194	W	W	W
Other uses[1]	1,572	20	75	723	9	228
Total[2]	272,190	3,532	10,192	246,550	3,195	9,129

W Withheld to avoid disclosing company proprietary data; included with "Other uses."
[1]Includes curbing, dressed construction (1976), rough monumental (1976), and uses indicated by symbol W.
[2]Data may not add to totals shown because of independent rounding.

Table 26.—Crushed sandstone sold or used by producers in the United States, by use

(Thousand short tons and thousand dollars)

Use	1976 Quantity	1976 Value	1977 Quantity	1977 Value
Roadbase aggregate	6,798	14,940	7,017	16,763
Other aggregate and roadstone	4,886	10,862	5,702	12,758
Bituminous aggregate	3,067	8,141	3,952	11,616
Concrete aggregate	2,223	6,645	2,620	8,263
Riprap	1,575	3,819	1,637	3,800
Railroad ballast	1,116	2,587	1,504	3,765
Flux stone	1,259	5,685	1,439	6,025
Surface treatment aggregate	1,237	2,895	1,237	3,255
Glass	1,080	6,810	915	6,102
Refractories	741	4,956	809	5,599
Roofing granules	W	W	769	1,788
Stone sand	442	1,792	740	2,463
Cement	757	2,186	664	2,238
Fill	190	285	312	624
Filter stone	66	198	267	800
Other fillers	142	1,838	162	2,128
Abrasives	81	539	97	686
Ferrosilicon	93	559	84	575
Terrazzo	43	573	29	356
Macadam aggregate	241	555	W	W
Mineral food	5	17	W	W
Bedding material	5	7	--	--
Other uses[1]	676	2,615	233	1,604
Total[2]	26,723	78,506	30,187	91,210

W Withheld to avoid disclosing company proprietary data; included with "Other uses."
[1]Includes porcelain, building products, waste material (1977), drain fields, and uses indicated by symbol W.
[2]Data may not add to totals shown because of independent rounding.

MARBLE

Dimension.—Dimension marble was used for building stone (80%), monuments (15%), and other uses. Output of house stone veneer was 28,637 tons valued at $1.5 million. Production of rough blocks was 16,195 tons valued at $586,800. Output of rough construction stone was 14,172 tons valued at $466,900. Production of dressed monumental stone was 13,552 tons valued at $5.2 million. These four uses accounted for 75% of the total output of dimension marble.

Crushed.—Crushed marble was used for filler, roadstone, terrazzo, and other uses. Output of stone for other fillers decreased 6% to 860,000 tons valued at $14 million. Production of other aggregate and roadstone was 188,900 tons valued at $382,000. Output of terrazzo was 170,800 tons valued at $3.8 million. These three uses accounted for 79% of the total output of crushed marble.

Table 27.—Dimension marble sold or used by producers in the United States, by use

Use	1976 Short tons	1976 Cubic feet (thousands)	1976 Value (thousands)	1977 Short tons	1977 Cubic feet (thousands)	1977 Value (thousands)
House stone veneer	W	W	W	28,637	336	$1,527
Rough blocks	23,176	254	$2,207	16,195	185	587
Rough construction	3,958	47	116	14,172	164	467
Dressed monumental	11,078	130	3,888	13,552	156	5,217
Sawed building stone	1,093	11	255	8,610	95	2,049
Rubble	2,505	29	87	5,088	57	167
Cut building stone	6,805	80	2,847	4,860	57	1,471
Rough flagging	W	W	W	1,544	18	70
Other uses[1]	7,362	87	916	3,996	46	593
Total[2]	55,977	638	10,318	96,654	1,113	12,148

W Withheld to avoid disclosing company proprietary data; included with "Other uses."
[1]Includes other dressed stone, rough monumental stone, dressed flagging, dressed construction stone, other rough stone (1977), and uses indicated by symbol W.
[2]Data may not add to totals shown because of independent rounding.

Table 28.—Crushed marble sold or used by producers in the United States, by use

(Thousand short tons and thousand dollars)

Use	1976 Quantity	1976 Value	1977 Quantity	1977 Value
Other filler	915	14,373	860	14,046
Other aggregate and roadstone	152	322	189	382
Terrazzo	170	3,598	171	3,843
Stone sand	7	151	8	161
Mineral food	1	22	1	25
Riprap	6	19	--	--
Other uses[1]	205	2,100	311	5,490
Total	1,456	[2]20,586	1,540	23,947

[1]Includes whiting, aglime, roofing granules, concrete aggregate, macadam aggregate, and surface treatment aggregate (1976).

[2]Data do not add to total shown because of independent rounding.

SLATE

Dimension.—Dimension slate was used for flagging (41%), structural shapes (20%), roofing (17%), flooring (11%), and other uses. Output of flagging decreased 9% to 23,310 tons valued at $1.1 million. Production of structural shapes expanded 13% to 11,419 tons valued at $3.1 million. Output of roofing slate was 9,934 tons valued at $2.3 million. Production of flooring increased 2% to 6,349 tons valued at $954,700. These four uses accounted for 89% of the total output of dimension slate.

Crushed.—Crushed slate was used for lightweight aggregate (55%), roadstone, and other uses. Output of slate for lightweight aggregate was 491,600 tons valued at $5.4 million.

Table 29.—Dimension slate sold or used by producers in the United States, by use

Use	1976 Short tons	1976 Value (thousands)	1977 Short tons	1977 Value (thousands)
Flagging	25,489	$1,141	23,310	$1,120
Structural shapes	10,065	2,408	11,419	3,118
Roofing	9,960	2,045	9,934	2,338
Flooring	6,205	1,046	6,349	955
Billiard tables	1,772	405	2,090	451
House stone veneer	198	4	190	3
Blackboards	193	101	134	107
Other uses[1]	4,166	107	3,839	152
Total	58,048	7,257	57,265	8,244

[1]Includes electrical fixtures and other uses.

SHELL

Crushed shell was used for roadstone (71%), cement (16%), and other uses. Output of roadbase aggregate increased to 4.9 million tons valued at $15.7 million. Production of other aggregates and roadstone decreased 5% to 4.6 million tons valued at $10.5 million. Output of shell for cement decreased 1% to 2.1 million tons valued at $3.8 million. These three uses accounted for 86% of the total shell production.

Table 30.—Crushed shell sold or used by producers in the United States, by use

(Thousand short tons and thousand dollars)

Use	1976 Quantity	1976 Value	1977 Quantity	1977 Value
Roadbase aggregate	3,363	9,722	4,860	15,671
Other aggregate and roadstone	4,892	10,842	4,643	10,474
Cement	2,125	5,111	2,103	3,787
Mineral food	W	W	380	770
Bituminous aggregate	1,248	5,856	139	444
Other uses[1]	2,125	5,862	1,368	2,341
Total	13,753	37,393	[2]13,492	33,487

W Withheld to avoid disclosing company proprietary data; included with "Other uses."
[1]Includes lime, fill, riprap (1977), surface treatment aggregate (1976), agstone (1976), railroad ballast (1976), other uses, and uses indicated by symbol W.
[2]Data do not add to total shown because of independent rounding.

CALCAREOUS MARL

Crushed marl was used for cement (82%), roadbase aggregate, soil conditioning, and other aggregate and roadstone. Output of marl for cement declined 29% to 2.1 million tons valued at $2.8 million.

MISCELLANEOUS STONE

Dimension.—Other kinds of dimension stone were used for rough construction (58%), rubble (22%), and other uses. Output of rough construction stone increased 4% to 14,445 tons valued at $426,300. Production of rubble increased 10% to 5,486 tons valued at $109,000.

Crushed.—Other kinds of crushed stone were used for roadstone (84%) and other uses. Output of roadbase stone increased 6% to 5.7 million tons valued at $13.7 million. Production of other aggregate and roadstone declined 18% to 3.6 million tons valued at $7.8 million.

Table 31.—Other dimension stone sold or used by producers in the United States, by use

Use	1976 Short tons	1976 Cubic feet (thousands)	1976 Value (thousands)	1977 Short tons	1977 Cubic feet (thousands)	1977 Value (thousands)
Rough construction	13,829	169	$361	14,445	176	$426
Rubble	5,006	61	95	5,486	67	109
Cut stone	1,159	14	99	W	W	W
Rough blocks	W	W	W	1,500	19	38
House stone veneer	717	8	31	150	2	4
Rough flagging	27	1	1	88	1	4
Other uses[1]	4,265	51	323	3,146	37	322
Total[2]	25,003	303	911	24,815	301	903

W Withheld to avoid disclosing company proprietary data; included with "Other uses."
[1]Includes dressed construction stone, dressed flagging, structural shapes, other rough stone, sawed stone, curbing (1976), and uses indicated by symbol W.
[2]Data may not add to totals shown because of independent rounding.

Table 32.—Other crushed stone sold or used by producers in the United States, by use

(Thousand short tons and thousand dollars)

Use	1976 Quantity	1976 Value	1977 Quantity	1977 Value
Roadbase aggregate	5,359	12,818	5,680	13,749
Other aggregate and roadstone	4,405	9.135	3,598	7,822
Bituminous aggregate	2,366	7,444	983	3,023
Concrete aggregate	785	1,894	774	1,567
Riprap	1,628	3,095	676	1,199
Fill	833	1,290	374	610
Surface treatment aggregate	1,487	3,778	284	686
Macadam aggregate	217	346	256	556
Railroad ballast	303	435	148	335
Filter stone	26	63	21	50
Terrazzo	17	225	12	58
Abrasives	--	--	1	1
Other uses[1]	238	577	38	150
Total[2]	17,664	41,099	12,843	29,806

[1]Includes roofing granules, other fillers, cement, drain fields (1976), and other uses.
[2]Data may not add to totals shown because of independent rounding.

PRICES

Values indicated are the company-reported selling prices f.o.b. quarry or plant, and do not include transportation away from the plant.

Unit values for dimension stone ranged from $13.12 per ton for rubble to $799.87 for slate used for blackboards and averaged $73.38, 2% below the 1976 average. Values per cubic foot were $6.00 for rough monumental stone, $2.27 for rough blocks, $13.30 for cut building stone, $6.10 for curbing, and $5.68 for sawed building stone, averaging $6.09 per cubic foot.

Unit values for crushed stone ranged from $1.17 per ton for waste material to $26.05 for whiting and averaged $2.47 per ton, an increase of 5% over 1976. Values included $2.24 per ton for roadbase aggregate, $2.35 for other aggregate and roadstone, $2.59 for concrete aggregate, $1.83 for stone used in cement, and $2.69 for bituminous aggregate.

Table 33.—Unit values of stone sold or used by producers in the United States

Stone	1976 Dimension stone Per ton	1976 Dimension stone Per cubic foot	1976 Crushed stone, per ton	1977 Dimension stone Per ton	1977 Dimension stone Per cubic foot	1977 Crushed stone, per ton
Limestone	$47.81	$3.60	$2.26	$42.54	$3.24	$2.38
Granite	97.39	8.84	2.44	99.83	9.11	2.55
Traprock	12.31	1.05	2.56	25.58	2.17	2.68
Sandstone	37.44	2.89	2.94	37.02	2.86	3.02
Marble	184.32	16.18	14.14	125.68	10.91	15.55
Slate	125.01	11.05	6.60	143.96	13.09	8.58
Shell	--	--	2.72	--	--	2.48
Marl	--	--	1.32	--	--	1.49
Miscellaneous	36.45	3.01	2.33	36.39	3.00	2.32
Average	74.55	6.16	2.46	73.38	6.09	2.57

FOREIGN TRADE

Exports.—Dimension stone was exported all over the world; major markets were Canada (55%) and Japan (18%). Of the total, 29% was granite, 15% was limestone and marble, and 7% was and 7% was slate. Total exports were estimated at 97,000 tons.

Crushed stone was exported mainly to Canada (99%). Of the total, 82% was limestone. Total exports were estimated at 4 million tons.

Imports.—Dimension stone was imported from all over the world, mainly from Italy (63%), Canada (16%), and Mexico (7%). Of the total, 62% was limestone and marble, 20% was granite, and 14% was slate. Total imports were estimated at 238,000 tons.

Crushed stone was imported from all over the world, mainly from Canada (79%), the Bahamas (13%), and the Dominican Republic (4%). Of the total, 66% was limestone and 2% was quartzite. Total imports were estimated at 4 million tons.

Table 34.—U.S. exports of stone

(Thousand short tons and thousand dollars)

Year	Building and monumental stone			Crushed, ground, or broken				Other manufactures of stone (value)
	Dolomite		Other (value)	Limestone		Other		
	Quantity	Value		Quantity	Value	Quantity	Value	
1975	49	1,464	2,449	3,386	9,993	896	5,843	2,376
1976	63	1,486	2,596	3,191	10,537	866	7,073	2,273
1977	12	484	3,476	3,235	10,365	694	6,048	2,242

Table 35.—U.S. imports for consumption of stone and whiting, by class

Class	1976		1977	
	Quantity	Value (thousands)	Quantity	Value (thousands)
Granite:				
Monumental, paving and building stone:				
Rough ---- cubic feet	227,749	$2,234	213,596	$2,119
Dressed ---- do	193,825	4,669	231,404	4,610
Not manufactured and not suitable for monumental, paving, or building stone ---- short tons	11,313	127	87	3
Other, n.s.p.f	([1])	67	([1])	163
Total	XX	7,097	XX	6,895
Marble, breccia, and onyx:				
In block, rough, or squared ---- cubic feet	17,726	156	20,443	161
Sawed or dressed, over 2 inches thick ---- do	710	15	2,195	43
Slabs and paving tiles ---- superficial feet	8,019,528	8,277	7,656,083	10,324
All other manufactures	([1])	7,344	([1])	8,963
Total	XX	15,792	XX	19,491
Travertine stone:				
Rough, unmanufactured ---- cubic feet	41,268	103	5,941	25
Dressed, suitable for monumental, paving, and building stone ---- short tons	26,469	3,667	15,505	3,016
Other, n.s.p.f	([1])	248	([1])	307
Total	XX	4,018	XX	3,348
Limestone:				
Monumental, paving, and building stone:				
Rough ---- cubic feet	12,111	19	15,242	21
Dressed, manufactured ---- short tons	580	41	3,072	49
Crude, not suitable for monumental, paving, or building stone ---- do	104,605	492	181,754	782
Other, n.s.p.f	([1])	42	([1])	97
Total	XX	594	XX	949

See footnotes at end of table.

Table 35.—U.S. imports for consumption of stone and whiting, by class —Continued

Class	1976 Quantity	1976 Value (thousands)	1977 Quantity	1977 Value (thousands)
Slate:				
Roofing ---- square feet	13,936	$4	--	--
Other, n.s.p.f ----	(1)	5,880	(1)	$4,239
Total ----	XX	5,884	XX	4,239
Quartzite ---- short tons	75,404	744	66,708	527
Stone and articles of stone, n.s.p.f.:				
Statuary and sculptures ----	(1)	354	(1)	313
Stone, unmanufactured ---- short tons	4,532	116	6,186	126
Building stone, rough ---- cubic feet	11,622	15	22,264	32
Building stone, dressed ---- short tons	1,552	146	258	51
Other ----	(1)	2,816	(1)	3,247
Total ----	XX	3,452	XX	3,769
Stone,chips, spall, crushed or ground:				
Marble, breccia, and onyx chips ---- short tons	2,503	86	1,761	61
Limestone, chips and spalls, crushed or ground ---- do	1,580,391	2,376	1,526,235	2,608
Stone chips and spalls, and stone crushed or ground, n.s.p.f ---- do	1,280,573	2,746	1,133,291	2,344
Slate chips and spalls, and slate crushed or ground ---- do	(1)	1	(1)	2
Total ----	XX	5,209	XX	5,015
Aragonite ----	573,580	620	516,059	925
Whiting:				
Whiting, dry, ground, or bolted ---- short tons	35,920	2,227	32,472	2,159
Chalk, whiting, precipitated ---- do	4,349	579	8,127	1,264
Total ----	40,269	2,806	40,599	3,423
Grand total ----	XX	46,211	XX	48,581

XX Not applicable.
[1]Quantity not reported.

WORLD REVIEW

Stone was produced all over the world, in almost every country. World output was estimated at 4 billion tons in 1977, 47% in Europe, 27% in North America, 17% in Asia, 4% in South America, 3% in Oceania, and 2% in Africa. The United States was the leading country, with 23% of the world total.

Canada.—Production of stone in Canada in 1976 was 87 million tons valued at $210 million, or 2% of the world total. The stone was used for road metal (37%), concrete aggregate (15%), asphalt aggregate (7%), railroad ballast (4%), and many other uses. Of the total, 81% was limestone and 13% was granite. Leading Provinces were Quebec (59%) and Ontario (31%).

France.—France ranked second in production of dimension stone, with 11% of the world total, and was fifth in output of crushed stone, with 6% of the total.

Germany, Federal Republic of.—Among the countries, the Federal Republic of Germany ranked fourth in stone output with about 7% of the world total.

Italy.—Italy ranked first in output of dimension stone, with 59% of the world total, and was sixth in production of crushed stone, with 4%.

Japan.—Japan ranked second in stone production, with 8% of the world total.

U.S.S.R.—Russia ranked third in output of crushed stone, with 8% of the world total.

United Kingdom.—The United Kingdom produced about 6% of the world's stone, ranking fifth among the countries.

TECHNOLOGY

The stated presence of asbestos fibers in crushed stone could be an environmental problem. Quarries in serpentine or related rocks are being examined by the Environmental Protection Agency (EPA). The claim was made that crushed stone from an operation in Maryland, which was used on streets and roads, contained asbestos, and that use was banned by local authorities. The question of the possible health hazard of these and other asbestiform fibers is being considered by EPA. The Bureau of Mines has established a Particulate Mineralogy Unit at its Avondale, Md., Metallurgy Research Center to examine and classify dusts and fibers. Two Bureau publications discussed asbestos.[2]

[1]Supervisory physical scientist, Division of Nonmetallic Minerals.

[2]Campbell, W. J., R. L. Blake, L. L. Brown, E. E. Cather, and J. J. Sjoberg. Selected Silicate Minerals and Their Asbestiform Varieties. Mineralogical Definitions and Identification-Characterization. BuMines IC 8751, 1977, 56 pp.

Clifton, R. A. Asbestos—1977. BuMines MCP 6, 1977, 17 pp.

Sulfur and Pyrites

By John E. Shelton[1]

There was a slight decrease in sulfur prices in 1977 compared with those in 1976. The average net shipment value f.o.b. mine or plant for Frasch and recovered elemental sulfur decreased 3% from $46.45 per long ton in 1976 to $45.09 per ton in 1977. Both export and import prices decreased. The yearend price for Frasch sulfur was $61 per ton, f.o.b. Gulf Ports.

Production of sulfur in all forms in 1977 decreased 1.4% below that of 1976. For the second year, production was less than apparent domestic consumption. Sulfur was produced by 74 companies at 190 operations in 33 States, with 10 companies having 55 operations accounting for 75% of the output. Distribution of production was Frasch sulfur 55%, recovered elemental sulfur 34%, and the contained sulfur in other production 11%. Production was concentrated in Texas and Louisiana. Together, these two States accounted for 67% of the total output.

Shipments of sulfur in all forms to domestic and export markets increased 4% above those in 1976. Frasch and elemental sulfur accounted for 89% of the total shipments of sulfur in all forms in 1977. The total value of shipments f.o.b. mine or plant was $485.9 million in 1977 compared with

Table 1.—Salient sulfur statistics

(Thousand long tons, sulfur content, and thousand dollars unless otherwise noted)

	1973	1974	1975	1976	1977
United States:					
Production:					
Frasch	7,605	7,901	7,211	6,264	5,822
Recovered elemental	2,416	2,632	2,969	3,138	3,567
Other forms	900	886	1,079	1,305	1,169
Total	10,921	11,419	11,259	10,707	10,558
Shipments:					
Frasch	7,438	7,898	6,077	5,860	5,935
Recovered elemental	2,451	2,547	2,902	3,146	3,570
Other forms	900	886	1,079	1,305	1,169
Total	10,789	11,331	10,058	10,311	10,674
Exports, crude and refined	1,776	2,663	1,352	1,270	1,178
Imports, elemental	1,222	2,150	1,897	1,727	1,977
Consumption, apparent all forms[1]	10,235	10,818	10,603	10,768	11,473
Stocks, Dec. 31: Producer, Frasch and elemental	3,927	3,957	5,126	5,563	5,469
Value:					
Shipments, f.o.b. mine or plant:					
Frasch	$138,578	$241,066	$304,843	$299,999	$294,733
Recovered elemental	37,873	60,599	104,886	118,322	133,849
Other forms	31,363	35,422	50,053	59,050	57,304
Total	207,814	337,087	459,782	477,371	485,886
Exports, crude[2]	$34,330	$95,516	$69,553	$60,226	$47,599
Imports, elemental[2]	$14,871	$51,124	$70,848	$59,494	$65,154
Price, elemental, dollars per long ton, f.o.b. mine or plant	$17.84	$28.88	$45.63	$46.45	$45.09
World production: All forms (including pyrites)	47,437	50,345	[r]49,397	[r]49,697	50,649

[r]Revised. NA Not available.
[1]Measured by shipments, plus imports, minus exports.
[2]Declared customs valuation.

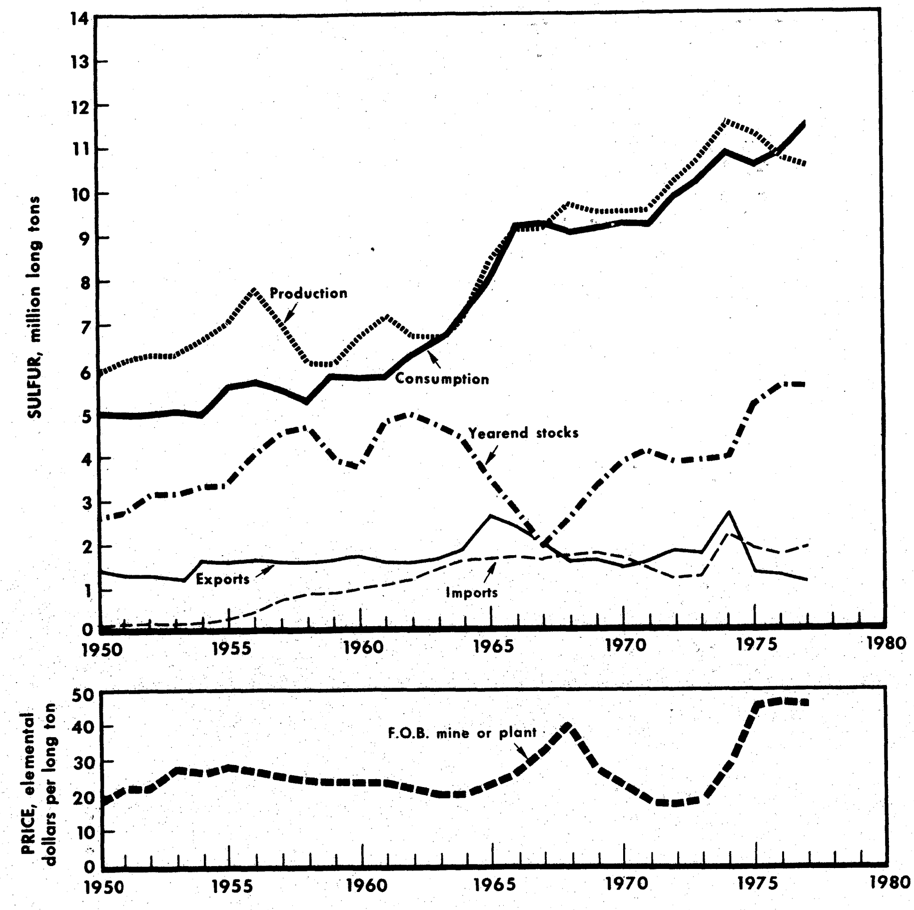


Figure 1.—Trends in the sulfur industry in the United States.

$477.4 million in 1976, an increase of 2%. Eighty-nine percent of the shipments was for domestic consumption and 11% for export. Shipments of sulfur in all forms in 1977 were 1% more than the quantity produced. Producers' yearend stocks of Frasch and recovered elemental sulfur were almost 2% less than those at yearend 1976.

The apparent domestic consumption of sulfur in all forms increased 7% over that of 1976. Sulfur for domestic consumption was obtained mainly from domestic sources: Frasch 43%, recovered elemental 30%, and sulfur in other forms 10%. The remaining 17% of the sulfur was obtained by imports of Frasch and recovered elemental sulfur.

The United States was a net importer again in 1977. Exports of sulfur in all forms decreased 7% from those of 1976. Imports of sulfur in all forms in 1977 were 14% greater than in 1976.

DOMESTIC PRODUCTION

Frasch Sulfur.—Output of Frasch sulfur was 55% of the domestic production of sulfur in all forms in 1977, compared with 59% in 1976.

In 1977, there were 11 Frasch mines, all in Texas and Louisiana. Producers and mines in Louisiana were Freeport Minerals Co. at Garden Island Bay, Grand Isle, and Grand Ecaille; and Texasgulf, Inc., at Bully Camp. Producers and mines in Texas were Farmland Industries, Inc. at Fort Stockton; Duval Corp. at Culberson; Jefferson Lake Sulfur Co. at Long Point Dome; and Texasgulf, Inc., at Boling Dome, Fannett Dome, Moss Bluff Dome, and at Comanche Creek. Production was stopped at Fannett Dome in February.

The nine mines operated by Duval Corp., Freeport Minerals Co., and Texasgulf, Inc., accounted for most of the Frasch sulfur production. A relatively small portion of the output was from the other two producers operating one mine each.

Production was again concentrated in the larger low-cost mines to counteract increasing production costs. The five largest mines, with four having a production rate in excess of one-half million tons per year each, accounted for 83% of the total Frasch sulfur production, compared with 82% in 1976. These mines also accounted for 46% of the total output of sulfur in all forms in 1977, compared with 48% in 1976.

Producers' shipments of Frasch sulfur were 1% more than in 1976. Approximately 18% of the total shipments were for export and 82% were for the domestic market, compared with 20% and 80%, respectively, in 1976. Shipments were greater than production for the first time since 1972. Producers' reported stocks after inventory adjustments were 2% less than at yearend 1976. The value of Frasch sulfur shipments, f.o.b. mine, decreased almost 2% below that of 1976.

Table 2.—Production of sulfur and sulfur-containing raw materials by producers in the United States

(Thousand long tons)

	1974		1975		1976		1977	
	Gross weight	Sulfur content	Gross weight	Sulfur content	Gross weight	Sulfur content	Gross weight	Sulfur content
Frasch sulfur	7,901	7,901	7,211	7,211	6,264	6,264	5,822	5,822
Recovered elemental sulfur	2,632	2,632	2,969	2,969	3,138	3,138	3,567	3,567
Byproduct sulfuric acid (basis 100%) produced at copper, zinc, and lead plants	2,001	654	2,345	767	2,881	942	2,890	945
Pyrites	424	162	625	237	750	286	435	166
Other forms[1]	82	70	110	75	116	77	84	58
Total	XX	11,419	XX	11,259	XX	10,707	XX	10,558

XX Not applicable.
[1]Hydrogen sulfide and liquid sulfur dioxide.

Table 3.—Sulfur produced and shipped from Frasch mines in the United States

(Thousand long tons and thousand dollars)

Year	Production			Shipments	
	Texas	Louisiana	Total	Quantity	Value[1]
1973	4,294	3,311	7,605	7,438	138,578
1974	4,593	3,308	7,901	7,898	241,066
1975	4,141	3,070	7,211	6,077	304,843
1976	3,777	2,487	6,264	5,860	299,999
1977	3,400	2,422	5,822	5,935	294,733

[1]F.o.b. mine.

Recovered Sulfur.—Production of recovered elemental sulfur, a nondiscretionary byproduct from natural gas and petroleum refinery operations, accounted for 34% of the total domestic production of sulfur in all forms compared with 29% in 1976. Production reached an alltime high with an increase of 14% over that recorded in 1976, indicating the continuing increase in importance of recovered sulfur as a source of domestic supply. This type of sulfur was produced by 56 companies at 146 plants in 29 States, 2 plants in Puerto Rico, and 1 in the Virgin Islands. Most of the plants were relatively small, with only five reporting an annual production exceeding 100,000 tons. The 10 largest plants accounted for 38% of the output. By source, 61% was produced by 39 companies at 83 refineries or satellite plants treating refinery gases, and 1 coking operation; 39% was produced by 29 companies at 62 natural gas treatment plants. The five largest recovered elemental sulfur producers were Chevron U.S.A., Inc.; Exxon Co., U.S.A.; Mallard Exploration, Inc.; Shell Oil Co.; and Standard Oil Co. (Indiana). Together, their 37 plants accounted for 54% of recovered elemental sulfur production in 1977.

The leading States in production of recovered elemental sulfur were Texas, California, Florida, Mississippi, and Alabama. Together these States contributed 67% of the total 1977 output. Compared with that of 1976, production in 1977 increased by 36% in Alabama, 18% in Mississippi, 16% in California, 15% in Texas, and 7% in Florida. Recovery of sulfur in Alabama,

Table 4.—Recovered sulfur produced and shipped in the United States

(Thousand long tons and thousand dollars)

Year	Production			Shipments	
	Natural gas plants	Petroleum refineries	Total[1]	Quantity	Value[2]
1973	1,046	1,370	2,416	2,451	37,873
1974	1,219	1,414	2,632	2,547	60,599
1975	1,342	[3]1,627	2,969	2,902	104,886
1976	1,277	[3]1,860	3,138	3,146	118,322
1977	1,404	[3]2,163	3,567	3,570	133,849

[1]Data may not add to totals shown because of independent rounding.
[2]F.o.b. plant.
[3]Includes a small quantity from coking operations.

Table 5.—Recovered sulfur produced and shipped in the United States, by State

(Thousand long tons and thousand dollars)

State	1976			1977		
	Production (quantity)	Shipments		Production (quantity)	Shipments	
		Quantity	Value		Quantity	Value
Alabama	206	206	9,441	280	280	12,761
California	432	432	7,940	499	499	9,398
Florida	307	308	W	327	326	W
Illinois and Indiana	220	223	7,470	244	242	8,469
Kansas	7	7	253	5	5	157
Louisiana	123	122	6,228	157	157	7,281
Michigan and Minnesota	60	58	1,867	73	75	2,375
Mississippi	245	224	11,264	289	335	16,655
New Jersey	107	108	5,043	128	126	5,920
New Mexico	45	45	1,480	57	57	1,782
Ohio	16	17	714	23	22	965
Oklahoma	9	9	324	10	10	364
Pennsylvania	91	91	3,876	82	81	3,467
Texas	872	872	34,397	1,007	982	38,709
Wisconsin	([1])	([1])	3	2	1	23
Wyoming	44	51	W	45	48	W
Other States[2]	352	374	28,021	338	321	25,522
Total[3]	3,138	3,146	118,322	3,567	3,570	133,849

W Withheld to avoid disclosing company proprietary data; included with "Other States."
[1]Less than 1/2 unit.
[2]Combined to avoid disclosing company proprietary data; includes Arkansas, Colorado (1977), Delaware, Kentucky (1977), Missouri, Montana, New York, North Dakota, Utah, Virginia, Washington, Virgin Islands, and Puerto Rico.
[3]Data may not add to totals shown because of independent rounding.

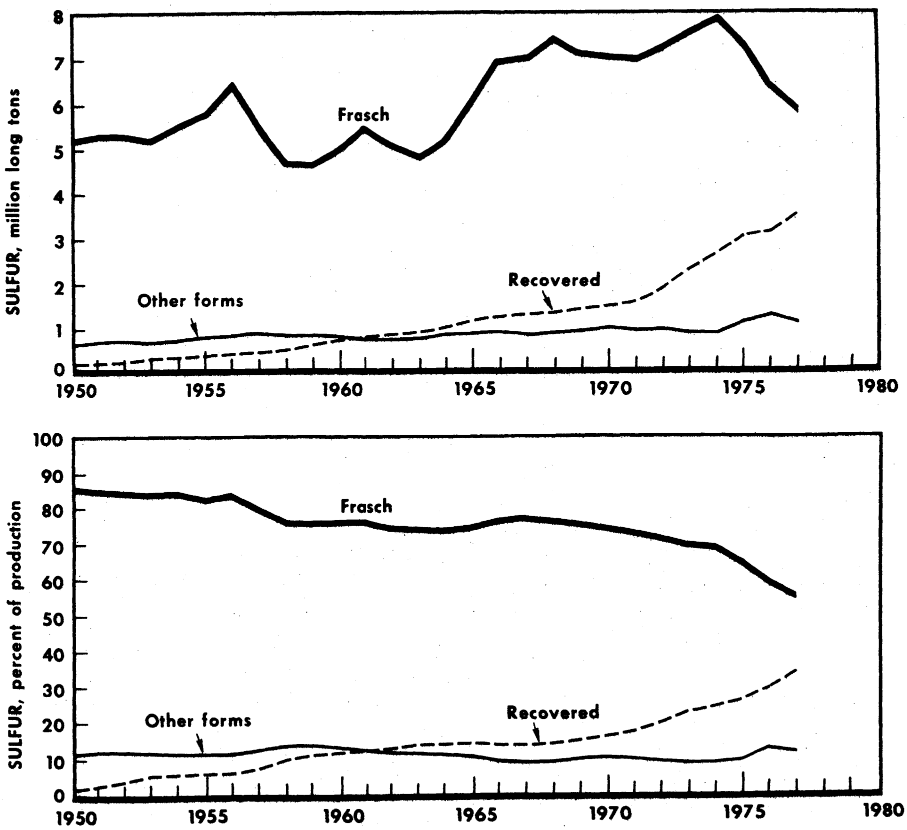


Figure 2.—Trends in the production of sulfur in the United States.

Florida, and Mississippi was mainly from the treatment of dry sour natural gas and sour natural gas associated with petroleum in the deep Jurassic formations. Indications were of further increases in sulfur recovery in future years. The total value of shipments of recovered elemental sulfur in 1977 increased 13% to an alltime high of almost $134 million.

Byproduct Sulfuric Acid.—Sulfur contained in byproduct sulfuric acid produced at copper, lead, and zinc smelters and roasters during 1977 was 9% of the total domestic production of sulfur, unchanged from 1976. The total output and value were slightly higher than in 1976 and each reached an alltime high. Byproduct sulfuric acid was produced by 13 companies at 24 plants in 13 States. Fourteen acid plants operated in conjuction with copper smelters and 10 plants were accessories to lead and zinc roasting and smelting operations. The five largest acid plants accounted for 48% of the output, and production in five States was 82% of the total. The five largest producers of byproduct sulfuric acid were ASARCO Incorporated, Magma Copper Co., Kennecott Copper Corp., Phelps Dodge Corp., and St. Joe Minerals Corp., whose 14 plants produced 74% of the byproduct sulfuric acid in 1977.

Table 6.—Byproduct sulfuric acid[1] (sulfur content) produced in the United States

(Thousand long tons and thousand dollars)

Year	Copper plants[2]	Lead and zinc plants[3]	Total	Value
1973	318	282	600	24,175
1974	373	281	654	29,370
1975	521	246	767	42,956
1976	666	276	942	46,181
1977	688	257	945	46,236

[1]Includes acid from foreign materials.
[2]Excludes acid made from pyrites concentrates.
[3]Excludes acid made from native sulfur.

Pyrites, Hydrogen Sulfide, and Sulfur Dioxide.— Sulfur contained in pyrites, hydrogen sulfide, and sulfur dioxide represented 2% of the total production of sulfur. The total sulfur content in these products was 38% less than that of 1976, and the value of shipments was 14% lower. Pyrites was produced by three companies at three mines in three States; hydrogen sulfide by three companies at four plants in three States; and sulfur dioxide by two companies at two plants in two States. The three largest producers of these products were Cities Service Co., (pyrites and sulfur dioxide), Lion Oil Co. (hydrogen sulfide), and Shell Oil Co. (hydrogen sulfide). These companies combined, at one mine and four plants, accounted for 92% of the contained sulfur produced in the form of these products.

Table 7.—Pyrites, hydrogen sulfide, and sulfur dioxide sold or used in the United States

(Thousand long tons sulfur content and thousand dollars)

Year	Pyrites	Hydrogen sulfide and sulfur dioxide	Total	Value
1973	212	88	300	7,188
1974	162	70	232	6,052
1975	237	75	312	7,097
1976	286	77	363	12,869
1977	166	58	224	11,068

CONSUMPTION AND USES

In 1977, apparent domestic consumption of sulfur in all forms was 11.5 million tons, 7% greater than in 1976. Eighty-three percent of this consumption was from domestic sources compared with 84% in 1976. The supply sources of sulfur were domestic Frasch sulfur, almost 43% compared with 43% in 1976; domestic recovered elemental sulfur, 30% compared with 29% in 1976; and combined domestic byproduct sulfuric acid, pyrites, hydrogen sulfide, and sulfur dioxide, 10% compared with 12% in 1976. The remaining 17% of the sulfur was from imports of Frasch and recovered elemental sulfur compared with 16% in 1976.

The apparent sales of domestic Frasch sulfur to domestic consumers increased 202,000 tons, or 4% higher than shipments in 1976. Shipments of recovered elemental sulfur for domestic consumption increased by 389,000 tons, or 13% over those in 1976. Reported sales of sulfur contained in byproduct sulfuric acid, pyrites, hydrogen sulfide, and sulfur dioxide decreased 136,000 tons or 10% below those in 1976. Total supplies of domestic sulfur in all forms to the domestic market increased by 455,000 tons, or 5% more than in 1976. Imports of Frasch and recovered elemental sulfur increased 250,000 tons, 14% greater than in 1976. By source, imports of Frasch sulfur from Mexico increased 38,000 tons; imports of recovered elemental sulfur from Canada increased 198,000 tons, and from other countries, almost 15,000 tons.

The Bureau of Mines continued to collect data on the end uses of sulfur and sulfuric acid by Standard Industrial Classification (SIC) of industrial activities. In 1977, 63 elemental sulfur and 73 sulfuric acid producing companies responded to the canvass. Of the foregoing companies, 16 reported shipments of both sulfur and sulfuric acid.

Producers of sulfur who responded to the canvass reported shipments of 12.2 million long tons of sulfur in 1977. Of these reported shipments, 1.0 million tons were for export. The largest use, sulfuric acid production, increased 19% to 9.4 million tons, and represented 85% of shipments for domestic consumption compared with 84% in 1976. Shipments in 1977 of sulfur for other industrial inorganic chemicals decreased 36%; synthetic rubber, cellulosic fibers, and other plastic products decreased 25%; paints and allied products, explosives, industrial organic chemicals, and other chemical products increased 208%; petroleum refining and petroleum and coal products increased 30%; pulp and paper products increased 32%; and agricultural chemicals increased 188%. Some companies did not identify shipments by end use. Some of the identified end uses were tabulated with the unidentified uses because of company confidentiality.

Reported shipments of 100% sulfuric acid increased 13% to 37.9 million short tons in 1977. Shipments of acid for phosphatic fertilizers, the largest end use and 59% of the total, were up 13% to 22.4 million tons. Reported shipments for the category "Other chemical products" were 1.0 million tons compared with 2.9 million tons in 1976. Respondents' reports in 1977 showed a more detailed breakdown of shipments than in

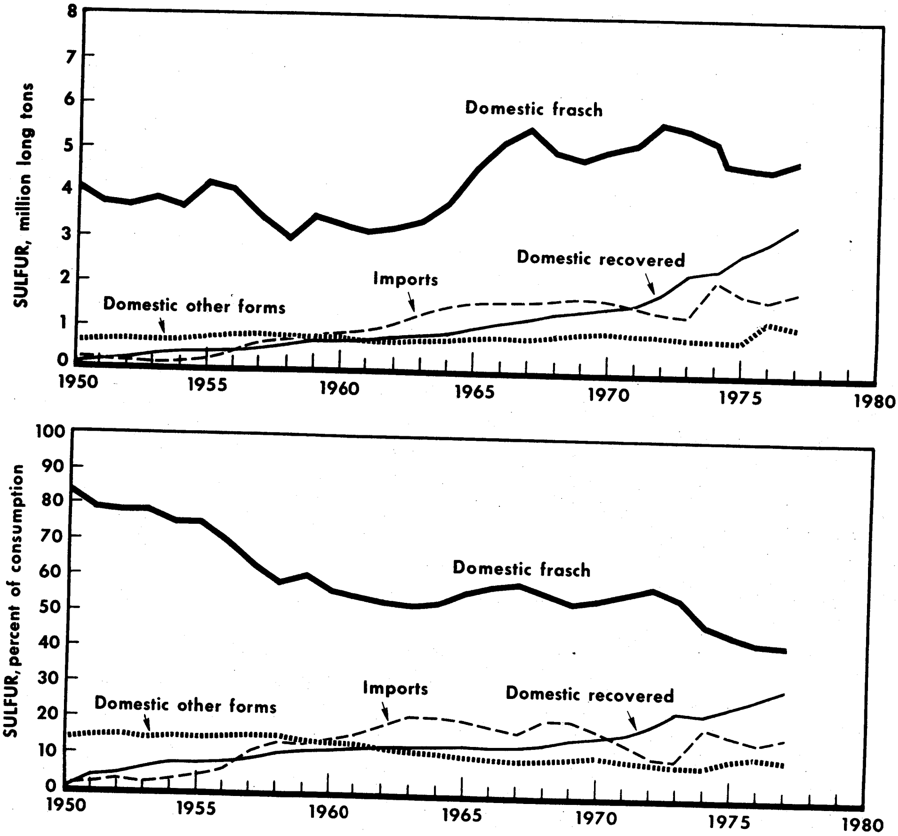


Figure 3.—Trends in the consumption of sulfur in the United States.

prior years. Because of the change in reporting, shipments were greater for most chemical use categories, particularly for other inorganic chemicals and industrial organic chemicals. Petroleum refining and other petroleum and coal production received 2.6 million tons of acid or 7% of the shipments of sulfuric acid in 1977, up 28%. The petroleum refining industry was a net user of about 1.3 million tons of sulfuric acid.

Usage of acid for copper ore leaching increased from 1.8 million tons in 1976 to 2.0 million tons in 1977, representing 5% of the total shipments. Shipments for other categories are shown in table 10. Several end uses for sulfuric acid such as food products, automotive and electrical equipment, rubber, and metal fabrication were tabulated with "Unidentified" because of company confidentiality.

Of the total in 1977 of 2.6 million short tons of spent acid returned for reclaiming, 211,000 tons or 8% was from the production of industrial organic chemicals. Petroleum refineries accounted for 50% of the total spent acid returned for reclaiming. The remaining reclaimed acid was from production of plastic materials, nonferrous metals, phosphatic fertilizers, paints and allied products, other chemical products, inorganic pigments, soaps and detergents, explosives, other agricultural chemicals, other inorganic chemicals, other ores, pesticides, and steel pickling.

Table 11 shows the domestic uses of sulfur including the sulfur contained in sulfuric acid. The largest identified end use in 1977 for sulfur (as sulfuric acid) was the 51% for phosphatic fertilizers. Other uses were for other chemical products (2%), petroleum refining and other petroleum and coal products (7%), and other inorganic chemicals (7%). Sulfur used for copper ore processing (as sulfuric acid) increased 9% from 533,000 tons in 1976 to 579,000 tons, 5% of the total in 1977.

Table 8.—Apparent consumption of sulfur in the United States[1]

(Thousand long tons)

	1973	1974	1975	1976	1977
Frasch:					
Shipments	7,438	7,898	6,077	5,860	5,935
Imports	302	954	967	731	769
Exports	1,776	2,601	1,295	1,198	1,071
Total	5,964	6,251	5,749	5,393	5,633
Recovered:					
Shipments	2,451	2,547	2,902	3,146	3,570
Imports	920	1,196	930	996	1,208
Exports from the Virgin Islands	--	62	57	72	107
Total	3,371	3,681	3,775	4,070	4,671
Pyrites	212	162	237	286	166
Byproduct sulfuric acid	600	654	767	942	945
Other forms[2]	88	70	75	77	58
Total all forms	10,235	10,818	10,603	10,768	11,473

[1]Crude sulfur or sulfur content.
[2]Includes consumption of hydrogen sulfide and liquid sulfur dioxide.

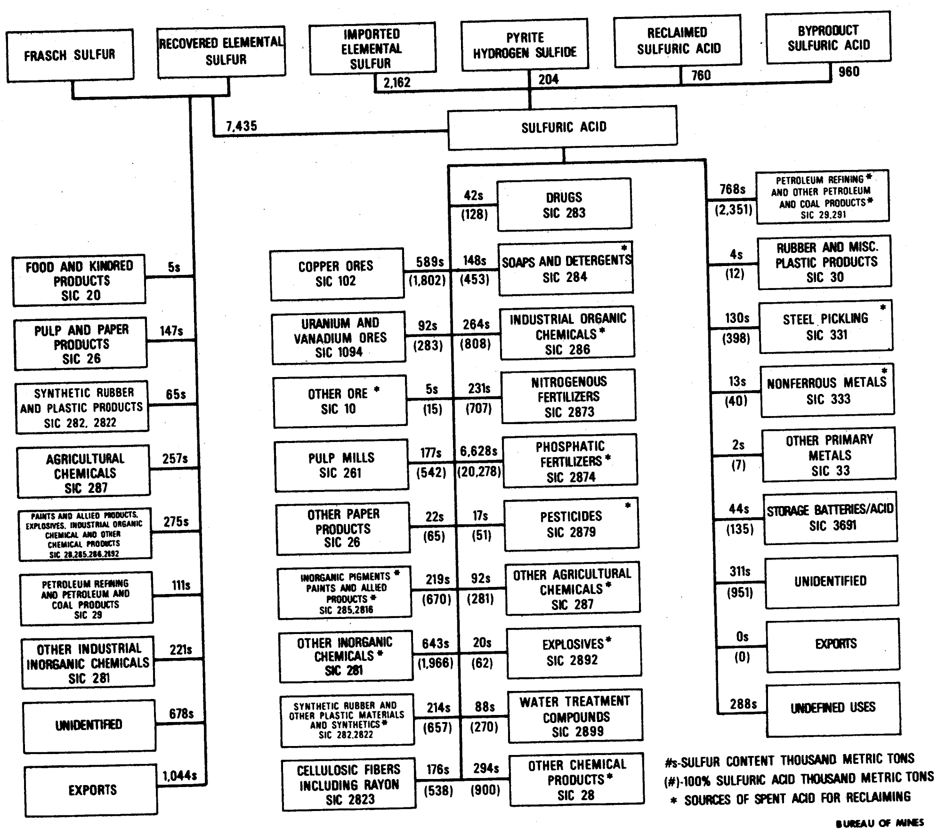


Figure 4.—Sulfur-sulfuric acid supply and end-use relationship, 1977.

Table 9.—Elemental sulfur sold or used in the United States, by end use

(Thousand long tons)

SIC	Use	1976	1977
20	Food and kindred products	4	5
26	Pulp and paper products	110	145
282, 2822, 2823	Synthetic rubber, cellulosic fibers and other plastic products[1]	85	64
287	Agricultural chemicals	88	253
28, 285, 2892, 286	Paints and allied products, explosives, industrial organic chemicals, and other chemical products[2]	88	271
29	Petroleum refining and petroleum and coal products	84	109
281	Other industrial inorganic chemicals	337	217
30	Rubber and miscellaneous plastic products	10	([3])
	Sulfuric acid:		
	Domestic sulfur	7,047	7,318
	Imported sulfur	873	2,128
	Total sulfuric acid	7,920	9,446
	Unidentified	660	667
	Total domestic uses	9,386	11,177
	Exports	1,169	1,027
	Total	10,555	12,204

[1]Includes cellulosic fibers 1976.
[2]Includes explosives 1977.
[3]Included in "Unidentified."

Table 10.—Sulfuric acid sold or used in the United States, by end use

(Thousand short tons of 100% H_2SO_4)

SIC	Use	Quantity 1976	Quantity 1977
102	Copper ores	1,829	1,986
1094	Uranium and vanadium ores	309	312
10	Other ores	11	16
261	Pulp mills	511	598
26	Other paper products	43	72
285, 2816	Inorganic pigments and paints and allied products	600	738
281	Other inorganic chemicals	783	2,167
282, 2822	Synthetic rubber and other plastic materials and synthetics	408	724
2823	Cellulosic fibers including rayon	359	593
283	Drugs	127	141
284	Soaps and detergents	393	499
286	Industrial organic chemicals	470	891
2873	Nitrogenous fertilizers	494	779
2874	Phosphatic fertilizers	19,696	22,353
2879	Pesticides	18	56
287	Other agricultural chemicals	305	310
2892	Explosives	109	68
2899	Water treating compounds	272	298
28	Other chemical products	2,895	992
29, 291	Petroleum refining and other petroleum and coal products	2,026	2,592
30	Rubber and miscellaneous plastic products	([1])	13
331	Steel pickling	325	439
333	Nonferrous metals	60	44
33	Other primary metals	11	8
3691	Storage batteries/acid	114	149
	Unidentified	1,381	1,048
	Total domestic	[2]33,550	37,886
	Exports	28	--
	Total	33,578	37,886

[1]Included in "Unidentified."
[2]Data do not add to total shown because of independent rounding.

Table 11.—Sulfur and sulfuric acid sold or used in the United States, by end use

(Thousand tons sulfur content)

SIC	Use	Elemental sulfur[1] 1976	Elemental sulfur[1] 1977	Sulfuric acid (sulfur equivalent) 1976	Sulfuric acid (sulfur equivalent) 1977	Total 1976	Total 1977
102	Copper ores	--	--	533	579	533	579
1094	Uranium and vanadium ores	--	--	90	91	90	91
10	Other ores	--	--	3	5	3	5
20	Food and kindred products	4	5	--	--	4	5
261, 26	Pulpmills and paper products	110	145	162	195	272	340
2816, 285 2892, 28, 286	Inorganic pigments, paints and allied products, explosives, industrial organic chemicals, and other chemical products	88	[2]271	175	215	263	486
281	Other inorganic chemicals	337	217	228	632	565	849
2822, 2823, 282	Synthetic rubber, cellulosic fibers, other plastic materials and synthetics[3]	85	64	224	384	309	448
283	Drugs	--	--	37	41	37	41
284	Soaps and detergents	--	--	115	146	115	146
286	Industrial organic chemicals	--	--	137	260	137	260
2873	Nitrogenous fertilizers	--	--	144	227	144	227
2874	Phosphatic fertilizers	--	--	5,741	6,516	5,741	6,516
2879	Pesticides	--	--	5	16	5	16
287	Other agricultural chemicals	88	253	89	90	177	343
2892	Explosives	--	--	32	20	32	20
2899	Water treating compounds	--	--	79	87	79	87
28	Other chemical products	--	--	844	289	844	289
29, 291	Petroleum refining and other petroleum and coal products	84	109	591	756	675	865
30	Rubber and miscellaneous plastic products	10	([4])	([4])	4	10	4
331	Steel pickling	--	--	95	128	95	128
333	Nonferrous metals	--	--	17	13	17	13
33	Other primary metals	--	--	3	2	3	2
3691	Storage batteries	--	--	33	43	33	43
	Exported sulfuric acid	--	--	8	--	8	--
	Subtotal	806	1,064	9,385	10,739	10,191	11,803
	Unidentified	660	667	403	305	1,063	972
	Total	1,466	1,731	9,788	11,044	11,254	12,775

[1]Does not include elemental sulfur used for production of sulfuric acid.
[2]Includes explosives 1977.
[3]Includes cellulosic fibers 1976.
[4]Included in "Unidentified."

STOCKS

Yearend producers' stocks of Frasch sulfur decreased 2%, but recovered elemental sulfur stocks were essentially unchanged. The combined yearend stocks amounted to approximately a 6.9-month supply based on 1977 domestic and export demands for domestically produced Frasch and recovered elemental sulfur.

Table 12.—Producers' yearend stocks

(Thousand long tons)

Year	Frasch	Recovered	Total
1973	3,816	111	3,927
1974	3,744	213	3,957
1975	4,857	269	5,126
1976	5,297	266	5,563
1977	5,204	265	5,469

PRICES

The quoted price for liquid sulfur exterminal Tampa, Fla., was $61 to $65 per long ton at yearend 1977. There were price decreases in other markets.

On the basis of shipments and total value reported to the Bureau of Mines, the average value of shipments of Frasch sulfur f.o.b. mine for both domestic consumption and exports during 1977 dropped 3% to $49.66 per ton in 1977 from $51.19 per ton in 1976. The recovered elemental sulfur industry was in a less favorable marketing position to obtain full benefit of the higher sulfur prices. This market was subject to regional competitive forces. Also, as a nondiscretionary byproduct there was a general tendency to sell sulfur in local markets where sales were more dependent upon the industrial sector. Shipment values varied widely in different regions; lowest in the West, somewhat higher in the midcontinent, and near the values for Frasch sulfur in the East and South. Overall, the reported unit shipment values for recovered elemental sulfur, f.o.b. plant, in 1977 were $37.50 per ton, compared with $37.61 per ton in 1976.

The marketing of sulfur produced in other than the elemental form reflected competitive positions in the limited regional markets for these products. In 1977, the average price per ton of sulfur contained in byproduct sulfuric acid remained nearly the same as in 1976 at about $49. The average unit value for sulfur contained in pyrites, hydrogen sulfide, and sulfur dioxide, combined, increased 39% to $49.41 per ton compared with 1976.

Table 13.—Reported sales values of shipments of elemental sulfur, f.o.b. mine or plant

(Dollars per long ton)

Year	Frasch	Recovered	Total
1973	18.63	15.45	17.84
1974	30.52	23.79	28.88
1975	50.16	36.14	45.63
1976	51.19	37.61	46.45
1977	49.66	37.50	45.09

FOREIGN TRADE

The United States was a net importer of sulfur in 1977, for the third year. Exports were down 7% to about 1.2 million tons. Imports in the form of elemental sulfur increased 14% to 2.0 million tons. The net import balance in 1977 was 799,000 tons compared with 457,000 tons in 1976.

Exports from the United States were almost entirely in the form of Frasch sulfur. The tonnage of crude sulfur exported in 1977 was 10% less than in 1976. Exports of refined sulfur dropped 20%. The total value of exports declined 21% below that of 1976. The reported average export value of crude sulfur was $44.95 per ton in 1977 compared with $50.91 in 1976, a decrease of 12%. Belgium-Luxembourg and the Netherlands received 83% of the exports, mainly for transshipment to other European Community Countries. Brazil was the third largest customer, receiving 7% of the exports. Not included in the foregoing were exports from the Virgin Islands, which were 107,000 tons valued at $5.5 million in 1977.

Imports of Frasch sulfur from Mexico increased from 731,000 tons in 1976 to 769,000 tons in 1977. Imports of recovered elemental sulfur, mostly from Canada, increased 21%. Imports from Canada totaled 1.2 million tons, and imports from Japan were 25,000 tons. The unit value of imports of sulfur from Canada declined $2.52 to $15.78, whereas the value of imports from Mexico increased $2.47 to $59.07 in 1977.

Table 14.—U.S. exports of sulfur

(Thousand long tons and thousand dollars)

Year	Crude		Refined	
	Quantity	Value	Quantity	Value
1973	1,771	34,330	5	1,461
1974[1]	2,580	95,516	21	1,829
1975[1]	1,288	69,553	7	2,248
1976[1]	1,183	60,226	15	3,358
1977[1]	1,059	47,599	12	4,512

[1]Excludes exports from the Virgin Islands to foreign countries: 1974—61,556 long tons ($1,891,142); 1975—56,632 long tons ($3,172,094); 1976—71,643 long tons ($3,516,220); 1977—106,756 long tons ($5,536,861); see table 16.

Table 15.—U.S. exports of crude sulfur, by country

(Thousand long tons and thousand dollars)

Destination	1976		1977	
	Quantity	Value	Quantity	Value
Argentina	21	1,122	12	548
Belgium-Luxembourg	599	30,019	504	20,429
Brazil	118	6,539	73	3,345
Canada	58	1,813	19	881
Colombia	1	66	(1)	7
France	--	--	26	1,017
Greece	23	1,341	(1)	1
Honduras	1	60	--	--
Mexico	3	70	1	24
Netherlands	283	15,249	378	19,106
New Zealand	51	2,616	26	1,252
Peru	7	379	(1)	2
Spain	6	266	--	--
Trinidad and Tobago	--	--	7	362
Uruguay	7	400	13	572
Other	5	r286	(1)	53
Total[2]	1,183	60,226	1,059	47,599

rRevised.
[1]Less than 1/2 unit.
[2]Excludes exports from the Virgin Islands to foreign countries: 1976—71,643 long tons ($3,516,220); 1977—106,756 long tons ($5,536,861); see table 16.

Table 16.—Sulfur exported from the Virgin Islands to foreign countries

(Thousand long tons and thousand dollars)

Country	1976		1977	
	Quantity	Value	Quantity	Value
Brazil	22	937	10	365
Italy	10	461	28	1,044
Jamaica	2	68	2	90
Morocco	--	--	12	426
South Africa, Republic of	38	2,050	55	3,612
Total	72	3,516	107	5,537

Table 17.—U.S. imports of elemental sulfur, by country

(Thousand long tons and thousand dollars)

Country	1976		1977	
	Quantity	Value	Quantity	Value
Canada	969	17,728	1,167	18,414
Germany, Federal Republic of	(1)	20	(1)	116
Japan	26	343	25	348
Mexico	731	41,378	769	45,422
Venezuela	--	--	16	853
Other	1	25	(1)	1
Total	1,727	59,494	1,977	65,154

[1]Less than 1/2 unit.

WORLD REVIEW

World production of sulfur increased slightly in 1977. Although demand increased about 8%, production of sulfur continued to exceed usage. World producers' stocks increased more than 1 million tons.

Canada.—Production of sulfur in all forms totaled 7.2 million tons in 1977, little changed from 1976. Recovered elemental sulfur, representing 89% of the total output, was produced at 45 sour natural gas plants, 42 in Alberta, 2 in British Columbia, and 1 in Saskatchewan. The remaining production, mostly from metal smelter gases, was essentially unchanged.[2]

Production of sulfur in Alberta increased about 70,000 tons to 6.4 million in 1977. Of this total output, almost 100,000 tons was from tar sands, 16,000 was from refinery output, and the remainder was from natural gas operations. Exports of elemental sulfur increased from 3.7 million tons in 1976 to 4.3 million tons in 1977. Of these shipments, 3.1 million tons was to offshore markets other than the United States, up from 2.7 million tons in 1976. Producers' stocks rose from 18.5 million tons at the end of 1976 to 19.8 million tons at the end of 1977.

The average value of marketed sulfur, f.o.b. plant, was $15.89 per ton in December 1977 down from $16.21 in December 1976.[3]

Cyprus.—A fertilizer complex was planned for Cyprus. The complex will include a 180,000-ton-per-year sulfuric acid plant to take advantage of the pyrite resources.[4]

France.—Production of sulfur in 1977 was about 2.1 million tons. Production of sulfuric acid increased about 15%.

Japan.—Capacity to produce recovered elemental sulfur from imported oil was 2.1 million tons in 1977. Sulfur recovery at refineries was 1.1 million tons in 1977.

Mexico.—Production of Frasch sulfur was 1.7 million tons in 1977, down from the 2.0 million tons in 1976. Capacity to produce recovered elemental sulfur from oil and gas is being expanded, and output may reach 300,000 tons per year by 1985.[5]

Poland.—The first sulfur mine in the Lubaczow sulfur basin in Przcmysl Province started production.

Table 18.—Sulfur: World production in all forms, by country and source

(Thousand long tons)

Country[1] and source[2]	1975	1976	1977[p]
Algeria, byproduct, petroleum and natural gas	10	10	15
Argentina:			
Native (from caliche)	10	20	19
Byproduct, all sources	22	18	20
Total	32	38	39
Australia:[3]			
Pyrite[4]	r105	107	106
Byproduct:			
Metallurgy[5]	137	141	133
Petroleum	9	6	7
Total	r251	254	246
Austria:			
Byproduct:			
Metallurgy	8	8	8
Petroleum and natural gas	r16	17	24
Gypsum	28	23	26
Total	r52	48	58
Bahamas: Byproduct, petroleum	10	5	5
Bahrain: Byproduct, petroleum	24	10	15
Belgium: Byproduct, all sources[6]	193	244	253
Bolivia:[7] Native[8]	22	15	6
Brazil:[2] [9] Byproduct, petroleum	19	29	44
Bulgaria:			
Pyrite[e]	r167	r276	300
Byproduct, all sources[e]	r76	r59	64
Total[e]	r243	r335	364

See footnotes at end of table.

Table 18.—Sulfur: World production in all forms, by country and source —Continued

(Thousand long tons)

Country[1] and source[2]	1975	1976	1977[p]
Canada:			
Pyrite	10	15	9
Byproduct:			
Metallurgy	684	694	724
Natural gas	6,469	6,102	6,201
Petroleum	170	197	197
Tar sands	84	99	98
Total	7,417	7,107	7,229
Chile:[7]			
Native:			
Refined	5	16	5
From caliche	16	1	26
Byproduct, metallurgy	26	29	26
Total	47	46	57
China, People's Republic of:			
Native[e]	[r]88	[r]88	89
Pyrite[e]	[r]886	[r]886	935
Byproduct, all sources[e]	[r]79	[r]89	98
Total[e]	[r]1,053	[r]1,063	1,122
Colombia:			
Native	30	26	22
Byproduct, petroleum	[r]1	2	3
Total	[r]31	28	25
Cuba:			
Pyrite[e]	20	20	20
Byproduct, petroleum[e]	8	8	8
Total[e]	28	28	28
Cyprus:[10] Pyrite	97	94	78
Czechoslovakia:			
Native	10	12	5
Pyrite	66	49	54
Byproduct, all sources	60	10	8
Total	136	71	67
Denmark: Byproduct, petroleum	[r]8	10	11
Ecuador:			
Native	([11])	1	1
Byproduct:			
Natural gas[e]	3	3	3
Petroleum[e]	[r]5	[r]5	5
Total[e]	[r]8	[r]9	9
Egypt:[3] [9] Byproduct, petroleum and natural gas	[r]10	5	5
Finland:			
Pyrite	242	230	231
Byproduct:			
Metallurgy	[r]340	360	305
Petroleum[e]	15	25	25
Total	597	615	561
France:			
Byproduct:			
Natural gas[12]	1,764	1,709	1,881
Petroleum[12]	91	87	88
Unspecified[13]	107	141	157
Total	1,962	1,937	2,126
German Democratic Republic:			
Pyrite[e]	[r]10	[r]10	10
Byproduct, all sources[14]	349	239	335
Total[e]	[r]359	[r]249	345

See footnotes at end of table.

Table 18.—Sulfur: World production in all forms, by country and source —Continued

(Thousand long tons)

Country[1] and source[2]	1975	1976	1977[p]
Germany, Federal Republic of:			
Pyrite	217	229	231
Byproduct:			
Metallurgy[15]	355	384	379
Natural gas[12]	378	453	621
Petroleum[12]	[r]113	117	183
Unspecified	199	158	162
Total	[r]1,262	1,341	1,576
Greece:			
Pyrite	[r]72	96	75
Byproduct, petroleum[e]	3	3	3
Total[e]	[r]75	[r]99	78
Hungary:			
Pyrite[e]	3	3	3
Byproduct, all sources	9	8	8
Total[e]	12	[r]11	11
India:[3]			
Pyrite	[r]18	19	14
Byproduct:			
Metallurgy[e]	[r]125	[r]109	115
Petroleum	6	7	7
Total[e]	[r]149	[r]135	136
Indonesia:[10] Native	4	3	2
Iran:			
Native[e]	20	20	20
Byproduct, petroleum and natural gas	467	392	518
Total[e]	487	[r]412	538
Iraq:			
Frasch	591	600	611
Byproduct, petroleum and natural gas[e]	108	64	54
Total[e]	699	664	665
Ireland: Pyrite	32	30	22
Israel: Byproduct, petroleum and natural gas	10	10	10
Italy:			
Native	[r]51	34	62
Pyrite	416	368	374
Byproduct, all sources[e] [16]	225	[r]208	255
Total	[r]692	610	691
Japan:			
Pyrite	530	463	383
Byproduct:			
Metallurgy[17]	1,145	1,163	1,301
Petroleum[18]	775	980	1,097
Total	2,450	2,606	2,781
Korea, North:			
Pyrite[e]	[r]256	[r]241	246
Byproduct, metallurgy[e]	16	[r]20	12
Total[e]	[r]272	[r]261	258
Korea, Republic of:			
Pyrite	([11])	([11])	--
Byproduct:			
Metallurgy[e]	20	22	25
Petroleum[e]	10	25	24
Total[e]	30	47	49
Kuwait: Byproduct, petroleum and natural gas	[r]54	74	78
Libya: Byproduct, petroleum and natural gas	20	20	20

See footnotes at end of table.

Table 18.—Sulfur: World production in all forms, by country and source —Continued

(Thousand long tons)

Country[1] and source[2]	1975	1976	1977[p]
Mexico:			
Frasch	2,041	2,021	1,696
Byproduct:			
Metallurgy[e]	51	74	79
Petroleum and natural gas	89	95	131
Total[e]	2,181	2,190	1,906
Morocco: Pyrite	62	23	44
Netherlands: Byproduct:			
Metallurgy[e]	40	39	62
Petroleum[e]	65	64	64
Total[e]	105	103	126
Netherlands Antilles: Byproduct, petroleum	86	93	94
Norway:			
Pyrite	229	185	155
Byproduct:			
Metallurgy[e]	39	[r]32	37
Petroleum[e]	5	7	7
Total	273	224	199
Pakistan:			
Native	1	1	1
Byproduct, all sources	12	12	12
Total	13	13	13
Peru: Byproduct, all sources	16	16	20
Philippines: Pyrite	74	76	50
Poland:[19]			
Frasch[e]	4,253	[r]4,273	4,336
Native[e]	443	541	354
Byproduct:			
Metallurgy[e 20]	226	231	236
Petroleum[e 20]	25	25	30
Gypsum[e]	54	54	54
Total[e]	5,001	[r]5,124	5,010
Portugal:			
Pyrite	197	178	154
Byproduct:			
Metallurgy	([21])	([21])	--
Petroleum	2	2	2
Total	199	180	156
Rhodesia, Southern:			
Pyrite[e]	[r]29	30	29
Byproduct: Coal and/or metallurgy[e]	2	[r]2	3
Total[e]	[r]31	[r]32	32
Romania:			
Pyrite[e]	[r]369	[r]369	389
Byproduct, all sources[e]	89	[r]97	108
Total[e]	[r]458	[r]466	497
Saudi Arabia: Byproduct, petroleum and natural gas	3	3	3
Singapore: Byproduct, petroleum	6	6	6
South Africa, Republic of:			
Pyrite	256	289	327
Byproduct:			
Metallurgy	79	90	103
Petroleum	25	27	27
Total	360	406	457
South-West Africa, Territory of (Namibia): Pyrite	4	4	4

See footnotes at end of table.

Table 18.—Sulfur: World production in all forms, by country and source —Continued

(Thousand long tons)

Country[1] and source[2]	1975	1976	1977[p]
Spain:			
Pyrite	1,244	1,053	1,084
Byproduct:			
Metallurgy	102	121	127
Petroleum	2	4	10
Coal (lignite) gasification[e]	1	1	2
Total	1,349	1,179	1,223
Sweden:			
Pyrite	208	202	201
Byproduct:			
Metallurgy	128	128	128
Unspecified[22]	[r]12	28	28
Total	348	358	357
Switzerland: Byproduct, all sources	2	2	2
Syria: Byproduct, petroleum and natural gas	1	5	3
Taiwan:			
Native	5	6	5
Pyrite	5	3	3
Byproduct, all sources[e]	2	2	2
Total[e]	12	11	10
Thailand: Byproduct, all sources	1	1	1
Trinidad and Tobago: Byproduct, petroleum[3]	[r]49	54	54
Turkey:			
Native	19	20	19
Pyrite	11	39	11
Byproduct, all sources	60	68	69
Total	90	127	99
U.S.S.R.:[23]			
Frasch[e]	315	492	492
Native[e]	1,841	2,165	2,362
Pyrite[e]	3,149	3,248	3,248
Byproduct:[e]			
Coal	39	40	39
Metallurgy	1,860	2,008	2,146
Natural gas	463	856	905
Petroleum	187	187	197
Total[e]	[r]7,854	[r]8,996	9,389
United Kingdom:			
Byproduct:			
Metallurgy	45	37	60
Spent oxides	[r]5	6	5
Unspecified	[r]60	72	64
Gypsum	50	--	--
Total	160	115	129
United States:			
Frasch	7,211	6,264	5,822
Pyrite	237	286	166
Byproduct:			
Metallurgy	767	942	945
Natural gas	1,342	1,277	1,404
Petroleum	1,627	1,860	2,163
Unspecified	75	77	58
Total	11,259	10,707	10,558
Uruguay: Byproduct, petroleum	2	2	2
Venezuela: Byproduct, petroleum and natural gas	81	89	94
Yugoslavia:			
Pyrite	[r]143	181	163
Byproduct:			
Metallurgy[e]	177	197	167
Petroleum[e]	5	5	5
Total	[r]325	383	335
Zaire: Byproduct, metallurgy	49	37	30

See footnotes at end of table.

Table 18.—Sulfur: World production in all forms, by country and source —Continued

(Thousand long tons)

Country[1] and source[2]	1975	1976	1977[p]
Zambia:			
Pyrite	7	9	8
Byproduct, all sources	79	90	115
Total	86	99	123
Grand total	[r]49,397	49,697	50,649
Of which:			
Frasch	[r]14,411	13,650	12,957
Native	[r]2,565	2,969	2,998
Pyrite	[r]9,371	9,311	9,127
Byproduct:			
Coal and coal gasification	[r]40	41	41
Metallurgy	[r]6,419	6,866	7,148
Natural gas	[r]10,419	10,400	11,015
Petroleum	[r]3,353	3,852	4,383
Tar sands	84	99	98
Petroleum and natural gas undifferentiated	[r]869	784	955
Spent oxides	[r]5	6	5
Unspecified sources	[r]1,729	1,641	1,842
Gypsum	[r]132	77	80

[e]Estimate. [p]Preliminary. [r]Revised.

[1]In addition to the countries listed, a number of nations may produce limited quantities of either elemental sulfur or compounds (chiefly H_2S or SO_2) as a byproduct of petroleum, natural gas, and/or metallurgical operations, but output, if any, is not quantitatively reported, and no basis is available for the formulation of reliable estimates of output. Countries not listed in this table which may recover byproduct sulfur from oil refining include: Albania, Bangladesh, Brunei, Burma, Costa Rica, Guatemala, Honduras, Jamaica, Malaysia, Nicaragua, Paraguay, and People's Democratic Republic of Yemen. Albania and Burma may also produce byproduct sulfur from crude oil and natural gas extraction. No complete listing of other nations which may produce byproduct sulfur from metallurgical operations (including processing of coal for metallurgical use) can be compiled, but the total of such output is considered as small. Nations listed in the table which may have production from sources other than those listed are identified by individual footnotes.

[2]The term "source" reflects both the means of collecting sulfur and the type of raw material. Sources listed include the following: 1) Frasch recovery; 2) native, comprising all production of elemental sulfur by traditional mining methods (thereby excluding Frasch); 3) pyrite (whether or not the sulfur is recovered in the elemental form or as acid): 4) byproduct recovery, either as elemental sulfur or as sulfur compounds from coal gasification, metallurgical operations including associated coal processing, crude oil and natural gas extraction, petroleum refining, tar sand cleaning, and processing of spent oxide from stack-gas scrubbers; and 5) recovery from the processing of mined gypsum. Recovery of sulfur in the form of sulfuric acid from artificial gypsum produced as a byproduct of phosphatic fertilizer production is excluded because to include it would result in double counting. It should be noted that production of Frasch sulfur, other native sulfur, pyrite derived sulfur, mined gypsum derived sulfur, byproduct sulfur from extraction of crude oil and natural gas, and recovery from tar sands are all credited to the country of origin of the extracted raw material; in contrast, byproduct recovery from metallurgical operations, petroleum refineries, and spent oxides are credited to the nation where the recovery takes place, which in some instances is not the original source country of the crude product from which the sulfur is extracted.

[3]In addition may produce limited quantities of byproduct sulfur from natural gas.

[4]Excluding sulfur content of auriferous pyrites, for which data are not available.

[5]Excluding sulfur recovered, if any, from processing copper concentrates.

[6]Includes the following quantities recovered in elemental form in thousand long tons: 1974—26; 1975—24; 1976—59; 1977—NA.

[7]In addition, may produce limited quantities of byproduct sulfur from crude oil and natural gas and/or from petroleum refining.

[8]Exports; regarded as tantamount to production owing to minimal domestic consumption levels.

[9]In addition, may produce limited quantities of byproduct sulfur from metallurgical operations and/or coal processing.

[10]In addition, may produce limited quantities of byproduct sulfur from oil refining.

[11]Less than 1/2 unit.

[12]Elemental byproduct recovered sulfur only; sulfur recovered as SO_2, H_2S and/or other compounds are included under unspecified.

[13]Comprises all byproduct sulfur recovered in the form of compounds including that, if any, recovered from petroleum and natural gas operations, as well as total recovery from metallurgical operations.

[14]Official German Democratic Republic sources record production of elemental sulfur as follows in thousand long tons: 1975—84; 1976—78; 1977—NA. Presumably the differences between these figures and quantities listed in the table represent recovery in the form of compounds.

[15]Includes only the elemental sulfur equivalent of sulfuric acid produced as a byproduct from metallurgical furnaces; additional output may be included under undifferentiated.

[16]Includes recovery from gypsum, if any.

[17]Presumably includes sulfur recovered from coal processed to coke at metallurgical facilities, and excludes sulfur, if any, recovered by metallurgical facilities in elemental form.

[18]Includes sulfur recovered in the form of acid from coal, heavy oil and other unspecified sources, as well as sulfur, if any, recovered by metallurgical facilities in elemental form.

[19]Official Polish sources report total mined elemental sulfur output annually; this figure has been divided between Frasch and other native sulfur on the basis of information obtained from supplementary sources. Therefore, although both numbers are estimates, the total is not an estimate. Estimates for production of byproduct and gypsum-derived sulfur are based on officially published data on sulfuric acid production and additional information from unofficial sources.

[20]Estimates reported under "Metallurgy" represent byproduct recovery in the form of compounds (principally sulfuric acid) from all sources (including coal and fertilizer plants); estimates reported under "Petroleum" represent only elemental sulfur recovery from petroleum, with any recovery in the form of compounds included under "Metallurgy."

[21]Revised to zero.

[22]Elemental sulfur only.

[23]Classification used for detailing output revised, therefore detail does not correspond to that in previous editions of this table.

TECHNOLOGY

A computer model for the U.S. Frasch industry was developed using a systems dynamics approach rather than the standard econometric model used for many commodities. The main variables used in the study were inventory, price, production, capacity utilization, and sales. The model was used with some success to compute data for the 1955-75 period and was compared graphically with the actual data. A major problem with the model was that it would not allow substitution of pyrites for elemental sulfur.[6]

Many U.S. mining and utility companies have turned to flue gas desulfurization (FGD) units to cut down their air pollution problems. In the United States, in August 1977, there were 29 FGD units on line with 28 under construction and 68 more planned. One of the current trends is the development of a process that yields a useful byproduct. This byproduct may be regenerated as a high-grade gypsum. These and other developments were discussed at the CPA-sponsored 4th Annual Symposium on Flue Gas Desulfurization held in November in Hollywood, Fla.[7]

The primary source of air pollution in geothermal-steam electrical generators is hydrogen sulfide (H_2S) gas. Removal of this potentially hazardous gas is accomplished by absorbing the gas in an aqueous solution of copper salts thereby precipitating copper sulfides. Another common component of geothermal steam, ammonia, also is absorbed, thereby partially neutralizing the acidic solution formed as the H_2S is dissolved. The products of this process are soluble sulfates and sulfites of ammonia. The salts are disposed of by dissolution in cooling-tower blowdown water.[8]

Six processes for removing sulfur from coal were tested for their technical and economic viability. Each process was tested using Pittsburgh seam coal pulverized to 70% to 80% minus 200 mesh. Each process removed 90% of the mineral sulfur. All processes proved technically feasible but economically unattractive. It was concluded that an inexpensive cleaning operation could be developed to realize the potential of high-sulfur Eastern Coal.[9]

Sample tests indicated that, at a particular size distribution, more pyritic sulfur and comparable amounts of ash could be liberated from chemically comminuted coal than from mechanically crushed coal.[10]

A rational modified design of the existing Kellogg-Weir slurry spray system to remove SO_2 from boiler flue gases was developed. The design was based on measured adsorption rates and theoretical rates calculated using a mass transfer model.[11]

Descriptions of a number of flue-gas desulfurization processes used in Japan were published. Methods described include wet-type flue gas desulfurization processes, the Wellman-lord process, the "Evergreen process," and the lime-gypsum CM-type process. Flow diagrams were included.[12]

An unusual environmental engineering problem at powerplants, arising from the use of low-sulfur coal, is being corrected through flue-gas conditioning systems, which add sulfur trioxide to stack gas. This seemingly strange control strategy is needed because the efficiency of electrostatic precipitators is reduced when the sulfur dioxide emission falls below a certain level, leading to a rise in particulate emissions. This innovative system permits use of elemental sulfur instead of the much more expensive commercial liquid sulfur dioxide. Both approaches offer substantial savings over the other alternative of increasing electrostatic precipitator capacity by as much as two or three times. The tradeoffs involve capital expenditures versus operating costs.[13]

Pilot-scale testing of a process for the treatment and removal of sulfur compounds from Claus-type sulfur-recovery-plant tail gas was successfully completed. Overall sulfur recovery was raised to as high as 99.9% by converting all of the sulfur compounds to sulfur dioxide. The three stages of the process are incineration of the tail gas or low hydrogen sulfide gas, reaction of impurities in the gas with hot coke, and removal of the sulfur dioxide.[14]

Molten sulfur, obtained from four Claus units and a Sulfreen unit, was solidified and formed into slates using Savdvik stainless steel cooling belts at Société Nationale Elf Aquitaine's Ram River natural gas processing plant. The process was used to decrease pollution and health problems related to solid sulfur transport and handling. The belts, 262 feet long and 4 feet wide, had a capacity of 24 tons per hour.[15]

A Wellman-Lord sulfur dioxide recovery system and an Allied Chemical Co. direct-reduction unit were successfully combined in an experimental pollution control system at a coal-fired powerplant. The Environmental Protection Agency announced that the system had reduced pollution to acceptable levels over the designated test period with a removal efficiency of 91%. Energy and material costs for the Wellman-Lord unit were within allowable limits.[16]

A study by Battelle Columbus Laboratories concluded that under certain conditions magnesia-based scrubber systems may be less expensive than wet-limestone processes. The magnesium-based systems result in soluble sulfuric acid and regenerated magnesium oxide. The cost advantage of the magnesia system was found to be dependent on sale of the sulfuric acid in a nearby market.[17]

A report described the results of a laboratory test program on the use of cobalt molybdenum alloy-zinc oxide (CoMo-ZnO) systems in the desulfurization of natural gases. The trend in changing natural gas feedstocks toward increased use of CoM0-ZnO desulfurization systems had created a need to better define their performance. It was concluded that (1) 2 volume-percent of hydrogen in the inlet gas treating natural gas feedstocks should normally be sufficient to assure proper sulfur conversion, (2) CoMo catalyst can convert COS in the natural gas streams at temperatures as low as 400° F, (3) when CO_2 is present in the feed stream to the CoMo catalyst, a reserve shift reaction on the COS equilibrium must be considered to properly predict the level of uncoverted COS, and (4) ZnO by itself will remove COS 650° to 700° F, but at much sacrifice in ZnO capacity to that attainable with a combined CoMo-ZnO system.[18]

A series of tracer-element tests were conducted in Canada by the University of Calgary Interdisciplinary Sulphur Research Group to determine the degree of oxidation of SO_2 at various distances from a sulfur-recovery-plant stack. The study revealed that there was little oxidation of the SO_2 within the first 2.5 miles.[19]

Certain basic characteristics of sulfur formed for transport were measured at the Sulphur Development Institute of Canada. The chosen characteristics were friability, moisture performance, and handling. Three important characteristics related to moisture performance were the moisture content of the product when formed, moisture absorbtion when wetted, and moisture loss. Handling and storage properties of interest were bulk density, angle of repose, compressibility, and flowability.[20]

THERMOPAVE, a registered trademark of Shell Canada Ltd., is a mixture of about 6% asphalt, 13% sulfur, and 81% sand (by weight). This form of sulfur asphalt was tested to evaluate its performance under a variety of climatic conditions. THERMOPAVE was reported to have the advantages of needing little or no high-quality aggregate other than sand and requires no rolling because compaction is accomplished by the paving machine. Suggested areas of possible usage include road paving, road patching, utility trench backfill, and high-bearing-strength applications.[21] Also molten sulfur, dispersed in liquid asphalt, had been used to replace asphalt in the preparation of road-construction-quality asphaltic concretes. The sulfur-asphalt emulsion reduces the quantity of asphalt used, thereby, reducing paving costs.[21]

Commercial equipment capable of laying sulfur-insulating foam for permafrost protection was successfully demonstrated in Calgary, Canada. A specially designed tractor-trailer truck put down several 10-feet-wide swaths. No weather-related difficulties were experienced and rates were compatible with those in commercial construction. It was reported that sulfur foam insulation appeared promising for permafrost protection in large-scale projects such as airfields or pipelines.[22]

Sulfur for use as a fertilizer nutrient has been slowly declining. However, such factors as changing patterns in fertilizer use, crop patterns, and soil treatment present a market of considerable potential. It was reported that a key factor in the future demand of sulfur fertilizer may be the quantity of sulfur supplied by fallout from industrial air pollution. Decreases in fallout caused by environmental regulations may eventually require the addition of sulfur fertilizer.[23]

A symposium on new uses for sulfur was held in New Orleans, La., in March 1977. Some of the general areas of consideration were sulfur concrete, sulfur asphalt mixtures, and sulfur composites for coatings and construction materials.[24]

A book published in 1977 provides information on many aspects of the sulfur industry, and covers such areas as sulfur occurrence, production, and usage plus a chapter on new uses such as sulfur asphalt, concrete, and batteries.[25]

---

[1]Supervisory physical scientist, Division of Nonmetallic Minerals.

[2]Pearse, G. H. K. Sulphur, Canadian Mineral Survey, 1977. February 1978, pp. 69-70.

[3]Energy Resources Conservation Board, Province of Alberta, Canada. Summary of Monthly Statistics, Alberta Energy Resource Industries. December 1977, p. 10.

[4]Sulphur (London). Cyprus Sulphuric Acid Project Goes Ahead. No. 133, November-December 1977, pp. 30-32.

[5]———.Pemex Expands Recovered Sulfur Output. No. 132, September-October 1977, pp. 28-30.

[6]Laulajainen, R. The U.S. Frasch Industry 1955-75, A Study in System Dynamics. Sulphur (London), No. 129, March-April 1977, pp. 33-39.

[7]Environmental Science & Technology. SO_2 Scrubbing: Cleaning the Air. V. 12, No. 1, January 1978, pp. 16-18.

[8]Coury, G. E., and M. Vorum. Removing H_2S From Geothermal Steam. Chem. Eng. Prog., v. 73, No. 9, September 1977, pp. 93-98.

[9]Oder, R. R., L. Kulapaditharom, A. K. Lee, and E. L. Ekholm. Technical and Cost Comparisons for Chemical Coal Cleaning Processes. Min. Cong. J., v. 63, No. 8, August 1977, pp. 42-49.

[10]Howard, P. H., and R. S. Datta. Desulfurization of Coal by Use of Chemical Comminution. Science, v. 197, No. 4304, August 1977, pp. 668-669.

[11]Edwards, W. M., and P. Huang. The Kellogg-Weir Air Quality Control System. Chem. Eng. Prog., v. 73, No. 8, August 1977, pp. 64-65.

[12]Harima, M. Operation of Various Flue Gas Desulfurization Processes. Chem. Econ. & Eng. Rev., v. 9, No. 10, October 1977, pp. 38-48.

[13]Chemical Week. Sulfur Oxides Help To Clean Up the Stack. V. 121, No. 10, September 1977, p. 42.

[14]Sulphur (London). The LUCAS Tail Gas Treatment Process. No. 128, January-February 1977, pp. 41-42.

[15]———.Sulphur Slating at Ram River. No. 129, March-April 1977, p. 41.

[16]———.NIPSCO SO_2 Removal Plant Successful in Early Operation. No. 132, September-October 1977, pp. 42-45.

[17]———.Magnesium-Based Systems are Possibly More Advantageous. No. 131, July-August 1977, p. 53.

[18]Burklow, B. W., and R. L. Coleman. Developments in Natural Gas Desulfurization. Chem. Eng. Prog., v. 73, No. 6, June 1977, pp. 55-58.

[19]Sulphur (London). The Fate of Emitted Sulfur Dioxide in the Neighborhood of a Sulfur Recovery Plant. No. 133, November-December 1977, pp. 41-43.

[20]Raymont, M. E. D. The Evaluation of Formed Sulphur for Transport and Handling. Sulphur (London), No. 130, May-June 1977, pp. 41-45.

[21]Terry, J. W. Sulphur Asphalts. Sulphur (London), No. 130, May-June 1977, pp. 46-47.

[22]Raymont, M. E. D. Commercial Scale Sulphur Foaming Unit Demonstrated. Sulphur (London), No. 131, July-August 1977, pp. 35-37.

[23]Sulphur (London). Sulphur as a Fertilizer Nutrient. No. 131, July-August 1977, pp. 28-33.

[24]Bourne, D. J. New Uses of Sulfur-II. American Chemical Society, Washington, D.C., 1978, 282 pp.

[25]Meyer, B. Sulfur, Energy, and the Environment. Ersevier Scientific Publishing Company, Amsterdam, The Netherlands, 1977, 448 pp.

Talc and Pyrophyllite

By Robert A. Clifton[1]

Increasing demand for talc on the world market led to a 10% increase in total domestic production of talc and pyrophyllite. Production of talc increased, while that of pyrophyllite declined. The value of crude talc and pyrophyllite produced increased 32% and averaged $10.86 per ton.

Table 1 shows a 24% increase in total sales of crude and processed talc and pyrophyllite and a 54% increase in value. Apparent domestic consumption increased minimally over that of 1976, but exports increased 52% in tonnage and 1% in value.

Cyprus Industrial Minerals Co. announced plans to double the capacity of its Ghent, Belgium, talc-processing facility.

A new organization, the Scientific and Technical Association of the European Talc Industry (EUROTALC), was founded on May 3, 1977. The association membership is open to any company mining its own talc and grinding it in Europe. The six charter members established EUROTALC's headquarters at 22 Rue du Musee, 1000 Brussels, Belgium. One of the first acts of the association was to initiate a physiological and epidermoidal survey among European talc workers. This survey follows the association's announced aim of encouraging fundamental research for the promotion of the

Table 1.—Salient talc and pyrophyllite statistics

(Thousand short tons and thousand dollars)

	1973	1974	1975	1976	1977
United States:					
Mine production, crude:					
Talc	W	1,183	873	W	1,099
Pyrophyllite	W	106	92	W	106
Total	1,247	1,289	965	1,092	1,205
Value:					
Talc	W	$8,022	$7,454	$9,542	$12,524
Pyrophyllite	W	1,547	1,475	360	561
Total	$9,144	9,569	8,929	9,902	13,085
Sold by producers, crude and processed:					
Talc	1,071	963	845	794	996
Pyrophyllite	113	101	86	107	118
Total	1,184	1,064	931	901	1,114
Value:					
Talc	$30,757	$31,125	$16,496	$33,014	$50,647
Pyrophyllite	1,469	1,474	1,379	934	1,708
Total	32,226	32,599	17,875	33,948	52,355
Exports[1]	180	183	158	212	322
Value	$6,618	$6,711	$6,338	$9,034	$9,166
Imports for consumption	23	30	23	20	22
Value	$1,658	$2,233	$1,471	$1,861	$2,094
Apparent consumption	1,027	911	796	709	814
World: Production	5,957	6,406	[r]5,403	[r]5,976	6,331

[r]Revised. W Withheld to avoid disclosing company proprietary data.
[1]Excludes powders—talcum (in package), face, and compact.

technology of talc and on problems more specifically related to public health and environment.

Legislation and Government Programs.—On January 19, the day before he left office, Dr. Morton Corn, Assistant Secretary of Labor and head of the Occupational Safety and Health Administration (OSHA), rescinded OSHA Field Information Memorandum No. 74-92, issued in 1974, that set forth scientific criteria for the detection and identification of mineral fibers for the purpose of differentiating between asbestiform and nonasbestiform minerals. Also rescinded was a 1974 letter from John Stender, then OSHA chief, that allowed the Vanderbilt Co. to certify to its customers, after testing, that its talc contained no asbestos. In April, in an Atlanta, Ga., court, a citation against a Vanderbilt customer accused of using asbestos-containing talc was dismissed for insufficient evidence.

Talc was one of the materials listed in the Federal Register on October 28, 1977, when the National Institute of Occupational Safety and Health (NIOSH) asked for information on certain "Chemical Agents and Processes" prior to writing criteria for exposure.

The national stockpile inventory of steatite, block or lump, was reduced by 6 tons to 1,113 tons during 1977. During that year the ground steatite inventory was reduced by 527 tons to 2,389 tons.

The allowable depletion rates established under the Tax Reform Act of 1969 remained at 22% for domestic block steatite and 14% for foreign through 1977.

Tariff rates on imported talc minerals follow: Crude and unground, 0.02 cent per pound; ground, washed, powdered and/or pulverized, 6% ad valorem; cut, sawed, or in blanks, crayons, cubes, disks or other forms, 0.2 cent per pound; other not specifically provided for, 12% ad valorem.

DOMESTIC PRODUCTION

Talc.—Production from U.S. talc mines in 1977 was significantly higher than in 1976 but still only 93% of that in the record year, 1974. The value of the mine production established another record high, 32% above the 1976 record.

Talc, including soapstone, was produced at 36 mines in 12 States in 1977, with California's 12 mines being by far the largest number for any State. Mines in four States produced 80% of the tonnage and 70% of the value of talc in 1977. Eight States produced the remainder. The States producing the the highest tonnage in decreasing order are Vermont, Texas, Montana, and New York. Montana again led all States in the value of the talc produced. Of the talc-producing States, only Nevada had no milling facilities. One company milled Montana talcs in Nebraska.

The seven largest domestic producers of talc in 1977, listed alphabetically, were Cyprus Industrial Minerals Co., with mines in California, Montana, and Texas; Eastern Magnesia Talc Co. in Vermont; Pfizer Inc., Minerals, Pigments & Metals Div., in California and Montana; Southern Clay Products, Inc., in Texas; R. T. Vanderbilt Co., Inc., in New York; Western Minerals, Inc., in Texas; and Windsor Minerals, Inc., in Vermont. Those firms supplied 40% of the 1977 tonnage, and the combined output of about 14 smaller producers made up the remainder.

At yearend, demand for Montana talcs was so strong that shipping delays of several weeks were common.

Pyrophyllite.—The pyrophyllite-producing mines of the United States in 1977 were again all in North Carolina. The slight reduction in production still left the total at the second highest level ever. Four companies operated seven mines during the year.

There was mining activity for talc and pyrophyllite in 1976 at 42 sites, including 2 where assessment work only was done. Three mines shipped only from stockpiles, three were idle all year, and one was abandoned.

Table 2.—Talc and pyrophyllite produced in the United States, by State

(Thousand short tons and thousand dollars)

State	1976		1977	
	Quantity	Value	Quantity	Value
California (talc)	57	1,513	96	2,373
Georgia (talc)	W	W	24	63
Montana (talc)	225	2,960	226	2,947
North Carolina[1]	114	1,087	111	1,267
Texas (talc)	200	1,071	233	2,191
Vermont (talc)	252	1,685	310	2,006
Other States[2] (talc)	245	1,586	205	2,238
Total	[3]1,092	9,902	1,205	13,085

W Withheld to avoid disclosing company proprietary data.

[1]Talc and pyrophyllite produced, pyrophyllite only reported in 1977.

[2]Includes Arkansas, Nevada, New York, North Carolina (talc, 1977), Oregon, Virginia, and Washington.

[3]Data do not add to total shown because of independent rounding.

Of the 42 active mines, 7 were underground and 35 were open pit. The underground mines produced 7% of the talc but 12% of the value, because their talc was valued at an average of $15.30 per ton while that from the open pits brought only $8.44 per ton.

CONSUMPTION AND USES

The apparent domestic consumption of talc and pyrophyllite increased in 1977 and was 79% of the 1973 record. The $50 million sales value set a new record high.

The 1977 end use distribution showed 32% of the ground talc used in ceramics, 22% in paint, 13% in plastics, 8% in cosmetics, 7% in paper, 6% in rubber, 2% each in insecticides and roofing, 1% in refractories, and the remainder in other uses.

The largest portion, 52%, of the pyrophyllite was used in refractories, 25% was used in insecticides, 18% in ceramics, and 5% in other uses.

Table 3.—End uses for ground talc and pyrophyllite, 1977

(Thousand short tons)

Use	Talc	Pyrophyllite	Total
Ceramics	300	17	317
Cosmetics[1]	75	--	75
Insecticides	23	24	47
Paint	211	--	211
Paper	69	--	69
Plastics	120	--	120
Refractories	13	50	63
Roofing	25	1	26
Rubber	52	--	52
Other uses[2]	55	4	59
Total[3]	943	96	1,039

[1]Incomplete data. Some cosmetic talc known to be included in "Other."

[2]Includes art sculpture, asphalt filler, crayons, floor tile, foundry facings, rice polishing, stucco, and other uses not specified.

[3]Data may not add to totals shown because of independent rounding.

PRICES

Depending on quality and degree and method of processing, talc prices vary over a wide range. Engineering and Mining Journal, December 1977, quoted prices for domestic talc, ground, in carload lots, f.o.b. mine or mill, containers included, per short ton, as follows:

Vermont:	
98% through 325 mesh, bulk	$51.00
99.99% through 325 mesh, bags:	
Dry processed	91.00
Water beneficiated	$141.00-151.00
New York:	
96% through 200 mesh	36.00- 38.00
98% to 99.25% through 325 mesh	48.00
100% through 325 mesh, fluid-energy ground	75.00-105.00
California:	
Standard	69.50
Fractionated	37.00- 71.00
Micronized	62.00-104.00
Cosmetic steatite	44.00- 65.00
Georgia:	
98% through 200 mesh	20.00
99% through 325 mesh	35.00
100% through 325 mesh, fluid-energy ground	85.00

American Paint & Coatings Journal, December 26, 1977, listed the following prices per ton for paint-grade talcs in carload lots:

California:	
325 mesh, bags, mill:	
Fibrous, white, high oil absorption	$34.00- $37.00
Semifibrous, medium oil absorption	32.00 - 73.95
Montana: Ultrafine grind, f.o.b. mill	70.00
New York:	
Nonfibrous, bags, mill:	
98% through 325 mesh	46.50 - 50.50
99.4% through 325 mesh	55.50
Trace retained on 325 mesh	105.00
Fine micron talcs (origin not specified)	68.00 -111.50

The approximate equivalents, in dollars per short ton, of the price ranges quoted in Industrial Minerals (London), December 1977, for steatite talc, c.i.f. main European ports, were as follows:

Norwegian:	
Ground (ex store)	$76.50
Micronized (ex store)	127.50
French, fine-ground	161.50
Italian, cosmetic-grade	212.50
Chinese	$153.00-170.00

FOREIGN TRADE

Exports.—There was another dramatic increase in talc exports during 1977. The 52% rise in tonnage over 1976 established a new record. However, the value of exported talc rose less than 2% and averaged $28.47 per ton compared with $42.61 per ton in 1976. The great increase of lower priced talc exported to Canada was a major factor in the lower export unit value, as was a decrease in value of exports to Mexico.

Canada was the major importer of U.S. talc in 1977 with 41% of the exports at an average value of $21.49 per ton, followed by Mexico with 39% of the exports at $14.56 per ton, Belgium with 6% at $35.94 per ton, Japan with 6%, at $46.42 per ton, and Venezuela with 2% at $133.63 per ton. A total of 61 countries imported U.S. talc.

Imports.—U.S. imports of talc increased 10% in 1977 over those in 1976. The average value of imports was $94.79 per ton. The cosmetic grades accounted for the high price. Italy with 38% was the leading source of imported talc, followed by Canada with 31% and France with 23%.

Table 4.—U.S. exports of talc, crude and ground

(Thousand short tons and thousand dollars)

Year	Quantity	Value
1975	158	6,338
1976	212	9,034
1977	322	9,166

Table 5.—U.S. imports for consumption of talc, by class and country

Year and country	Crude and unground		Ground, washed, powdered, or pulverized		Cut and sawed		Total unmanufactured	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value[1] (thousands)
1975	13,942	$663	9,004	$494	432	$314	23,378	$1,471
1976:								
Australia	--	--	1	1	--	--	1	1
Belgium-Luxembourg	--	--	17	6	--	--	17	6
Canada	3,840	92	2,873	162	6	3	6,719	257
Finland	--	--	4	(2)	--	--	4	(2)
France	--	--	592	54	--	--	592	54
Hong Kong	--	--	--	--	218	119	218	119
India	--	--	22	2	3	1	25	3
Israel	--	--	137	9	--	--	137	9
Italy	10,913	926	287	57	--	--	11,200	983
Japan	--	--	67	8	246	208	313	216
Kenya	(2)	1	--	--	--	--	(2)	1
Korea, Republic of	55	3	505	54	244	150	804	207
Netherlands	--	--	2	1	--	--	2	1
Spain	6	1	--	--	--	--	6	1
United Kingdom	--	--	33	3	--	--	33	3
Total	14,814	1,023	4,540	357	717	481	20,071	1,861
1977:								
Belgium-Luxembourg	--	--	42	9	--	--	42	9
Canada	--	--	6,760	391	5	2	6,765	393
China, People's Republic of	--	--	8	1	--	--	8	1
Dominican Republic	--	--	20	2	--	--	20	2
France	4,537	159	595	58	--	--	5,132	217
Hong Kong	--	--	--	--	91	40	91	40
India	28	2	11	1	1	1	40	4
Israel	--	--	218	46	--	--	218	46
Italy	8,047	739	290	58	--	--	8,337	797
Japan	--	--	8	4	435	346	443	350
Korea, Republic of	--	--	729	85	264	149	993	234
Nepal	--	--	1	1	--	--	1	1
Total	12,612	900	8,682	656	796	538	22,090	2,094

[1]Does not include talc, n.s.p.f.; 1975—$198,090; 1976—$302,455; 1977—$593,240.
[2]Less than 1/2 unit.

WORLD REVIEW

Belgium.—Cyprus Industrial Minerals Co. of Los Angeles announced that it planned to spend $3 million on expansion of its Ghent, Belgium, talc-processing plant. The planned expansion was expected to double the facility's capacity and to be completed early in 1978.

Canada.—Johns-Manville Corp. closed its talc mine and processing facilities near Timmins, Ontario. Also in the Timmins area, Rosario Resources Corp. announced its investigation of another promising talc-magnesite deposit. Broughton Soapstone & Quarry Co., Ltd., Quebec, continued as a major source of soapstone for sculpture.

Finland.—The new Oy Lohja A. B. talc plant became operational and produced filler-grade talc for the paper industry. The 99% less-than-20-micron product was 96% talc with an 86 brightness. Plans for a less-than-10-micron product should be realized in 1978.

France.—Société des Talcs de Luzenac with recent acquisitions has become the largest talc producer among the market economy countries. The acquisitions were 49% of Spain's Compañia Talcos Pirenaicos, which has about 20,000 tons' annual production and an 80% share of Austria's Talkumwerke Naintsch GmbH's Graz mine, which has a 100,000-ton-per-year capacity. Luzenac now controls about 400,000 tons per year of capacity.

Japan.—Japan is a leading producer of talc with an estimated 149,000-short-ton production and a major consumer using approximately 480,000 short tons per year. In 1976 the major supplying countries to Japan were the People's Republic of China, with 55% of the imports, the Republic of South Korea with 16%, North Korea with 13%; and Australia with 9%. The United States supplied 0.6% of the imports.[2]

Japan is also the world's largest producer and consumer of pyrophyllite. The production, with no reported exports, is a nominal 1.1 to 1.3 million short tons per year but did reach 1.7 million short tons in 1970. Roseki (a pyrophyllite-kaolin mixture reported under clays) is also mined in great quantities. In 1975 Japan produced 2.2 million short tons of roseki and another 0.4 million short tons of "Roseki concentrate." Fifty to sixty percent of pyrophyllite production is used in refractories, and the remainder in paper, china and tiles, and cement products.[3]

Pakistan.—A deposit with an estimated 1 million tons of good-quality soapstone was found in the Swat district.

South Africa, Republic of.—There are thought to be several million tons of industrial grades (no cosmetic grades) of talc in South Africa. At present four companies are mining a nominal 8,000 tons per year for domestic use.

Thailand.—Pyrophyllite production in Thailand exceeded 10,000 tons per year for the first time in 1975. Small-scale production from a new mine in Chiang Rai with reportedly large reserves was started, but lack of appropriate infrastructure will probably inhibit production. A new talc discovery in Chiang Rai was awaiting a Government mining concession.

United Kingdom.—The building of a barite processing plant in the Shetland Islands opened the possibility of processing other indigenous Shetland minerals such as talc. Unst, the northernmost of the Shetlands, is the site of the United Kingdom's only talc mine; its 20,000-ton-per-year production is shipped all the way to Sharpness, Gloucestershire, for milling.

The United Kingdom imported 66,769 short tons of talc in 1977. Norway led the supplying countries with 26% of the imports. France and the People's Republic of China each had 17%, and Italy had 16%.

Table 6.—Talc, soapstone, and pyrophyllite: World production, by country

(Short tons)

Country[1]	1975	1976	1977[p]
North America:			
Canada (shipments)	72,784	75,877	80,470
Mexico	1,631	212	180
United States	[r]964,609	1,092,433	1,204,835
South America:			
Argentina	[r]53,394	59,698	62,141
Brazil (talc and pyrophyllite)	243,248	248,394	[e]250,000
Chile	524	143	471
Colombia	1,102	[e]1,100	1,268
Paraguay	[e]280	155	144
Peru (talc and pyrophyllite)[e]	15,400	15,400	15,400
Uruguay	1,398	1,398	1,829
Europe:			
Austria	95,363	110,947	114,357
Finland	136,973	163,728	172,605
France (ground talc)	265,800	281,971	316,664
Germany, Federal Republic of (marketable)[e]	33,000	33,000	33,000
Greece (steatite)	[r]6,468	[e]6,600	[e]6,600
Hungary[e]	17,600	17,600	17,600
Italy (talc and steatite)	158,823	169,575	179,056
Norway	115,735	[e]110,000	[e]110,000
Portugal	1,731	1,264	1,662
Romania[e]	66,000	66,000	66,000
Spain	52,159	[e]55,000	[e]55,000
Sweden	26,286	22,534	[e]22,000
U.S.S.R.[e]	460,000	485,000	500,000
United Kingdom	21,054	16,315	16,540
Africa:			
Angola[e]	110	110	110
Botswana	248	[2]159	318
Egypt	[r]4,858	6,213	7,709
Ethiopia	28	[e]30	[e]30
South Africa, Republic of[3]	17,657	14,135	8,883
Sudan[e]	5,500	5,500	5,500
Zambia	181	117	[e]110
Asia:			
Afghanistan[4]	6,945	9,574	[e]10,000
Burma	383	462	--
China, People's Republic of[e]	300,000	330,000	330,000
India	[r]220,985	266,460	268,831
Japan[5]	1,313,489	1,482,875	1,492,302
Korea, North[e]	140,000	140,000	140,000
Korea, Republic of (talc and pyrophyllite)	458,422	547,262	667,151
Nepal[6]	571	58	85
Pakistan (pyrophyllite)	[r]5,318	5,551	[e]8,700
Philippines	[r]1,480	1,556	1,323
Taiwan	13,283	17,065	11,200
Thailand (talc and pyrophyllite)	[r]11,737	[e]11,000	10,859
Oceania: Australia	90,816	104,017	139,597
Total	[r]5,403,373	5,976,488	6,330,530

[e]Estimate. [p]Preliminary. [r]Revised.
[1]In addition to the countries listed, Southern Rhodesia is believed to produce talc, but available information is inadequate to make reliable estimates of output levels.
[2]Exports.
[3]Includes talc and soapstone.
[4]Data are for calendar year beginning March 20 of that stated.
[5]Includes talc and pyrophyllite; in addition, pyrophyllite clay is produced as follows in short tons: 1975—483,857; 1976—497,912; 1977—492,043.
[6]Data based on Nepalese fiscal year, beginning mid-July of year stated.

TECHNOLOGY

A new citizens' group, "Preserve Soapstone" was formed in Atlanta to protect and save a site on Soapstone Ridge, south of Atlanta, where Indian miners and artificers produced utensils, pipes, beads, and weapons many centuries ago.

The large tailings piles of impure magnesite discarded by the Finnish talc industry have been under investigation as a possible source of high-purity magnesia for several years. Kimira Oy, Finland's leading chemical company, has now developed a process tested through the pilot plant stage, capable of producing high-purity magnesium hydroxide filter cake suitable for calcination and dead burning. The process, which involves acid dissolution and base precipitation, is reported to be economically viable only if connected with a nitrogen fertilizer plant so that nitric acid and ammonia are cheaply available, as at Kimira's Oulu plant.

Americ Mines, Ltd., of Canada purchased world rights to a process for making an inexpensive home insulating material from talc.

The health hazards of exposure to talc are the subject of both controversy and research. A conference paper[4] reporting on work by Harvard University and NIOSH stated that there was no asbestos in Vermont talcs, and that using the OSHA method for asbestos identification would give erroneous measurements indicating high hazard in some mine and mill areas.

Testing cosmetic-grade talc aerosols on hamsters at exposures that exceeded weekly infant exposures by some 30 to 1,700 times revealed no influence on body weight, survival, or the type incidence or degree of histopathological change in the exposed groups when compared with the controls.[5]

Another work correlating this hamster study with humans concluded that there was no reason to believe that normal consumer exposure to cosmetic talc has in the past led either to cancer or to measurable loss of lung function.[6] Both of these papers deal with cosmetic talcs, the highest purity talcs marketed, and strongly infer that if any health hazards are present, they are not related to talc but to another component.

---

[1]Physical scientist, Division of Nonmetallic Minerals.

[2]Industrial Minerals (London). Japan's Industrial Minerals. No. 118, July 1977, pp. 18-33.

[3]Work cited in footnote 2.

[4]Boundy, M. G., K. G. Gold, W. A. Burgess, and J. M. Dement. Exposure to Industrial Talc in Vermont Mines and Mills. Pres. at American Industrial Hygenist Assoc. Conference, New Orleans, La., May 26, 1977.

[5]Wehner, A. P., G. M. Zwicker, W. C. Cannon, C. R. Watson, and W. W. Carlton. Inhalation of Baby Powder by Hamsters. Fd. Cosmet. Toxicol., v. 15, 1977, pp. 121-129. Pergammon Press, 1977. (Printed in Great Britain).

[6]The Lancet. Cosmetic Talc Powder. V. 6, June 25, 1977, pp. 1348-1349.

Thorium

By Martha L. Kahn[1]

Monazite, the principal source of thorium, continued to be a byproduct of titanium and tin mining and was recovered domestically for its rare-earth content in Florida. Thorium-containing residues remaining after extraction of rare earths from monazite were stored for future use. Practically all thorium compounds used by the domestic industry during 1977 came from existing company stocks or imports.

No major developments occurred in the nonenergy uses of thorium, which include mantles for incandescent lamps, hardeners in magnesium alloys, refractories, and electronic and chemical applications.

The future prospects for thorium's use in nuclear fuels remained uncertain in 1977. The only commercial thorium-fueled, high-temperature, gas-cooled reactor (HTGR), located at Fort St. Vrain, Colo., with a capacity of 330 megawatts, reached almost 70% of power capacity in 1977. The experimental thorium-fueled, light-water breeder reactor (LWBR), at Shippingport, Pa., reached full capacity by yearend.

The U.S. Geological Survey (USGS) began an evaluation of thorium resources recoverable at costs of $30 and $50 per pound.

DOMESTIC PRODUCTION

Exploration.—Five deposits of heavy minerals containing thorium were reported[2] in ancient beach sands in Charleston County, S.C., by the USGS. An aerial geophysical survey and preliminary ground checks indicated that the deposits contain 2 million tons of potentially economic heavy minerals, including monazite. The three largest deposits are 9 miles north of McClellanville, 9 miles southwest of Charleston, and 12 miles southwest of Charleston.

Buttes Gas and Oil Co. continued feasibility and pilot-plant studies of its southwestern Colorado titanium prospect.[3] The ore mineral perovskite reportedly contains significant amounts of thorium that could be recovered.

The USGS began studying thorium resources available at $30 and $50 per pound for the U.S. Department of Energy (DOE).[4] The first phase of the study, to be completed in May 1978, was to assess better known deposits. The U.S. Bureau of Mines provided mining and milling cost analyses for the USGS study. The principal deposits to be studied included the vein deposits of the Wet Mountains, Colo., Lemhi Pass, Idaho, and the Bokan Mountains, Ala.; massive carbonatites of the Powderhorn Pass district, Colo., and Mountain Pass district, Calif.; deposits in fractured and brecciated rocks in Wyoming and Illinois; Piedmont-stream placers of the Carolinas; and current monazite-producing areas in northern Florida. Coproducts were also to be considered.

Mine Production.—Monazite, a thorium-containing, rare-earth, phosphate mineral, was produced as a byproduct of processing beach sands for titanium minerals in 1977. Two mines in Florida, Humphreys Mining Co., near Hilliard, and Titanium Enterprises, near Green Cove Springs, were the only domestic producers of monazite. Humphreys Mining Co. continued to truck wet titanium concentrates from its mine in Florida to the company's dry plant at Folkston, Ga.

Refinery Production.—In 1977, there was only one domestic firm, W. R. Grace & Co., Davison Chemical Div., at Chattanooga, Tenn., with facilities for processing large tonnages of monazite. Although W. R. Grace did not produce any thorium compounds from monazite for sale, thorium was extracted from monazite during the refining of rare-earth elements and stored.

Table 1.—Companies with thorium processing and fabricating capacity

Company	Plant location	Operations and products
Atomergic Chemetals Corp	Plainview, N.Y	Processes oxide, fluoride, and metal.
Babcock & Wilcox Co	Apollo, Pa	Nuclear fuels.
Do	Leechburg, Pa	Do.
Do	Lynchburg, Va	Do.
Bettis Atomic Power Laboratory	West Mifflin, Pa	Nuclear fuels, Government research and development.
Cerac, Inc	Milwaukee, Wis	Processes compounds.
Ceradyne, Inc	Santa Anna, Calif	Processes oxide.
Consolidated Aluminum Corp	Madison, Ill	Magnesium-thorium alloy.
Controlled Castings Corp	Plainview, N.Y	Do.
General Atomic Co	San Diego, Calif	Nuclear fuels.
General Electric Co	San Jose, Calif	Do.
Do	Wilmington, N.C	Do.
W. R. Grace & Co	Chattanooga, Tenn	Processes domestic and imported monazite; stocks thorium-containing residues.
Hitchcock Industries, Inc	South Bloomington,Minn	Magnesium-thorium alloys.
Kerr-McGee Chemical Corp	Cimarron, Okla	Nuclear fuels.
Tennessee Nuclear Specialities, Inc	Jonesboro, Tenn	Do.
Union Carbide Corp., Nuclear Div	Oak Ridge, Tenn	Nuclear fuels, test quantities.
Ventron Corp.,Alfa Div	Danvers, Mass	Metallic thorium.
Westinghouse Electric Corp	Bloomfield, N.J	Processes compounds; produces metallic thorium.
Do	Columbia, S.C	Nuclear fuels.

CONSUMPTION AND USES

It was estimated that industrial demand for thorium was about 50 tons, ThO_2 equivalent, and was met by imports and existing company stocks.

Nonenergy uses consumed about 40 tons of ThO_2. The principal application was as a constituent in mantles for Welsbach incandescent lamps (estimated to be around 20 tons). Other nonenergy uses were as follows: As a hardener in magnesium-thorium alloys (5 tons), in refractories (5 tons), in electronic and chemical applications, plus other applications and research (10 tons).

The 330-megawatt HTGR at Fort St. Vrain, Colo., was up to almost 70% of electrical power capacity by yearend 1977. The commercial reactor was the Nation's first to use a prestressed concrete reactor vessel, helium coolant, steam turbine-driven, primary coolant helium circulators, and a fully ceramic core utilizing the uranium-thorium fuel cycle. The core of the reactor contains about 22 tons of thorium. A reload section containing about 3 tons of thorium was scheduled to be added in 1978. The organization of a utility industry group to promote HTGR utilization was planned in 1977, and General Atomic Co. (GA), developer of the HTGR, and Combustion Engineering were reported to be negotiating an arrangement to jointly sell HTGRs. HTGRs reportedly exhibit higher conversion efficiency, superior fuel utilization, and lower fuel costs than light-water reactors (LWR); however, there have been startup problems associated with commercialization of the new technology.

Development of a 50-megawatt LWBR by DOE continued at Shippingport, Pa. Initial loading of about 46 tons of thorium took place in 1977 and full power production was reached on December 2. The LWBR was converted from a 90-megawatt, pressurized-water reactor, using current LWR plant technology. Although some existing reactors could be converted to LWBRs, the economic viability was uncertain.[5]

STOCKS

On December 31, 1977, the stockpile inventory of the General Services Administration (GSA) totaled 7,221,646 pounds of thorium nitrate (1,675 short tons ThO_2 equivalent). The thorium nitrate stockpile goal remained 1.8 million pounds (418 short tons ThO_2 equivalent).

The DOE inventory as of December 31, 1977, was 1,059 short tons of thorium. About 122 tons of this material was being utilized in research and development.

PRICES

Prices for domestic monazite containing approximately 4% ThO_2 rose about 5% in 1977. The average declared value of imported monazite (from Australia and Malaysia) decreased to $164 per short ton from $205 in 1976. The average price per short ton of Australian monazite quoted in Metal Bulletin (London) was $171-$186 (A$154-A$168) until June 1977 when it decreased to $166-$176 (A$150-A$159).

Prices for thorium compounds varied depending upon purity and quantity. Thorium nitrate was quoted at $2.75 per pound; thorium oxide, 99.99% pure, $7.94 per pound; thorium metal in pellets, $15 per pound; and nuclear-grade metal powder, $100 per pound.

FOREIGN TRADE

During 1977, no thorium concentrates or ores were exported. Other thorium export data were combined with those for uranium. Although these two elements were not statistically differentiated, it was believed that the amount of thorium exported was minor.

Monazite containing about 6% thorium was imported from Australia and Malaysia for its rare-earth content. In 1977, imports of gas mantles and thorium compounds decreased. France was the major country of origin of thorium compounds imported into the United States.

Table 2.—U.S. foreign trade in thorium and thorium-bearing materials

(Quantity in pounds unless otherwise specified)

	1975		1976		1977		Principal sources and destinations, 1977
	Quantity	Value	Quantity	Value	Quantity	Value	
EXPORTS[1]							
Metals and alloys[2]	14,840	$203,415	7,018	$145,758	2,840	$137,199	Canada 1,514; United Kingdom 573; Japan 345; Belgium-Luxembourg 175; Others 233.
Compounds[2]	3,837,266	52,039,852	369,036	7,232,389	245,570	2,847,944	United Kingdom 240,584; Canada 2.204; France 1,289; Brazil 500; Others 993.
IMPORTS							
Ore and concentrate:							
Monazite (short tons)	2,565	531,958	2,103	430,551	5,480	900,191	Australia 3,149; Malaysia 2,331.
ThO_2 content	307,800	XX	252,360	XX	657,600	XX	
Waste and scrap	115	2,165	--	--	--	--	
Compounds:							
Nitrate	66,102	118,343	69,900	152,860	46,440	118,555	France 23,680; Canada 22,760.
Oxide	9,500	55,382	5,007	16,517	10,911	46,147	France 8,707; Netherlands 2,204.
Oxide equivalent, in gas mantles[e] [3]	2,374	361,268	1,889	355,885	1,288	191,165	Malta 655; United Kingdom 316; Brazil 182; Others 135.
Other	76	18,438	71	19,085	473	52,947	Switzerland 462; Federal Republic of Germany 11.

[e]Estimate. XX Not applicable.
[1]No thorium ore and concentrates have been exported for the years 1975 through 1977.
[2]Includes uranium; thorium and uranium are undifferentiated in official statistics.
[3]Based on the manufacture of 1,000 gas mantles per pound ThO_2.

WORLD REVIEW

The predominate source of the world's thorium is monazite, a byproduct of titanium and tin mining. Australia, India, Malaysia, Brazil, and the United States continued to be the leading monazite producers among market economy countries. The small world demand for thorium, however, is not reflected by the quantity of this production, since monazite is processed mainly for its rare-earth element content.

Table 3.—Monazite concentrates: World production, by country

(Short tons)

Country[1]	1975	1976	1977[p]
Australia	4,968	5,016	9,646
Brazil	[e]1,600	1,775	[e]2,000
India[e]	3,300	3,300	3,300
Korea, Republic of[e]	10	10	10
Malaysia[2]	3,621	2,071	[e]2,200
Nigeria[e]	20	20	20
Sri Lanka	[e]5	1	[e]5
Thailand	405	--	--
United States	W	W	W
Zaire	328	265	106
Total	14,257	12,458	17,287

[e]Estimate. [p]Preliminary. W Withheld to avoid disclosing individual company confidential data.
[1]In addition to the countries listed, Indonesia and North Korea may produce monazite, but information is inadequate to make reliable estimates of output levels.
[2]Exports.

Australia.—According to the Mineral Sands Producers Association, Ltd., 1977 monazite production by member companies, by State, was as follows: New South Wales, 327 short tons; Queensland, 683 short tons; and Western Australia, 8,635 short tons.

A 2-year modernization program was being carried out by Cable Sands Pty., Ltd., of Western Australia. The Wickham separation plant in New South Wales of Rutile and Zircon Mines (New Castle) Ltd., was reportedly inactive.[6]

DuPont increased its ownership in Allied Eneabba Pty., Ltd., of Western Australia, from 25% to 40%. Westralian Sands Ltd., was merged with Western Mineral Sands and Ilmenite Pty.[7] Jennings Mining Ltd. reduced production by 75% at Eneabba and Geraldton. Western Mining Corporation's mine and treatment plant at Jurian Bay was on standby status.

Cameroon.—Resources of thorium were reported in a mineral research survey funded by the Canadian Government.[8]

Canada.—Research continued on a thorium fuel cycle for the Canadian-deuterium-uranium (CANDU) reactor. It was estimated[9] that development of the cycle would take 20 to 25 years and cost about $2 billion. The thorium fuel cycle could halve Canadian uranium requirements by early in the next century.

A selected bibliography on the geology of Canadian deposits and occurrences of uranium and thorium was published.[10]

Germany, Federal Republic of.—Construction of the 300-megawatt, pebble-bed, thorium high-temperature reactor (THTR) continued at the Hamm-Uentrop station of Vereinigte Elektrizitaetswerke Westfalen AG. The prestressed concrete reactor vessel was completed.

Operation of the THTR developed by Hochtemperatur-Reaktorbau GmbH was rescheduled for 1979.

Another THTR was studied[11] by the electrical authorities of Cologne and Dusseldorf. They are considering a 600-megawatt reactor at a cost of $420-$630 million, which would be scheduled for operation for 1985.

India.—The Bhabha Atomic Research Center (BARC) was designing an experimental reactor to be fueled by less than one-half a kilogram of U_{233}.[12] Thorium had been irradiated in nuclear reactor cores to produce the U_{233}. A 14-megawatt fast-breeder test reactor, in which large quantities of U_{233} could be bred from thorium, was being built at Kalpakkam with French assistance.

India's nuclear development was oriented toward the thorium fuel cycle because the country has large reserves of thorium and relatively small reserves of uranium.

Pakistan.—Thorium associated with uranium was indicated[13] in the Baghalchur area, west of Dera Ghazi Khan. Followup drilling was planned.

TECHNOLOGY

A book describing the mechanisms of migration of thorium and uranium within the earth and their significance to exploration programs was published.[14]

A method of determining thorium and uranium concentrations of up to 100 parts per million (ppm) in geologic samples by X-ray spectrometry was discussed.[15] Studies indicated that only one calibration curve for each element was necessary, because scattered tube radiation was used as an internal standard. The estimated error was 1.2 ppm thorium for a single analysis. This method may be useful in large-scale exploration programs.

The International Atomic Energy Agency published a report on the status of thorium technology.[16]

A new magnesium casting alloy, which contains from 0.6% to 1.6% thorium, was described.[17] The alloy, which possesses elevated temperature properties superior to other magnesium-sand casting alloys, could compete with high-strength aluminum alloys for aerospace applications.

A 2-year occupational health study for DOE and the Nuclear Regulatory Commission to determine possible effects of thorium on the human body continued at the Argonne National Laboratory. The study involves over 100 former employees of the now-closed Lindsay Light and Chemical Co., a former thorium processor. A preliminary summary of results was scheduled to be published in the summer of 1978.

In April, President Carter proposed to indefinitely postpone development of the Clinch River Breeder Reactor (CRBR) due to concern about the proliferation of nuclear weapons, and to redirect some research efforts toward alternate sources of energy, including the thorium fuel cycle of nuclear power generation.[18] Although the fate of the CRBR was uncertain at yearend, interest in the use of the thorium fuel cycle increased. A nuclear reactor fuel unsuitable for use in nuclear weapons could reportedly be made by diluting U_{233} bred from thorium with a small amount of naturally occurring U_{238}.[19] The current costly, time-consuming, advanced technology of isotope separation would be necessary to obtain a weapons-grade material from such a fuel. There are currently no similar means of diluting plutonium. Current research using lasers may, however, lead to a comparatively cheap and simple method of isotope separation.

Research continued on the thorium fuel cycle, with some emphasis on nonproliferation aspects, in several different reactors, including the HTGR, LWBR, CANDU, LWR, liquid-metal fast-breeder reactor, and gas-cooled fast-breeder reactor (GCFR). Large-scale development of any of these reactors could substantially increase the consumption of thorium.

Ramco, Inc., studied HTGR technology commercialization for DOE[20] and concluded that no major engineering problems associated with the technology exist and that there will be a market for the steam cycle HTGR. Ramco also concluded that commercialization would be beneficial as a means of uranium conservation and would enhance the control of nuclear proliferation. It was suggested that utilities, reactor vendors, and government form a new relationship which recognizes their interdependence and shares the risks involved in development of new reactor types.

Research on the use of a thorium-breeder blanket in a GCFR was conducted by GA. The GCFR utilizes the coolant and nonnuclear component technology of the conventional HTGR.

A GCFR commercialization study, which included consideration of a thorium-breeder blanket, was conducted by Helium Breeder Associates, a utility industry group.

A governmental information exchange agreement concerning high-temperature reactor development was reached by the United States, the Federal Republic of Germany, France, and Switzerland. Although no implementation agreements were signed, informal research and development cooperation between countries took place.[21]

A comprehensive study of the thorium fuel cycle in power reactors was published in January 1977 by Oak Ridge National

Laboratories.[22] The report concluded that the use of the thorium fuel cycle in thermal reactors would result in better uranium utilization and, in some cases, better economic performance, as well as add flexibility to the nuclear industry in case of delays in development of fast-breeder reactors. The HTGR was the only reactor type studied that was more economic with the thorium cycle than with the uranium cycle at current nuclear fuel costs.

---

[1]Physical scientist, Division of Nonferrous Metals.

[2]U.S. Geological Survey. Phosphate Rock, Titanium Deposits Found in South Carolina. News Release, Oct. 13, 1977, 2 pp.

[3]Thompson, J. V., and D. L. Watson. Appraising Large Diameter Core and Percussion Drilling for Bulk Samples. Eng. and Min. J., v. 178, No. 8, August 1977, pp. 80-82.

[4]DOE assumed the functions of the Energy Research and Development Administration (ERDA) in October 1977.

[5]The Energy Daily. General Atomic Develops Strategy for Gas Reactors. V. 5, No. 149, Aug. 2, 1977, p. 1.

[6]1977 E/MJ International Directory of Mining and Mineral Processing Operations. 1977, pp. 258, 270.

[7]Industrial Minerals. Heavy Mineral Hangovers. No. 0019-8544, February 1978, pp. 9-10.

[8]U.S. Embassy, Yaounde, Cameroon. State Department Airgram A-18, Apr. 25, 1977, p. 2.

[9]Nuclear Engineering. Thorium Cycle to Take 20-25 Years, $2 Billion. V. 22, No. 257, May 1977, p. 10.

[10]Garneau, D. M. Selected Bibliography on the Geology of Canadian Deposits and Occurrences of Uranium and Thorium. Geol. Survey of Canada Paper 75-45, 1976, 41 pp.

[11]Nuclear News. Pebble-Bed HTR Demo Planned in Germany. V. 20, No. 1, January 1977, p. 82.

[12]Nuclear Engineering. India's Nuclear Future Rests on the FBR. V. 22, No. 263, October 1977, pp. 35-36.

[13]Mining Journal. Uranium Follow-up. V. 289, No. 7,426, Dec. 16, 1977, p. 499.

[14]Gabelman, J. W. Migration of Uranium and Thorium-Exploration Significance. American Association of Petroleum Geologists, Tulsa, Okla., 1977, 168 pp.

[15]James, G. W. Parts-Per-Million Determinations of Uranium and Thorium in Geologic Samples by X-ray Spectrometry. Anal. Chem., v. 49, No. 7, June 1977, pp. 967-969.

[16]Garg, R. K., R. V. Raghavan, V. M. Karve, and G. R. Narayandas. Status of Thorium Technology. Internat. Atomic Energy Agency, Vienna, Austria, 1977, 11 pp.

[17]Unsworth, W. H. QH 21A—A New Magnesium Casting Alloy. Light Metal Age, v. 35, Nos. 5-6, June 1977, pp. 14-16.

[18]Chemical Engineering. Chementator. V. 84, No. 9, Apr. 25, 1977, p. 60.

[19]Scientific American. The Thorium Option. V. 236, No. 5, May 1977, pp. 57-61.

[20]King, L. New Support for the HTGR. Nuclear Eng., v. 22, No. 260, July 1977, p. 3.

[21]Nucleonics Week. The Swiss Joined the West German/U.S./French HTR Development Program. V. 18, No. 45, Nov. 10, 1977, p. 11.

[22]Kasten, P. R., and F. J. Homan. Assessment of the Thorium Fuel Cycle in Power Reactors. ERDA, ORNL/TM-5565, January 1977, 44 pp.

Tin

By Keith L. Harris[1] and James F. Carlin, Jr.[1]

World tin consumption declined while world tin mine production rose in response to prices that reached record highs during 1977. The International Tin Council (ITC) was powerless to stabilize tin prices after exhaustion of its buffer stock in early January, so the price of tin remained above the ITC ceiling price from January 13 throughout the remainder of the year. Little additional tin was available from U.S. Government stockpile excesses.

U.S. consumption of primary and secondary tin declined 3% in 1977 to 60,732 metric tons.[2] Decreased tinplate production as well as the declining quantity of tin coated on tinplate were major factors causing the decline. The major uses for tin were in tinplate, 31%; solder, 29%; bronze and brass, 14%; chemicals, 9%; and tinning, 4%. Malaysia, Thailand, and Bolivia were the major sources of U.S. tin supplies. Less than 100 tons of tin was produced in Colorado by the only domestic mine. About 22% of the tin consumed in the United States in 1977 was tin reclaimed from scrap.

In 1977, the sole primary tin smelter in the United States was the Texas City, Tex., facility of Gulf Chemical & Metallurgical Co. (GCMC). Bolivia's State-owned Corporación Minera de Bolivia (COMIBOL) provided most of the tin concentrate feed for this smelter.

In 1977, the average composite price of Straits (Malaysian) tin for New York delivery was at an alltime high of 534.60 cents per pound, $1.55 above the 1976 level.

The year marked the first full year of U.S. membership in the Fifth International Tin Agreement (ITA), the first metal commodity agreement in which the United States participated.

Legislation and Government Programs.—The General Services Administration (GSA) continued commercial sales of tin during the year. Sales totaled 2,679 tons, while shipments totaled 2,497 tons. As of December 31, 1977, the U.S. Government stockpile contained 204,176 tons, of which 330 tons was authorized for disposal. The stockpile goal was 33,021 tons. A bill to

Table 1.—Salient tin statistics

(Metric tons)

	1973	1974	1975	1976	1977
United States:					
Production:					
Mine	W	W	W	W	W
Smelter	4,877	6,096	6,500	5,700	6,700
Secondary	20,806	19,200	15,869	16,446	18,503
Exports (including reexports)	3,461	8,550	3,596	2,338	5,480
Imports for consumption:					
Metal	46,581	40,238	44,366	45,055	47,774
Ore (tin content)	4,875	5,971	6,415	5,733	6,724
Consumption:					
Primary	59,075	52,439	43,620	51,767	47,596
Secondary	16,763	13,341	12,180	11,161	13,136
Prices, average cents per pound:					
New York market	227.56	396.27	339.92	349.24	499.38
New York composite	NA	NA	NA	379.82	534.60
London	218.71	370.84	311.41	347.42	486.92
Penang	214.10	355.72	303.55	338.94	485.96
World production:					
Mine	237,847	232,880	r222,283	r228,005	231,438
Smelter	233,874	236,198	r227,895	r229,861	230,243

rRevised. NA Not available. W Withheld to avoid disclosing company proprietary data.

authorize a U.S. contribution of up to 5,000 tons of tin to the ITC buffer stock and numerous bills to authorize additional tin disposals from the Government stockpile were introduced in Congress, but none was enacted.

The depletion allowance for tin remained 22% for domestic deposits and 14% for foreign deposits.

DOMESTIC PRODUCTION

PRIMARY TIN

Mine Production.—Domestic production of tin in 1977 was less than 100 tons. All of the year's output came from Colorado as a byproduct of molybdenum mining.

Smelter Production.—The only domestic tin smelter, GCMC, received 6,724 tons of tin-in-concentrate, mostly from Bolivia, which formed the base feed together with domestic tin concentrate and secondary tin-bearing materials. Tin production was estimated at 6,700 tons.

SECONDARY TIN

The United States is the world's largest producer of recycled, or secondary, tin. Secondary tin furnishes about one quarter of the total U.S. supply each year. In 1977, secondary tin production increased 13% from the 1976 level to 18,503 tons. Of the tin recycled in 1977, 91% was as an alloy constituent in reclaimed bronzes, brasses, solders, and bearing and type metals, or as an element in chemical compounds. Only 9% of the recycled tin, mostly from new tinplate scrap, was reclaimed as metal.

Table 2.—Secondary tin recovered from scrap processed at detinning plants in the United States

		1976	1977
Tinplate scrap treated	metric tons	685,450	667,416
Tin recovered in the form of:			
Metal	do	1,195	1,376
Compounds (tin content)	do	424	365
Total[1]	do	1,619	1,741
Weight of tin compounds produced	do	1,348	1,516
Average quantity of tin recovered per metric ton of tinplate scrap used	kilograms	2.36	2.61
Average delivered cost of tinplate scrap	per metric ton	$67.26	$56.11

[1]Recovery from tinplate scrap treated only. In addition, detinners recovered 266 metric tons (250 tons in 1976) of tin as metal and in compounds from tin-base scrap and residues in 1977.

Table 3.—Tin recovered from scrap processed in the United States, by form of recovery

(Metric tons)

Form of recovery	1976	1977
Tin metal:		
At detinning plants	1,445	1,642
At other plants	22	26
Total	1,467	1,668
Bronze and brass:		
From copper-base scrap	8,282	10,319
From lead- and tin-base scrap	37	78
Total	8,319	10,397
Solder	4,513	4,094
Type metal	668	708
Babbitt	495	694
Antimonial lead	548	565
Chemical compounds	424	365
Miscellaneous[1]	12	12
Total	6,660	6,438
Grand total	16,446	18,503
Value (thousands)	$137,710	$218,075

[1]Includes foil, cable lead, and terne metal.

Table 4.—Shipments of metal cans[1]

(Thousand base boxes[2])

Type of can	1976	1977	1977 change, percent
FOOD AND BEVERAGE			
Fruit and fruit juices	12,596	13,809	+9.63
Vegetables and vegetable juices	21,058	22,560	+7.13
Dairy-based products	2,308	2,064	-10.57
Soft drinks	39,615	47,324	+19.46
Beer	54,651	56,627	+3.62
Meat and poultry	3,230	3,280	+1.55
Fish and other seafoods	2,210	1,949	-11.81
Coffee	3,375	2,189	-35.14
Lard and shortening	1,578	1,442	-8.62
Baby foods	1,529	1,656	+8.31
Pet foods	5,874	5,415	-7.81
All other foods, including soups	13,156	12,991	-1.25
Total	161,180	171,306	+6.28
NONFOOD			
Oils	2,465	2,416	-1.99
Paint and varnish	5,922	5,740	-3.07
Pressure packing (valve type)	5,082	4,739	-6.75
All other nonfood	4,857	4,247	-12.56
Total	18,326	17,142	-6.46
Grand total	179,506	188,448	+4.98
BY METAL			
Steel base boxes	120,101	117,703	-2.00
Aluminum base boxes	35,935	41,670	+15.96

[1]Includes tinplate and aluminum cans.

[2]The base box, a unit commonly used in the tinplate industry, equals 31,360 square inches of plate, or 62,720 square inches of total surface area.

Source: Can Manufacturers Institute.

Table 5.—Stocks, receipts, and consumption of new and old scrap and tin recovered in the United States, in 1977

(Metric 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)	3,755	64,073	--	63,648	63,648	4,180	--	2,737	2,737
Brass, composition or red	4,256	60,685	12,535	48,075	60,610	4,331	476	1,782	2,258
Brass, low (silicon bronze)	508	3,014	1,132	1,860	2,992	530	--	19	19
Brass, yellow	5,926	42,329	5,065	35,967	41,032	7,223	12	369	381
Bronze	1,856	19,041	3,024	16,001	19,025	1,872	239	1,256	1,495
Low-grade scrap and residues	12,086	85,986	65,498	16,219	81,717	16,355	14	--	14
Nickel silver	678	2,861	210	2,570	2,780	759	2	21	23
Railroad-car boxes	408	1,904	--	2,081	2,081	231	--	99	99
Total	29,473	279,893	87,464	186,421	273,885	35,481	743	6,283	7,026
Brass mills:[1]									
Brass, low (silicon bronze)	3,652	61,151	61,151	--	61,151	3,516	--	--	--
Brass, yellow	23,897	245,044	245,044	--	245,044	24,743	116	--	116
Bronze	726	4,728	4,728	--	4,728	722	227	--	227
Nickel silver	4,135	25,362	25,362	--	25,362	2,406	--	--	--
Total	32,410	336,285	336,285	--	336,285	31,387	343	--	343
Foundries and other plants:[2]									
Auto radiators (unsweated)	680	9,842	--	9,403	9,403	1,119	--	424	424
Brass, composition or red	395	5,329	1,718	3,673	5,391	333	81	174	255
Brass, low (silicon bronze)	61	1,351	897	429	1,326	86	--	--	--
Brass, yellow	386	8,094	5,410	2,614	8,024	456	--	24	24
Bronze	132	1,441	53	607	660	913	4	47	51
Low-grade scrap and residues	26	--	18	--	18	8	--	--	--
Nickel silver	5	110	--	105	105	10	--	--	--
Railroad-car boxes	1,243	4,930	--	5,370	5,370	803	--	255	255
Total	2,928	31,097	8,096	22,201	30,297	3,728	85	924	1,009
Total tin from copper-base scrap	XX	XX	XX	XX	XX	XX	1,171	7,207	8,378
Lead-base scrap:									
Smelters, refiners, and others:									
Babbitt	231	3,936	--	3,868	3,868	299	--	188	188
Battery lead plates	49,312	718,058	--	709,049	709,049	58,321	--	978	978
Drosses and residues	33,327	173,441	174,401	--	174,401	32,367	3,369	--	3,369
Solder and tinny lead	341	12,123	--	12,191	12,191	273	--	1,892	1,892
Type metal	2,623	17,467	--	17,307	17,307	2,783	--	779	779
Total	85,834	925,025	174,401	742,415	916,816	94,043	3,369	3,837	7,206
Tin-base scrap:									
Smelters, refiners, and others:									
Babbitt	13	187	--	177	177	23	--	123	123
Block-tin pipe	5	143	--	140	140	8	--	139	139
Drosses and residues	161	1,440	1,411	--	1,411	190	620	--	620
Pewter	3	32	--	35	35	--	--	30	30
Total	182	1,802	1,411	352	1,763	221	620	292	912
Tinplate and other scrap:									
Detinning plants	--	--	667,416	--	667,416	--	2,007	--	2,007
Grand total	XX	XX	XX	XX	XX	XX	7,167	11,336	18,503

XX Not applicable.

[1]Brass-mill stocks include home scrap, and purchased-scrap consumption is assumed equal to receipts; therefore, lines and total in brass-mill section do not balance.

[2]Omits "machine-shop scrap."

CONSUMPTION

Although total 1977 consumption declined only about 2,200 tons from the 1976 level, a shift from primary to secondary tin resulted in primary tin consumption declining about 4,200 tons from the 1976 level while secondary tin consumption increased about 2,000 tons. The higher cost of primary tin resulted in the increased reclamation of tin, especially in the solder sector. Also contributing to the decline in primary tin consumption was the declining ratio of tin on tinplate and a 3% drop in tinplate production. U.S. brass mills consumed 715 tons of primary tin and 356 tons of secondary tin, compared with 1976 levels of 751 tons and 233 tons, respectively.

Table 6.—Consumption of primary and secondary tin in the United States

(Metric tons)

	1973	1974	1975	1976	1977
Stocks Jan. 1[1]	18,787	18,534	20,228	19,440	16,860
Net receipts during year:					
Primary	60,125	55,382	43,183	50,031	48,234
Secondary	4,089	2,285	2,699	2,019	4,025
Scrap	13,915	12,296	10,568	10,189	10,604
Total receipts	78,129	69,963	56,450	62,239	62,863
Total available	96,916	88,497	76,678	81,679	79,723
Tin consumed in manufactured products:					
Primary	59,075	52,439	43,620	51,767	47,596
Secondary	16,763	13,341	12,180	11,161	13,136
Total	75,838	65,780	55,800	62,928	60,732
Intercompany transactions in scrap	2,544	2,489	1,438	1,891	2,148
Total processed	78,382	68,269	57,238	64,819	62,880
Stocks Dec. 31 (total available less total processed)	18,534	20,228	19,440	16,860	16,843

[1]Stocks shown exclude tin in transit or in other warehouses on January 1, as follows: 1973—986 tons; 1974—823 tons; 1975—70 tons; 1976—34 tons (revised); and 1977—15 tons.

Table 7.—Tin content of tinplate produced in the United States

(Metric tons)

Year	Tinplate waste-waste, strips, cobbles, etc., gross weight	Tinplate (all forms)		
		Gross weight	Tin content[1]	Tin per metric ton of plate (kilograms)
1973	473,590	4,452,779	21,608	4.9
1974	399,947	4,701,840	22,686	4.8
1975	336,967	r4,018,295	18,869	4.7
1976	439,988	4,372,639	r20,766	4.7
1977	355,841	4,228,325	18,539	4.4

rRevised.
[1]Includes small tonnage of secondary tin and tin acquired in chemicals.

Table 8.—Consumption of tin in the United States, by finished product

(Metric tons of contained tin)

Product	1976 Primary	1976 Secondary	1976 Total	1977 Primary	1977 Secondary	1977 Total
Alloys (miscellaneous)	513	93	606	499	115	614
Babbitt	1,832	591	2,423	1,586	507	2,093
Bar tin	656	102	758	492	86	578
Bronze and brass	2,860	4,796	7,656	2,833	5,773	8,606
Chemicals	4,718	903	5,621	4,655	1,072	5,727
Collapsible tubes and foil	679	15	694	749	38	787
Solder	13,506	4,222	17,728	12,173	5,142	17,315
Terne metal	180	9	189	632	58	690
Tinning	2,284	18	2,302	2,291	32	2,323
Tinplate[1]	20,766	--	20,766	18,539	--	18,539
Tin powder	1,208	--	1,208	1,281	6	1,287
Type metal	66	150	216	55	147	202
White metal[2]	2,093	254	2,347	1,505	150	1,655
Other	406	8	414	306	10	316
Total	51,767	11,161	62,928	47,596	13,136	60,732

[1]Includes secondary pig tin and tin acquired in chemicals.
[2]Includes pewter, britannia metal, and jewelers' metal.

STOCKS

Plant stocks of pig tin at yearend 1977 declined 1% from the yearend 1976 level to 6,803 tons, or about a 6-week supply. As the price of tin increased throughout the year, consumers drew down their inventories and tried to purchase tin during brief dips in the market price. Plant stocks were lowest in June, at 4,245 tons, but increased in the last quarter as consumption declined, ending the year at the year's highest level. Tinplate mills held 56% of the plant pig tin stocks at yearend.

Table 9.—U.S. industry yearend tin stocks

(Metric tons)

	1973	1974	1975	1976	1977
Plant raw materials:					
Pig tin:					
Virgin	7,658	8,784	7,090	6,613	6,158
Secondary	343	312	317	243	645
In process[1]	10,533	11,132	12,033	10,004	10,040
Total	18,534	20,228	19,440	16,860	16,843
Additional pig tin:					
In transit in United States	986	823	70	34	15
Jobbers-importers	1,153	691	2,059	1,009	1,436
Afloat to United States	3,688	4,409	4,115	3,582	3,072
Total	5,827	5,923	6,244	4,625	4,523
Grand total	24,361	26,151	25,684	21,485	21,366

[1]Tin content, including scrap.

PRICES

The price of tin in 1977 fluctuated considerably about a generally rising trend. Prices were influenced by the liquidation of the ITC buffer stock, speculative demand, pending legislation concerning additional disposals from the U.S. strategic stockpile, the July 15 ITC price-range hike, and purchases in anticipation of a U.S. dock strike.

The average 1977 composite price of tin at New York increased $1.55 over the 1976 level to $5.35 per pound. The average Penang price for ex-works Straits tin was M$1,588.03 per picul[3] ($4.86 per pound) compared with $1,146.56 per picul ($3.39 per pound) in 1976. The average price for cash tin, standard grade, on the London Metal Exchange was £6,181.17 per ton ($4.87 per pound), 45% higher than the 1976 average.

Table 10.—Monthly composite prices of Straits tin for delivery in New York

(Cents per pound)

Month	1976 High	1976 Low	1976 Average	1977 High	1977 Low	1977 Average
January	319.94	312.44	313.97	480.64	440.44	463.47
February	338.28	319.44	327.49	520.58	476.10	507.43
March	354.79	337.17	347.20	551.13	455.88	518.93
April	361.17	346.81	355.46	489.32	464.72	480.08
May	385.28	360.25	375.11	493.74	481.74	488.61
June	401.50	369.39	389.32	488.16	467.77	481.79
July	434.26	407.37	422.94	543.63	489.29	518.04
August	423.54	392.42	403.53	572.38	541.42	556.37
September	403.46	388.78	396.38	590.79	533.01	556.38
October	411.13	394.01	400.44	626.95	588.50	607.94
November	417.13	397.53	407.78	631.91	606.34	620.93
December	439.45	410.83	418.17	630.38	593.78	615.18
Average	XX	XX	379.82	XX	XX	534.60

XX Not applicable.
Source: Metals Week.

FOREIGN TRADE

Exports (including reexports) of tin, at 5,480 tons, were more than double the 1976 level. Reexports continued to be larger than exports, as has been the case since 1975.

Imports of tin-in-concentrates were up 17% over those of 1976. Bolivia, which has been the only source of tin concentrates since 1974, was joined by Indonesia and the Territory of South-West Africa as suppliers of tin concentrates to GCMC.

Dependency on imports has long been a characteristic of the U.S. tin market, and this pattern continued in 1977. Imports of tin metal increased 6% to 47,774 tons. The major suppliers were Malaysia, 57%; Thailand, 16%; Indonesia, 11%; Bolivia, 7%; and Brazil, 5%. Imports of tin from the People's Republic of China dropped substantially for the second consecutive year, from the 1976 level of 1,727 tons to 381 tons in 1977. China's internal manufacturing development left less tin available for export. Brazil continued the pattern of recent years of doubling its tin exports to the United States, reaching 2,380 tons in 1977.

Table 11.—U.S. exports and imports for consumption of tin, tinplate, and terneplate in various forms

Year	Ingots, pigs, and bars: Exports Quantity (metric tons)	Ingots, pigs, and bars: Exports Value (thousands)	Ingots, pigs, and bars: Reexports Quantity (metric tons)	Ingots, pigs, and bars: Reexports Value (thousands)	Tinplate and terneplate: Exports Quantity (metric tons)	Tinplate and terneplate: Exports Value (thousands)	Tinplate and terneplate: Imports Quantity (metric tons)	Tinplate and terneplate: Imports Value (thousands)	Tinplate circles, strips, and cobbles: Exports Quantity (metric tons)	Tinplate circles, strips, and cobbles: Exports Value (thousands)	Tinplate scrap: Imports Quantity (metric tons)	Tinplate scrap: Imports Value (thousands)
1975	1,444	$10,457	2,152	$15,531	232,052	$105,870	370,508	$170,191	2,574	$437	11,138	$786
1976	540	2,998	1,798	13,967	333,954	131,364	282,928	108,308	15,279	1,949	10,506	596
1977	545	5,176	4,935	50,175	296,614	115,579	4,046	1,372	21,347	2,821	11,335	778

Table 12.—U.S. imports for consumption and exports of miscellaneous tin, tin manufactures, and tin compounds

Year	Miscellaneous tin and manufactures				Tin compounds	
	Imports			Exports	Imports	
	Tinfoil, tin powder, flitters, metallics, tin and manufactures, n.s.p.f.	Dross, skimmings, scrap, residues, and tin alloys, n.s.p.f.		Tin scrap and other tin-bearing material, except tinplate scrap	Quantity (metric tons)	Value (thousands)
	Value (thousands)	Quantity (metric tons)	Value (thousands)	Value (thousands)		
1975	$7,257	2,468	$2,452	$4,343	122	$823
1976	8,148	2,666	3,550	7,391	176	1,195
1977	3,733	813	1,816	9,328	170	1,448

Table 13.—U.S. imports for consumption of tin, by country

Country	1976		1977	
	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Concentrates (tin content):				
Bolivia	5,733	$38,529	6,667	$60,399
Indonesia	--	--	55	420
South-West Africa, Territory of	--	--	2	21
Total	5,733	38,529	6,724	60,840
Metal:[1]				
Australia	198	1,417	36	347
Austria	18	123	--	--
Bolivia	1,978	14,181	3,358	34,029
Brazil	1,242	9,025	2,380	24,199
Canada	7	60	8	94
China, People's Republic of	1,727	13,195	381	4,345
Colombia	--	--	97	1,112
Germany, Federal Republic of	200	1,590	100	1,107
Hong Kong	84	491	--	--
India	100	868	483	4,861
Indonesia	4,972	35,160	5,294	46,410
Japan	--	--	50	451
Korea	21	124	--	--
Malaysia	26,981	196,454	27,084	261,073
Netherlands	(2)	2	1	17
Nigeria	--	--	2	19
Singapore	15	102	207	2,339
Taiwan	100	637	--	--
Thailand	6,885	47,903	7,780	75,729
United Kingdom	284	2,149	513	3,412
Uruguay	193	1,588	--	--
Vietnam	50	384	--	--
Total	45,055	325,453	47,774	459,544

[1]Bars, blocks, pigs, or granulated.
[2]Less than 1/2 unit.

WORLD REVIEW

International Tin Agreement.—The definitive entry into force of the Fifth International Tin Agreement (ITA) required the signature of at least six producing nations that held over 950 of the 1,000 producer votes in the Fourth ITA. Bolivia, which held 179 votes in the Fourth ITA, declined to ratify the Fifth ITA by the July 1, 1976, starting date, because the Bolivian Government felt the method for determining the ITC price range was inadequate. This action placed the Fifth ITA in provisional status, a status that could be maintained only through June 30, 1977, before necessitating the renegotiation of the Agreement.

In February, talks held in Bolivia be-

Table 14.—Tin: World mine production, by country[1]

(Metric tons)

Country	1975	1976	1977[p]
North America:			
Canada	[r]283	274	317
Mexico	378	481	220
United States	W	W	W
South America:			
Argentina	538	[e] [2]600	[e] [2]600
Bolivia[3]	[r]24,333	29,812	32,616
Brazil[e]	[2]5,000	5,900	[2]6,400
Peru	153	273	[e]300
Europe:			
Czechoslovakia	176	[2]180	[e] [2]180
France	[e]69	--	--
German Democratic Republic[e]	1,120	1,120	1,120
Portugal	375	346	258
Spain	737	390	457
U.S.S.R.[e]	30,000	31,000	33,000
United Kingdom	[r]4,091	4,015	3,851
Africa:			
Burundi	[r]78	26	[e]30
Cameroon	19	10	[e]11
Niger	98	91	[e]75
Nigeria	4,652	3,710	3,267
Rhodesia, Southern[e] [2]	[r]800	[r]800	800
Rwanda	[r]1,423	1,605	[2]1,200
South Africa, Republic of	2,643	2,784	2,864
South-West Africa, Territory of	760	800	[e]1,000
Swaziland[e] [2]	1	[r]4	4
Tanzania	2	3	[e]5
Uganda[e] [2]	117	120	120
Zaire	4,562	[e] [2]4,000	[e] [2]3,607
Zambia[e] [2]	10	10	10
Asia:			
Burma[e] [2]	750	750	760
China, People's Republic of[e]	22,000	20,000	20,000
Indonesia	[r]25,337	23,435	24,021
Japan	659	643	604
Korea, Republic of	4	35	15
Laos	518	[e] [2]576	[e] [2]600
Malaysia	64,364	63,401	58,703
Thailand	16,406	20,452	24,205
Vietnam[e]	250	250	250
Oceania: Australia	[r]9,577	10,109	9,968
Total	[r]222,283	228,005	231,438

[e]Estimate. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data.
[1]Contained-tin basis. Data derived in part from the Monthly Statistical Bulletin of the International Tin Council, London, England.
[2]Estimate by the International Tin Council.
[3]Production by COMIBOL mines, taken with exports of tin materials other than by COMIBOL, and sales to ENAF other than by COMIBOL.

tween the Bolivians and representatives of Malaysia, Indonesia, and Thailand resulted in a proposal to the ITC of establishing a system for periodic review of the ITC price range. Subsequently, the ITC established an Economic and Price Review Panel (EPRP), consisting of representatives of four producing and four consuming countries, that would meet semiannually to review the adequacy of the price range. The Bolivian Government agreed to ratify the Fifth ITA and, on June 14, the Fifth ITA definitively entered into force.

The June EPRP concluded that the price range was inadequate and on July 15, the ITC revised the price range as follows:

	Previous range		Revised range	
	M$ per picul	U.S. equivalent dollars per pound	M$ per picul	U.S. equivalent dollars per pound
Floor price	1,075	3.18	1,200	3.66
Lower sector	1,075-1,150	3.18-3.40	1,200-1,300	3.66-3.96
Middle sector	1,150-1,250	3.40-3.70	1,300-1,400	3.96-4.27
Upper sector	1,250-1,325	3.70-3.92	1,400-1,500	4.27-4.57
Ceiling price	1,325	3.92	1,500	4.57

Table 15.—Tin: World smelter production, by country[1]

(Metric tons)

Country	1975	1976	1977[p]
North America:			
Mexico[e 2 3]	1,000	800	800
United States[4]	6,500	5,700	6,700
South America:			
Argentina[e 2]	120	120	120
Bolivia[5]	7,533	10,100	13,287
Brazil[e 2]	5,400	6,600	6,800
Europe:			
Belgium	4,562	4,068	3,520
Czechoslovakia[6]	(7)	(7)	--
German Democratic Republic[e]	1,200	1,200	1,200
Germany, Federal Republic of	1,306	1,449	2,897
Portugal	409	355	[e]300
Spain	[r]5,249	5,368	5,343
U.S.S.R.[e]	30,000	31,000	33,000
United Kingdom	11,520	9,848	[e 2]10,493
Africa:			
Nigeria	4,677	3,667	3,315
Rhodesia, Southern[e 2]	[r]800	[r]800	800
South Africa, Republic of	780	683	582
Zaire	648	[e 2]600	[e 2]633
Asia:			
China, People's Republic of[e]	22,000	20,000	20,000
Indonesia	17,825	22,202	24,005
Japan	1,212	1,144	1,280
Malaysia[8]	83,070	78,017	66,305
Thailand	16,630	20,337	23,102
Vietnam[e]	200	200	200
Oceania: Australia	5,254	5,603	5,561
Total	[r]227,895	229,861	230,243

[e]Estimate. [p]Preliminary. [r]Revised.
[1]Data derived in part from the Monthly Statistical Bulletin of the International Tin Council, London, England.
[2]Estimate by the International Tin Council.
[3]Smelter output from domestic ores is as follows, in metric tons: 1975—378; 1976—481; 1977—220.
[4]Includes tin content of alloys made directly from ores.
[5]Excludes output of volatilization product (reported as "low grade volatilized powder") as follows, in metric tons: 1975—not available; 1976—675; 1977—964.
[6]Series revised. Czechoslovakia produces tin metal but available sources indicate that metallic tin production is based entirely on scrap. Czechoslovakia's mine production of tin is apparently exported for smelting.
[7]Revised to zero.
[8]Includes small production of tin from smelter in Singapore.

The ITC, without any tin in its buffer stock since January 13, was unable to defend its ceiling price. Many consuming nations realized that to protect their interests and keep the price below the ceiling, additional funds would be required by the buffer stock. By yearend, seven consuming nations had pledged contributions to the buffer stock fund. The United States announced on May 30 that, subject to Congressional approval, it would contribute up to 5,000 tons of metal to the buffer stock. By yearend, such approval had not been obtained.

Australia.—The Australian Bureau of Mineral Resources estimated Australian tin reserves at about 330,300 tons and subeconomic resources at 220,000 tons at the beginning of the year. The reserves were down 3,000 tons but the resources were up about 80,000 tons from the beginning of 1976. The large increase in resources was due to new discoveries as well as new data on known deposits.

Production from two of the top three producers declined in 1977, dropping the top three producers' share of Australia's production from 72% in 1976 to 70% in 1977. Production by Abminco N.L., Australia's second largest producer, declined from 1,691 tons of tin-in-concentrates in 1976 to 1,320 tons in 1977. A wall collapse resulted in a drop in head grade of ore to the mill, causing a fall in production. Ardlethan Tin N.L., the third largest producer, has been experiencing a decline in head grade of ore treated by the mill; even though the mill throughput increased over 20% in 1977, a 26% decrease in grade caused a decline in production to 1,193 tons of tin-in-concentrates.

Production by Renison Ltd., a subsidiary of Consolidated Gold Fields Australia Ltd., increased 11% in 1977 to 5,016 tons of tin-in-concentrate. The company installed an acid leaching plant to allow the production of a single concentrate, thus increasing the head grade of ore and mine output. Previously, Renison had to produce a high-grade and a low-grade tin concentrate due to the two different types of ore in the mine. Production was expected to reach 5,500 tons of tin-in-concentrate by 1978.

Bolivia.—Tin mine production increased 9% over the 1976 level to 32,616 tons. Production by the military-occupied COMIBOL mines, at 23,306 tons, increased 13% due primarily to a strike-free year. Medium mine production increased 1% to 6,753 tons, while small mine production declined 2% to 2,557 tons. Tin exports, at 30,855 tons, increased 2% over the 1976 level, but the value increased 43% to $326.6 million, reflecting the record high tin prices during the year. Tin exports accounted for 46% of the total value of Bolivian exports and 67% of the value of mineral exports.

During the year, the Bolivian Government created a $12 million National Mineral Exploration Fund to finance mine exploration in known deposits or in existing small mines. Priority was to be given to exploration for tin deposits and augmentation of tin reserves.

COMIBOL's total profits reached $5.7 million on sales of $332.8 million, compared with profits of $3.0 million on sales of $255.4 million in 1976. COMIBOL's tin mining costs reportedly increased $0.58 per pound to $4.38 per pound. Although direct mining costs decreased slightly, taxes and royalties increased $0.50 per pound.

After completing the prefeasibility study for conversion of the Catavi mine to an openpit operation, COMIBOL decided to expend an additional $1 million to further define the ore body through an additional 12,000 meters of drilling. The initial survey of the area put reserves of ore between 77 million and 80 million tons of ore grading 0.31% tin.

The Empresa Nacional de Fundiciones (ENAF) smelter produced 12,778 tons of tin and exported 12,095 tons. Production increases over the 9,185 tons produced in 1976 were possible because the smelter's capacity was expanded from 11,500 tons per year to 20,000 tons per year in June. Construction of another smelter to produce 12,500 tons of tin from low-grade tin ore was about 1 year behind schedule. The plant was not expected to reach full capacity until at least 1980.

Funestaño, a small private smelter, added a new 50-ton-per-day cyclone furnace and was expanding the capacity of its electrolytic refinery to 3,500 tons of tin by 1979.[4]

Brazil.—Appreciable quantities of tin have been identified in the 295,000-square-kilometer Tapajos region between Santarem and Manaus, as described in the 10th report in Brazil's 5-year Radam mapping project. All of Brazil was expected to be mapped by 1980.

Companhia Vale do Rio Doce (CVRD), the Government-owned mining company, proposed the formation of a consortium of private tin-mining companies operating in Goiás, Pará, and Roraima States to simplify and modernize production methods, in response to the Brazilian Government's request that CVRD carry out a rational exploitation of Brazil's tin reserves. Although the companies would mine individual areas, they would share a centralized marketing system, joint planning, research and development, and access to equipment. By using large scale mining methods, CVRD believes these companies could raise Brazil's tin production to 25,000 tons per year.

Burma.—New legislation approved by the Pyithu Hluttaw (People's Assembly) abrogated private—foreign or Burmese—investment in minerals development, even on a joint-venture basis. Tin was specifically listed as one of the many minerals affected by this new law.

The Heinda tin mine in southern Burma was modernized and expanded through a cooperative effort of the Governments of Burma and the Federal Republic of Germany and Krupp Industrie-und Stahlbau.[5] Although the Heinda tin deposit was a placer deposit, the cassiterite occurred in consolidated, lateritized conglomerates that required blasting and crushing prior to concentration. Other concentration problems arose from the wide range of grain size of the conglomerates and the large granite boulders in the conglomerates. The new concentration plant had a throughput of 600 tons per hour and an hourly recovery rate of 170 kilograms of concentrate containing 72% tin. Tin losses ranged from 10% to 15%.

Indonesia.—Indonesia, the world's third largest tin producer, exports all its production except about 400 tons per year, which is used domestically for solder, babbit, and pewter.

The Indonesian tin industry was dominated by Perusahaan Terbatas Tambang Timah (P.T. Timah), the State-owned tin mining company. In addition, three foreign companies had tin ventures in Indonesia: Billiton Exploratie Maatschappij Indonesia, B.V. (BEMI), with exploration rights in the area of offshore Tudjuh Island; P.T. Broken Hill Pty. Indonesia (BHPI), with exploration rights on Belitung Island; and P.T. Koba Tin, with operating rights along Bangka's southeast coast from Koba to Tanjung Berikat that includes both onshore and offshore areas.

P.T. Timah approved construction of a second major dredge, *Bangka II*, with construction to be done by Mitsubishi Heavy Industries Ltd. The $21 million dredge, scheduled for delivery in August 1978, will complement *Bangka I*, which has been in operation since May 1966.

BHPI continued production of tin concentrates at the old Kelapa Kampit lode mine at the pilot plant level. BHPI planned to install additional equipment to improve grade and recovery, but was unable to prove significant new reserves at Kelapa Kampit.

The smuggling of tin concentrates from Indonesia was a growing problem according to Government officials.[6] The main tin mining areas on and around the islands of Bangka, Belitung, and Singkep, which lie off the southeast coast of Sumatra, are a short boatride from Singapore. The Indonesian Department of Mines indicated that about 1,000 tons has been smuggled out of several small mines in the area each year. Miners who sell to the smuggling rings evade a 10% export duty levied through P.T. Timah, a 45% income tax on profits, and a 5% regional development tax.

Laos.—Société d'Etudes et d'Exploration Minièra de l'Indochine, the major tin mining company in Laos, was nationalized by the Laotian Government without compensation. The firm's yearly production averaged 1,000 tons of tin concentrate.

Malaysia.—Despite the record high tin prices, Malaysia's tin mine production, at 58,703 tons, was at its lowest level since 1961. The main factors in the 7% drop from the 1976 level were the restrictive State licensing policy and high taxation. At yearend, there were 53 tin dredges, 784 gravel pump mines, and 37 opencast, underground, and other miscellaneous mines in operation, reflecting an 8% increase in the number of active mines over the 1976 level. Gravel pump operations accounted for 51% of the concentrate produced; dredging, 35%; opencast, 4%; underground mining, 3%; and miscellaneous sources, 7%. The tin mining labor force increased 4% to 38,474 workers at yearend.

Metal production, at 66,305 tons, decreased 15% from the 1976 level. Exports of metal decreased to 60,688 tons from 82,162 tons in 1976. Imports of tin-in-concentrates totaled 5,903 tons, down 21% from those of 1976 because of decreased imports from Burma and Indonesia.

In Malaysia, the State governments issued the mining licenses but received only a minor share of the tax revenues from tin mining. The States tended to deny the renewal or the granting of mining leases, favoring other sectors, particularly agriculture, where the States received more of the tax revenue. To address the land-availability problem as well as the tax issue, the Federal Government consolidated its export duty and surcharge to provide a larger share to the State governments, and restructured its taxes to decrease taxes on smaller tin operations. Industry sources felt that, although additional revenues to the State governments would probably encourage land grants, the tax restructuring actually decreased the profitability of large companies, thus decreasing the incentive for investing in large-scale, more efficient ventures.

With no decrease in export duties, which totaled about 30% of the tin value at the 1977 average price, smuggling activities were not discouraged. Various sources placed the volume of tin concentrates smuggled out of Malaysia between 5,000 to 7,000 tons per year.[7] In an effort to solve the smuggling problem, the Malaysian Government amended the Tin Control Bill to increase maximum fines to M$50,000 and lengthen imprisonment to 2 years. The bill also provided for confiscation of ore and equipment.

Ayer Hitam Tin Dredging Malaysia Bhd.'s output declined from 5,923 tons of tin concentrate in 1976 to 2,051 tons of tin concentrate in 1977 because the No. 2 dredge worked low-grade tailings for the last half of the year. High production in 1976 resulted from the dredge working very rich, deep ground. Because of the extreme variability of tin values in the ground at Ayer Hetam and the limited area left to dredge, production equalization was difficult to achieve and 1977 output fell.

Berjuntai Tin Dredging Bhd. resumed its position as Malaysia's largest tin producer after the decline in Ayer Hitam's output in 1977. Berjuntai's output increased about 500 tons over the 1976 level to 4,718 tons of tin concentrate as its new $18 million dredge began its first full year of production. Berjuntai, on behalf of a newly formed joint-venture company, Malacca Timah Sdn. Bhd., began offshore prospecting in the coastal waters of the State of Malacca.

Conzinc Riotinto Malaysia Sdn. Bhd. (CRM) joined with the Selangor State Development Corp. (SSDC) and Syarikat Lumbong Setapak (SLS) in a joint-venture company called Perangsang Riotinto to mine a 569-hectare lease in Dengkil, southern Selangor, over the next 20 years. A dredge with an 8-million-cubic-meter annual throughput, recovering 1,000 tons of tin per year, was scheduled to begin operations in 1979. CRM's output increased about 200 tons over that of 1976 to 1,259 tons of tin concentrate. Following the 1976 withdrawal of Bethlehem Steel Corp., CRM was owned 41.5% by Rio Tinto-Zinc Corp. and 58.5% by Conzinc Riotinto of Australia.

Gopeng Consolidated Ltd., Malaysia's largest hydraulic mining company, had a 400-ton drop in output from its 1976 level of 2,139 tons of tin concentrate because of drought. The company's wholly owned Malaysian subsidiary, Mambang Di-Awan Sdn. Bhd., and the Perak State mining company, Syarikat Permodalan Dan Perusahaan Perak Bhd., will join to exploit a 223-hectare area in the Mukim of Chenderiang.

Nigeria.—The Nigerian Enterprises Promotion Decree 1977 required at least 60% Nigerian equity in mining companies by December 31, 1978. The Government-owned Nigerian Mining Corp. (NMC) and Nigerian employees of Amalgamated Tin Mines of Nigeria (Holdings) Ltd. (ATMN) increased their control of ATMN to the required 60% ownership through a $931,000 purchase of 1.2 million ATMN shares. ATMN mines about 2,000 tons of tin concentrate per year.

ATMN commissioned two bucket wheel excavators and began to strip overburden at the Sabon Gida tinfield where deep reserves of tin have been established. Tin production was expected in early 1978.

The Liruie venture in Kano State underwent a further change in terms of ownership to 55% for the NMC, 16% for Gold & Base Metal Mines of Nigeria Ltd., and the balance open to subscription.

Rwanda.—Sociêté Minera de Rwanda (Somirwa), a Rwandan-Belgian firm, planned construction of a 3,000-ton-per-year, $5 million tin smelter at Kigali. The tin smelter, the first for Rwanda, will be able to handle the country's entire tin ore production. A $3.5 million loan by the European Investment Bank will be used to finance the smelter. Most of Somirwa's production has been processed at Belgium's Hoboken smelter.

South Africa, Republic of.—Production of tin-in-concentrates in 1977 rose 3% over the 1976 level to 2,864 tons. Output was notably increased by Rooiberg Minerals Development Co. Ltd. to 4,563 tons of concentrates in 1977, a company record. Union Tin Mines Ltd. produced 1,268 tons of concentrates, a decline from that of 1976. Underground ore was very limited and it was highly unlikely that operations would be continued beyond 1978. Retreatment of tailings would continue while it remained profitable.

Zaaiplaats Tin Mining Co. Ltd., South Africa's only tin smelting company, with a 1,500-ton-per-year-capacity plant at Potgietersrust, constructed a third reverberatory furnace as part of its plan to enlarge smelter capacity. Zaaiplaats tin metal production was 582 tons in 1977.

Thailand.—Reported tin production, at 24,205 tons, increased 18% over the 1976 level, reaching record high levels although smuggling continued to be a problem. Gravel pump mines produced 34% of the output, although each mine's annual production averaged only about 30 tons of tin-in-concentrate. Suction boats provided 26% of the production and dredges, 20%. An estimated 5,000 tons of tin concentrates was believed to be smuggled out of the country to avoid payment of royalties.[8]

In an effort to share in some of the profits from the increased price of tin and decrease the loss of revenues from large-scale smuggling, the Thai Government increased royalties on domestic production on July 15. Prior to the revision, the Department of Mineral Resources (DMR) collected a royalty of 25% of the value of production when the market price exceeded Baht 1,000 per picul ($0.38 per pound).[9] The new schedule exempted royalties when the price was below Baht 3,000 per picul ($1.12 per pound). However, under heavy protest by the tin mining industry and because the increased royalty fell heavily on the Government's Offshore Mining Organization (OMO) the rates were reduced in February 1978. The revised rates were as follows:

Price, Baht per picul (dollars per pound)	Royalty, percent	
	July 1977	February 1978
3,000-6,000 (1.12-2.25)	30	30
6,000-9,000 (2.25-3.35)	40	35
9,000 and up (3.38 and up)	50	40

OMO granted a 5-year mining lease in Phangnga Bay to Sethasup Karn Rae, a local mining company. Two dredges, each with an annual capacity of 270 tons of tin-in-concentrate, began operation in November. A $12 million offshore dredge with a capacity of 329,000 cubic meters per month was ordered by OMO to work offshore deposits in Ban Do Dan, Phangnga.

Aokam Tin Bhd. recorded production increases from its two dredges operating in Phuket Bay. Production was up about 200 tons to 1,703 tons over that of strikebound 1976. The leases in Phuket Bay expire at the end of 1978, but Aokam has additional leases in Bangtao Bay that do not expire until June 30, 1982. The Bangtao Bay leases can only be dredged from November through April because of adverse weather conditions during the remainder of the year. Negotiations were started with the Thai Government, which holds a 15% share in Aokam, to fulfill the Government's policy of increased Thai participation in mining companies.

Southern Kinta Consolidated, Ltd., resumed dredging off the coast of Takuapa after a 1-year hiatus due to an unofficial strike. Illegal mining activity in the concession area during Southern Kinta's inactivity left doubt as to the extent of the remaining recoverable ore in the concession, but Southern Kinta estimated that operations could continue for an additional 3 years.

Tongkah Harbour Tin Dredging Bhd. said it will negotiate with DMR in 1978 to renew its Phuket Bay and Bangtao Bay mining leases, which are due to expire in 1978 and 1982, respectively. A Thai equity share in the company was expected to be a condition of lease renewal. The 40-year-old dredge working the leases was not expected to last the additional 20 years of operation required to exhaust the reserves when the leases are renewed.

The Thai Board of Investment approved the Euro-Thai Mining Co. Ltd.'s plans to mine tin and copper at Amphoe Bannang Sata in Yala Province. The mine was expected to produce 670 tons of tin and 892 tons of copper per year.

To decrease the transportation costs for small miners in northern Thailand, DMR approved the plans of the Thai Present Co. to build a 3,600-ton-per-year smelter at a site 40 kilometers north of Bangkok.

U.S.S.R.— A Central Intelligence Agency study[10] on the U.S.S.R. tin industry outlined salient points of Soviet tin production and consumption. The study quantified the U.S.S.R. as the world's second largest producer of primary tin with an estimated 1975 output of 25,000 tons, and indicated that the U.S.S.R. was the world's second largest consumer of primary tin with usage of 35,000 tons in 1975. Magadan Oblast' was the leading Soviet tin mining area, but Soviet tin mining was very costly due to the remoteness and climate conditions of most tin-deposit regions. Tin production was projected to be 35,000 tons in 1980.

United Kingdom.—Cornwall Tin & Mining Corp.'s Mt. Wellington mine, which began operations in May 1976, produced 417 tons of tin-in-concentrate in 1977, compared with the 1976 level of 85 tons. Although production was up, the mine only recovered about one-quarter of the 1,600 tons of tin-in-concentrate per year that the mill was designed to recover. Because of the lower-than-expected ore grade, the mining costs reached about £6,350 per ton ($4.99-$5.07 per pound), well above the £6,181 per ton ($4.89 per pound) 1977 average price.

Geevor Tin Mines Ltd. mined 111,600 tons of ore and recovered 621 tons of tin-in-concentrate during the fiscal year ending in March. Geevor proceeded with plans to dewater the old Levant mine, which extends under the sea three-quarters of a mile. Shaft sinking and development work would not be finished before 1979.

The combined production of St. Piram Ltd.'s South Crofty and Pendarves tin mines totaled 2,219 tons of tin concentrate and expansion continued at both locations.

Production at Consolidated Gold Fields Ltd.'s Wheal Jane mine decreased 2% from that of 1976 to 975 tons of tin-in-concentrate. The company experienced declining ore grades and increased operating costs.

AMAX Exploration (U.K.) entered a joint venture with Hemerdon Mining and Smelting Ltd. to further explore the Hemerdon tungsten-tin-china clay deposits near Plymouth. The joint venture gave AMAX an option to obtain a 50% interest in the mine in return for completing the exploration. Earlier exploration indicated 5.1 million tons of ore averaging 1.8 kilograms of tungsten and 0.5 kilogram of tin per ton.

The Capper Pass & Son Ltd. tin smelter awarded a $700,000 contract to Head Wrightson Process Engineering Ltd. to modify the waste gas handling section of an existing sinter plant at North Ferriby.

TECHNOLOGY

The International Tin Symposium was held on November 14-20 in La Paz, Bolivia.[11] Topics ranged from geology and resources to consumption and marketing. The symposium was organized by the Bolivian Ministry of Mining and Metallurgy and Resource Exploration International.

The majority of tin ores continued to be treated by gravity concentration, but significant improvements in recovery could be made in existing plants through application of new technology.[12] The major factors causing poor metallurgical results in existing plants included ore variability; mine drilling and blasting techniques; poor design and equipment selection; overgrinding in the primary, secondary, and regrind mills; and insufficient process control.

The increased use of aluminum to lower automobile weight to reduce fuel consumption and pollution levels led to the use of tin-cadmium coatings on fasteners.[13] Zinc-coated steel fasteners resulted in bimetallic corrosion between steel and aluminum once the zinc coating was worn.

The actinide nitride-fueled (ANF) reactor, using uranium nitride in molten tin for power generation, could develop into a future source of energy.[14] Although the ANF reactor was in a conceptual stage that may require up to $2 billion to prove, some advantages of the ANF reactor over present reactors could be (1) reduced problems of environmental safety and radioactive waste storage, (2) reduced danger of runaway reactors, and (3) relative ease of fuel recycling, resulting in savings of up to 90% over the present recycling methods.

The Organotin Environmental Program Association was established by 12 of the world's leading producers of organotin compounds and the International Tin Research Institute. The association will be based in The Hague, the Netherlands, to promote dissemination of technical and scientific information on the effect of organotins on the environment.[15]

A new class of estertin stabilizers that were less hazardous and easier to synthesize than intermediates of conventional organotin compounds was discussed.[16] In addition to the ease of synthesis of the intermediates, the stabilizers had favorable extraction, toxicity, and stability characteristics.

An indium phosphide/indium-tin oxide experimental solar cell developed by Bell Telephone Laboratories had an efficiency of 14.4% compared with production model silicon cell efficiency of 13.5%.[17] The new cell, made of a layer of amorphous indium-tin oxide on a single crystal of indium phosphide, could be manufactured more easily than the indium phosphide/cadmium sulphide cell.

The American Can Co., Continental Can Co., and Reynolds Metals Co. began manufacturing retortable, laminated aluminum and plastic pouches for food packaging.[18] Claimed to be a major development in food packaging, the retortable pouch requires less energy to produce than metal cans. With higher tin prices making tin cans a less attractive form of packaging, research for replacements has become more active. In 5 to 10 years, retortable pouches were expected to penetrate significantly into the can market.

---

[1]Physical scientist, Division of Nonferrous Metals.

[2]Unless otherwise specified, all units are metric tons of contained tin.

[3]One picul = 133.33 pounds. One ringget (M$) = U.S. $ 0.4063 in 1977, U.S. $0.3941 in 1976.

[4]U.S. Embassy, La Paz, Bolivia. State Department Airgram A-19, Apr. 10, 1978, 57 pp.

[5]Drescher, H. P., and W. Gocht. Increase of Production by Application of Dry Mining Method and Construction of a Modern Concentrator at Burma's Heinda Tin Mine. Tin Internat., v. 51, 1978, pp. 129-136; World Mining, v. 31, No. 6, June 1978, pp. 44-49.

[6]Metals Week. Tin Concentrates Smuggling—A Growing Problem in South East Asia. V. 48, No. 46, Nov. 14, 1977, pp. 9-10.

[7]Work cited in footnote 6.

[8]Work cited in footnote 6.

[9]One baht=U.S.$0.05.

[10]Central Intelligence Agency. Soviet Tin Industry: Recent Developments and Prospects Through 1980. ER77-10011, January 1977, 18 pp; Available from Document Expediting (DOCEX) Project, Exchange and Gift Division, Library of Congress, Washington, D.C. 20540.

[11]Tin International. Bolivian Tin Symposium. V. 51, 1977, p. 462.

Reed, B. L., J. Curry, and F. Urquidi. Tin Explored in La Paz. Geotimes, v.23, No.5, May 1978, pp. 16-17.

Davey, T. R. A., and G. M. Willis. Lead, Zinc and Tin. J. Metals, v. 30, No. 4, Apr. 4, 1978, pp. 16-19.

[12]Ottley, D. J. Gravity Concentrator Design and Operation— Developments and Problems. Mining Mag., v. 138, No. 1, January 1978, pp. 33-43.

[13]International Tin Research Institute. Quarterly Review. Tin and Its Uses. Mechanical Plating with Tin-Cadmium Alloy. No. 112, 1977, pp. 4-5.

[14]Jones, R. T. Meet the ANF Reactor. Ind. Res., v. 18, No. 5, May 1976, pp. 55-58.

[15]Chemical and Engineering News. Business Concentrates. V. 56, No. 11, Mar. 13, 1978, p. 10.

[16]Burley, J. W. The Chemistry of Estertin Stabilizers. Tin and Its Uses. Int. Tin Res. Inst., Quarterly Rev., No. 111, 1977, pp. 10-13.

[17]Chemical and Engineering News. Science Technology Concentrates. V. 56, No. 22, May 29, 1978, p. 17.

[18]American Metal Market. American Can: New Pouch Gets Food, Drug Unit Nod. V. 85, No. 255, Dec. 30, 1977, p. 7.

Titanium

By Langtry E. Lynd[1]

U.S. production of titanium sponge metal in 1977 was 43% higher than in 1976. Consumption of sponge metal was 16,236 tons, up 22% from that of 1976. Ingot production and consumption were 26,302 and 25,214 tons, respectively, in 1977, or 22% and 20% higher than in 1976. Sponge inventories decreased slightly from 3,617 tons to 3,546 tons, and scrap metal consumption increased from 9,211 tons in 1976 to 10,889 tons in 1977. Production of titanium dioxide pigment was about 687,000 tons, 4% lower than in 1976. Pigment imports increased from about 68,000 tons in 1976 to about 115,000 tons.

Domestic ilmenite production declined during 1977 for the fourth consecutive year to 638,503 tons, down 2% from that of 1976. Imports of ilmenite nearly doubled, and those of rutile decreased correspondingly as Kerr-McGee Chemical Corp. switched from using natural rutile to manufacturing synthetic rutile from imported ilmenite. Imports of titanium slag decreased 12% in 1977.

The main price changes during 1977 were as follows: A decrease in the price of rutile from $A220-$A230 to $A180-$A190 per metric ton ($185-$195 per short ton) f.o.b. Australian ports; an increase in the price of QIT slag to $102.50 per long ton f.o.b. Sorel, Quebec; a 2-cent-per-pound increase in the price of titanium dioxide pigments to 48.5 cents per pound for most rutile grades and 43.5 cents per pound for paper-grade anatase; and an increase in the price of domestic sponge from about $2.75 to $2.98 per pound.

Legislation and Government Programs.—The Government stockpile goal for titanium sponge metal remained at 131,503 tons during 1977. The quantity of specification titanium sponge metal in the Government stockpile in December 1977 was 27,853 tons. In addition, there was 4,476 tons of nonspecification material.

Table 1.—Salient titanium statistics

	1973	1974	1975	1976	1977
United States:					
Ilmenite concentrate:					
Mine shipments ______ short tons__	804,355	755,338	702,252	617,896	542,333
Value ____________ thousands__	$20,128	$22,715	$26,946	$27,578	$25,200
Imports ____________ short tons__	69,641	82,448	122,010	168,402	334,990
Consumption _____________ do__	807,733	851,977	747,821	822,259	866,504
Titanium slag:					
Imports _________________ do__	237,248	236,272	212,682	171,624	150,564
Consumption _____________ do__	281,791	257,125	147,965	203,964	149,454
Rutile concentrate, natural and synthetic:					
Imports _________________ do__	226,860	246,489	224,499	281,712	123,800
Consumption _____________ do__	276,907	292,661	231,430	237,718	185,419
Sponge metal:					
Imports for consumption ______ do__	5,172	6,963	4,190	1,778	2,387
Consumption _____________ do__	20,173	26,896	17,626	13,315	16,236
Price, Dec. 31, per pound ________	$1.42	$2.25	$2.70	$2.70	$2.98
World production:					
Ilmenite concentrate _____ short tons__	2,983,123	3,518,640	r3,194,028	r3,526,256	3,722,628
Titanium slag _________________ do__	947,394	936,023	r831,505	r911,044	785,096
Rutile concentrate, natural ______ do__	385,284	397,765	r [1]421,532	r [1]471,478	[1]395,502

rRevised.
[1]Excludes U.S. production data in order to avoid disclosing individual company confidential data.

The Government stockpile goal for rutile concentrate remained at 173,928 tons, and total rutile stockpile inventory in December 1977 was 39,186 tons.

A bill to continue the suspension of the import duty on synthetic rutile until June 30, 1979 became law on November 8, 1977 (Public Law 95-160).

At mid-year the B-1 bomber program was cancelled, which reportedly would have consumed about 165,000 pounds of titanium per plane. While the Cruise missile, which is to be developed instead, and refurbishing of the B-52 aircraft to carry the missile, will use significant amounts of titanium, the total quantity required was expected to be much less than for the B-1 program.

Under the terms of a consent decree settling an Environmental Protection Agency (EPA) lawsuit, NL Industries, Inc. agreed to build a new chloride process pigment plant at its St. Louis, Mo., sulfate process plant site. In addition, the company was to provide waste-treatment facilities costing about $30 million to reduce water discharges of solids and iron by 96% and 99%, respectively, from current levels by April 1980.

The Georgia Supreme Court upheld a lower court decision overturning a $321,000 fine against American Cyanamid Co. that was levied in 1973 for discharging titanium pigment plant wastes into the Savannah River. The fine was assessed for a period from before Cyanamid began construction of its Savannah waste-treatment facility until the wastes were treated to meet State standards.

The Federal Trade Commission authorized an investigation of the titanium dioxide pigment industry to determine whether producers or suppliers of TiO_2 pigments or titaniferous raw materials have been engaged in restraint-of-trade activities and price fixing. The fact that the industry shrank from nine producers in the early 1970's to six firms in 1977 was to be examined.

DOMESTIC PRODUCTION

Concentrates.—Production and shipments of ilmenite concentrate decreased 2% and 12%, respectively, the fourth consecutive yearly decline for both categories. Titanium dioxide contained in concentrates shipped was 12% less than in 1976. The average TiO_2 content of shipments increased from 60.7% in 1976 to 61.1% in 1977. Production increased 34% at the ASARCO Incorporated mine in Manchester, N.J.; 6% at the mines of E. I. du Pont de Nemours & Co., Inc. (Dupont), Starke and Highland, Fla.; and 44% at the mine of SCM Corp., near Lakehurst, N.J. These increases, however, were insufficient to offset decreases at the mines of NL Industries, Inc., Tahawus, N. Y.; Humphreys Mining Co., Boulougne, Fla.; and Titanium Enterprises, Green Cove Springs, Fla.

Kerr-McGee Chemical Corp. began operation of its $53 million synthetic rutile plant at Mobile, Ala., which has a reported production capacity of 110,000 tons per year. During 1977, this plant supplied feed material for Kerr-McGee's 11-year-old, 50,000-ton-per-year pigment plant at Hamilton, Miss., and was intended to eventually provide feed for a new pigment plant of the same capacity to be built at Mobile. The synthetic rutile plant was operated in 1977 using ilmenite from Australia and employed the Benilite Cyclic Process, which involves partial reduction of ilmenite, leaching of the reduced ore with 18% to 20% hydrochloric acid to remove iron, and recovery of the acid from the spent liquor.

Airborne radioactivity surveys and ground investigations conducted by the U.S. Geological Survey revealed deposits of titanium minerals and other heavy minerals at five locations in ancient beach sands in Charleston County, S. C. Evidence indicated that the beach sands contain about 1.1 million tons of titanium minerals, predominantly ilmenite. Survey investigators on the project emphasized that more detailed exploration will be needed to determine whether the deposits can be mined economically.[2]

A program of large-diameter core drilling to obtain representative bulk samples for laboratory and pilot plant metallurgical tests was completed by Buttes Gas & Oil Co. at its titanium deposit in Colorado. The property consists of a random mixture of coarse segregations of perovskite, the major titanium-bearing mineral, with magnetite, augite, biotite, and mica.[3]

Ferrotitanium.—Ferrotitanium was produced by Shieldalloy Corp. at Newfield, N.J., by the Pesses Co. at Solon, Ohio, and by Reactive Metals and Alloys Corp., West Pittsburgh, Pa. As in the years prior to 1977, most of the production contained 40% titanium or higher.

Table 2.—Production and mine shipments of ilmenite concentrates[1] from domestic ores in the United States

Year	Production (short tons, gross weight)	Shipments: Short tons (gross weight)	Shipments: TiO_2 content (short tons)	Shipments: Value (thousands)
1973	776,013	804,355	458,541	$20,128
1974	744,571	755,338	434,605	22,715
1975	717,281	702,252	404,269	26,946
1976	652,404	617,896	374,989	27,578
1977	638,503	542,333	331,139	25,200

[1]Includes a mixed product containing rutile, leucoxene, and altered ilmenite.

Table 3.—Titanium metal data

(Short tons)

	1973	1974	1975	1976	1977
Sponge metal:					
Imports for consumption	5,172	6,963	4,190	1,778	2,887
Industry stocks	1,941	3,822	5,669	3,617	3,546
Government stocks (total inventory)[1]	32,517	31,104	31,692	32,329	32,329
Consumption	20,173	26,896	17,626	13,315	16,236
Scrap metal:					
Consumption	10,038	10,599	8,316	9,211	10,889
Stocks	4,447	5,517	6,132	5,764	6,827
Ingot:[2]					
Production	28,932	36,132	25,560	21,614	26,302
Consumption	25,409	31,563	24,486	21,004	25,241
Stocks	NA	NA	1,032	[r]1,831	1,898
Net shipments of mill products[3]	14,530	17,443	15,628	14,498	15,466

[r]Revised. NA Not available.
[1]As of December 31 of each year.
[2]Includes alloy constituents.
[3]Bureau of the Census, Current Industrial Reports Series DIB-991.

Metal.—Production of titanium sponge metal in 1977 was 43% higher than in 1976. Ingot production was up about 22% from the 1976 level.

In October, an explosion in the titanium sponge metal plant of Oregon Metallurgical Corp. at Albany, Oreg., caused extensive damage and suspension of sponge production. The sponge plant was being repaired and was expected to be back in production by the end of March 1978.

Sponge-producing companies during 1977 were Titanium Metals Corp. of America (TMCA), Henderson, Nev., jointly owned by NL Industries, Inc., and Allegheny-Ludlum Steel Corp.; RMI Co., Ashtabula, Ohio, owned by National Distillers & Chemical Corp. and United States Steel Corp.; and Oregon Metallurgical Corp., Albany, Oreg., owned by Armco Steel Corp. and Ladish Corp., which resumed production late in 1976. The following eight companies produced titanium ingot:

Company	Plant location
Crucible, Inc., Colt Industries	Midland, Pa.
Howmet Corp., Alloy Division	Whitehall, Mich.
Lawrence Aviation Industries, Inc	Port Jefferson, N.Y.
Martin Marietta Aluminum, Inc	Torrance, Calif.
Oregon Metallurgical Corp	Albany, Oreg.
RMI Co	Niles, Ohio
Teledyne Allvac	Monroe, N.C.
Titanium Metals Corp. of America	Henderson, Nev.

Pigment.—Pigment production was 4% lower than in 1976. Rutile pigment accounted for 76% of total production and was produced by six manufacturers. Five companies produced anatase pigment. Companies producing titanium dioxide pigment during the year, with plant location and estimated capacity at yearend in tons per year, were as follows:

Company and plant location	Pigment capacity (tons per year)	
	Sulfate process	Chloride process
American Cyanamid Co., Savannah, Ga	50,000	50,000
E. I. du Pont de Nemours & Co., Inc.:		
Antioch, Calif	--	30,000
Edge Moor, Del	--	160,000
New Johnsonville, Tenn	--	235,000
Kerr-McGee Chemical Co., Hamilton, Miss	--	50,000
NL Industries, Inc.:		
St. Louis, Mo	40,000	--
Sayreville, N.J	100,000	--
Gulf + Western Natural Resources Group Chemicals Division (formerly New Jersey Zinc Co.):		
Gloucester City, N.J	42,000	--
Ashtabula, Ohio	--	30,000
SCM Corp., Pigments Group, Chemical/Metallurgical Division:		
Baltimore, Md	55,000	30,000
Ashtabula, Ohio	--	42,000
Total	287,000	627,000

Table 4.—Titanium pigment data

(TiO_2 content)

Year	Production (short tons)	Shipments[1]	
		Quantity (short tons)	Value, f.o.b. (thousands)
1973	784,996	793,991	$404,639
1974	786,672	759,068	513,409
1975	603,429	576,097	423,701
1976	712,940	711,774	594,846
1977[p]	687,103	696,552	602,383

[p]Preliminary.
[1]Includes interplant transfers.

Source: U.S. Bureau of the Census.

Dupont authorized final funding to complete construction of its 150,000-ton-per-year, chloride-process pigment plant at DeLisle, Miss. The plant was expected to be completed in 1979 at a total cost of over $150 million.

NL Industries cut production 50% late in the year at its St. Louis, Mo., pigment plant in an effort to reduce the plant's air emissions and to help achieve uninterrupted operations, following repeated St. Louis County air pollution alerts, which had required 25% to 50% curtailments in production, and one air pollution emergency order requiring a temporary plant shutdown. The company's Sayreville, N.J., plant, which resumed production in June after a 5-month post-strike startup and refurbishing period, operated at reduced capacity during the second half of the year.

SCM Corp., Pigments Group completed a 40% expansion of its chloride process TiO_2 plant in Ashtabula, Ohio, and installed new slurry facilities at its Baltimore, Md., and Ashtabula plants.

The total amount of TiO_2 pigment used in slurry form reportedly has been increasing steadily, and was expected to climb from 52,000 tons per year in 1975 to about 121,000 tons per year in 1980.

American Cyanamid Co. announced it was making available for licensing to other U.S. manufacturers its technology for the treatment of titanium dioxide pigment plant acid waste, involving neutralization with limestone and lime and formation of gypsum and iron oxides. American Cyanamid has used the process at its Savannah, Ga., titanium dioxide pigment plant since 1975, and was reported to be making progress in selling the gypsum byproduct. However, the company stated that even selling all of the gypsum would probably recover no more than 25% of treatment costs, said to be about $90 per ton of pigment.

SCM Corp. was reportedly operating the first stage of a similar waste-treatment facility at its Baltimore titanium pigment plant, and expected to start up the second stage by early 1978. SCM also planned to sell much of its gypsum byproduct, and has offered to sell its technology.

CONSUMPTION AND USES

Concentrates.—Consumption of ilmenite and titanium slag decreased 7% and 27%, respectively, from 1976 levels. Rutile consumption increased slightly during 1977.

Metal.—Consumption of titanium sponge and ingot increased 22% and 20%, respectively, while scrap metal consumption increased 18%. Net shipments of mill products increased 7% over the 1976 level. Improved demand was reported for all product categories except pipe, extrusions, tubing, and castings, which reflected a slowdown in requirements for chemical-process and power-generation equipment.

The military aircraft industry continued to be the main consumer of titanium mill products during 1977, although at a 15% to 20% lower rate than in 1976. Major programs contributing to military consumption were the McDonnell-Douglas F-15, the Grumman F-14, and the start of General Dynamics' F-16 production. Titanium consumption in the F-14 and F-15 was expected to decline further in 1978, offset somewhat by increased F-16 production.[4]

Titanium shipments for use in commercial airplanes increased in 1977, and commercial aircraft demand for titanium in 1978 and beyond was expected to be strong. Leading manufacturers of airframes and engines reportedly believe that the goals of better fuel consumption, smaller engines, and lower noise levels for jetliners scheduled for flight in the early 1980's will require more titanium than the 10% to 15%, by weight, used in current wide-body jets.[5] One source estimated that in Boeing's next major jetliner project, the medium-range "7 X 7," the proportion of titanium might be 50% greater than in the 747-SP, which currently contains about 12,000 pounds of finished titanium parts.[6]

Table 5.—Consumption of titanium concentrates in the United States, by product

(Short tons)

Year and product	Ilmenite[1] Gross weight	Ilmenite[1] TiO_2 content[e]	Titanium slag Gross weight	Titanium slag TiO_2 content[e]	Rutile Gross weight	Rutile TiO_2 content[e]
1973	807,733	479,231	281,791	199,287	276,907	263,365
1974	851,977	501,276	257,125	182,257	292,661	277,720
1975	747,821	432,409	147,965	104,585	231,430	218,923
1976:						
Alloys and carbide	(2)	(2)	(3)	(3)	(2)	(2)
Pigments	811,975	490,845	203,964	144,506	207,440	194,950
Welding-rod coatings and fluxes	(2)	(2)	--	--	8,153	7,736
Miscellaneous[4]	10,284	7,168	--	--	22,125	20,926
Total	822,259	498,013	203,964	144,506	237,718	223,612
1977:						
Alloys and carbide	(2)	(2)	(3)	(3)	(2)	(2)
Pigments	[5]856,922	[5]514,429	149,454	106,201	[6]145,493	[6]136,191
Welding-rod coatings and fluxes	(2)	(2)	--	--	8,616	8,184
Miscellaneous[4]	9,582	6,765	--	--	31,310	29,465
Total	[5]866,504	[5]521,194	149,454	106,201	[6]185,419	[6]173,840

[e]Estimate.
[1]Includes a mixed product containing rutile, leucoxene, and altered ilmenite.
[2]Included with "Miscellaneous" to avoid disclosing individual company confidential data.
[3]Included with "Pigments" to avoid disclosing individual company confidential data.
[4]Includes ceramics, chemicals, glass fibers, and titanium metal.
[5]Includes estimate of imported ilmenite used to make synthetic rutile in the United States.
[6]Includes imported synthetic rutile, but excludes synthetic rutile made in the United States from imported ilmenite.

Demand for titanium in the chemical-process, pulp and paper, and power-generation industries was relatively low in 1977, but was estimated at 25% to 30% of mill product shipments; the proportion is expected to double by 1980. Major growth in the use of titanium for industrial uses has been for surface condensers for power-generating stations, in handling of chlorine dioxide solutions in the pulp and paper industry, and in treating and handling seawater, brackish water, and industrial wastes.[7]

Pigment.—Preliminary figures showed a 2% decrease in pigment shipments in 1977. The largest increases in consumption, by use, were plastics 16%, rubber 13%, ceramics 7%, and paints 5%. Consumption in floor coverings increased 36%, and is included in the "Other" category which decreased 11%. Usage of TiO_2 in printing ink, the largest single item in "Other," was unchanged.

Ferrotitanium.—The amount of ferrotitanium and titanium metal used in steelmaking decreased 3% from 3,802 tons in 1976 to 3,688 tons in 1977. The use of these materials in stainless and heat-resisting steels increased 2% to 2,049 tons; usage in carbon steels dropped 20% to 780 tons. Consumption in other alloy steels, including high-strength, low-alloy (HSLA) steels, increased 5% to 859 tons.

The amount of these titanium materials used in cast irons, superalloys, and other alloys was 1,118 tons, down 30% from the corresponding 1976 figure.

Ferrotitanium is the main form in which titanium is added to steel or other alloys; however, scrap titanium is used to make most of the ferrotitanium and for direct additions to the alloy melt. Table 7 shows the amount of ferrotitanium plus titanium scrap used for steel and other alloys for 1973-77. Ferrotitanium is used in grades ranging from 20% to 70% titanium; information on the amount of each grade used is not available, but the 70% titanium grade is said to be preferred for steelmaking.

Table 6.—Distribution of titanium pigment shipments, titanium dioxide content, by industry

(Percent)

Industry	1973	1974	1975	1976	1977
Paints, varnishes, lacquers	52.5	52.5	58.7	51.1	52.0
Paper	19.8	18.7	19.0	21.4	20.7
Plastics (except floor covering and vinyl-coated fabrics and textiles)	9.8	11.3	7.4	10.6	11.7
Rubber	3.2	2.7	2.8	2.7	3.1
Ceramics	2.6	2.1	1.9	1.9	1.9
Other	9.8	8.8	7.6	9.4	8.2
Exports	2.3	3.9	2.6	2.9	2.4
Total	100.0	100.0	100.0	100.0	100.0

Table 7.—Consumption of titanium products[1] in steel and other alloys

(Short tons)

	1973	1974	1975	1976	1977
Carbon steel	981	1,065	804	976	780
Stainless and heat-resisting steel	970	2,386	1,117	2,008	2,049
Other alloy steel (includes HSLA)	1,153	969	838	818	859
Tool steel	W	W	W	W	W
Total steel[2]	3,104	4,420	2,759	3,802	3,688
Cast irons	124	108	96	100	92
Superalloys	583	779	585	455	482
Alloys, other than above	1,166	2,080	1,548	768	537
Miscellaneous and unspecified	142	34	182	273	7
Total consumption	5,119	7,421	5,170	5,398	4,806

W Withheld to avoid disclosing individual company confidential data; included in "Miscellaneous and unspecified."
[1]Includes ferrotitanium containing 20% to 70% titanium and titanium metal scrap.
[2]Except for data withheld and for unspecified included under "Miscellaneous and unspecified."

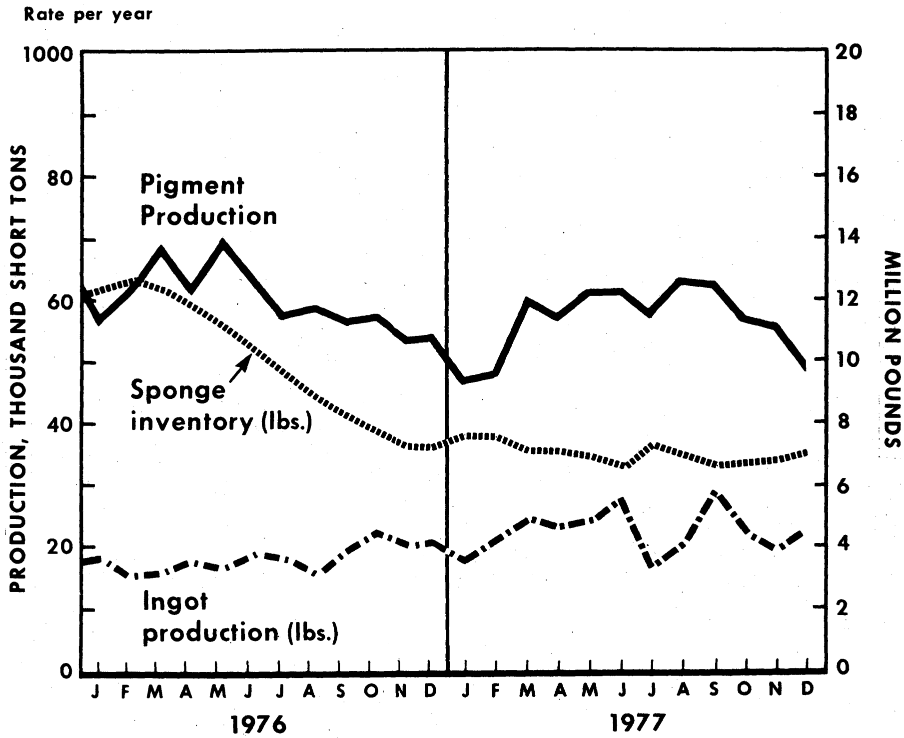


Figure 1.—Salient trends of titanium products, 1976-77.

STOCKS

During 1977, inventories of ilmenite increased 17%, while those of titanium slag and rutile decreased 37% and 15%, respectively. Stocks of titanium sponge decreased 10% in the first three quarters of 1977, then increased during the last quarter, and at yearend were 2% below the December 1976 level. Scrap inventories increased 18% during 1977. Industry stocks of various grades of titanium pigment were 75,234 tons at the end of 1977, up 5% from the corresponding 1976 figure.

Table 8.—Stocks of titanium concentrates in the United States, December 31

(Short tons)

	Gross weight	TiO_2 content[e]
Ilmenite:		
1975	636,881	378,181
1976	707,398	429,801
1977	825,912	514,379
Titanium slag:		
1975	87,683	62,130
1976	99,108	70,242
1977	62,582	44,463
Rutile:		
1975	139,572	131,742
1976	152,251	143,243
1977	129,332	121,297

[e]Estimate.

PRICES

Concentrates.—Price quotations of ilmenite (imported, 54% TiO_2) in domestic markets remained at $55 per long ton throughout the year, while Australian ilmenite prices increased in October 1977 from $A15-$A18 to $A17-$A19 per metric ton f.o.b. Australian ports. Prices of Indian concentrates (58% to 60% TiO_2) decreased in the third quarter from $23 per metric ton to $18 per metric ton f.o.b. Indian ports.

Rutile spot prices bulk, f.o.b. cars at Atlantic, Gulf, and Great Lakes ports, were quoted at $510 per short ton in January and at $360 in November and December. Long-term contracts presumably were concluded at somewhat lower figures. Published prices f.o.b. Australian ports began the year at $A220-$A230 per metric ton, decreasing to $A200-$A210 by April, $A190-$A200 in October, and $A180-$A190 in December. Declared valuations of shipments entering U.S. ports were in the range of $224-$353 per short ton in the first quarter, and $173-$238 per short ton in the last quarter of 1977. Declared valuations of synthetic rutile shipments entering U.S. ports averaged $133 per short ton for the year, and c.i.f. values averaged $152 per short ton.

The price of titanium slag f.o.b. Sorel, Quebec, was increased to $102.50 per long ton on January 1, 1977, and remained at that level throughout the year.

Metal.—The published price of domestic titanium sponge was increased in November from $2.75 per pound to $2.98 per pound. Published prices for Japanese sponge were in the range of $2.45 to $2.65 per pound throughout the year. Quotations for mill products throughout the year were as follows: Bar, $7.48; billet, $4.86; plate, $6.50; and sheet and strip, $11.90 per pound.

Pigment.—The price of titanium dioxide pigment in carload lots increased in June to 48.5 cents per pound for most grades of rutile and 43.5 cents per pound for paper-grade anatase, and remained at these levels for the rest of the year.

FOREIGN TRADE

Exports of titanium dioxide amounted to 16,336 tons, 21% below the 1976 total. Of the 1977 total, Canada received 18%, the Republic of Korea 18%, Venezuela 13%, Brazil 11%, other Latin American and West Indian countries 12%, Western Europe 11%, Japan 7%, other Far Eastern nations 6%, and other countries 4%.

Exports of unwrought, waste, and scrap titanium were 45% lower than in 1976; 46% went to the United Kingdom, 27% to Italy, 9% to Belgium, and 7% to the Federal Republic of Germany. The average valuation was 83 cents per pound, or 13 cents per pound more than in 1976. Exports of intermediate mill shapes and mill products were 1% lower than in 1976.

Imports of ilmenite from Australia in 1977 were nearly double those of 1976. Imports of Sorelslag were 12% less than in 1976. Imports of natural rutile were 50% lower and imports of synthetic rutile were 69% lower than in 1976.

Imports of unwrought, waste, and scrap titanium were 89% higher than those of 1976. Of the 1977 total, 2,387 tons was sponge. Sponge sources were Japan (1,673 tons), the U.S.S.R. (469 tons), and the United Kingdom (245 tons). The sponge shipments from Japan, the U.S.S.R., and the United Kingdom had an average declared valuation of $1.92, $1.91, and $1.89 per pound, respectively.

Imports of pigment totaled 114,810 tons during the year and constituted 14.7% of domestic consumption.

Table 9.—U.S. exports of titanium products, by class

Year	Ores and concentrates		Metal and alloy sponge and scrap		Intermediate mill shapes and mill products, n.e.c.		Pigments and oxides	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
1975	3,147	$505	4,326	$7,630	1,900	$24,726	15,807	$12,110
1976	4,802	477	6,144	8,547	1,065	15,039	20,580	16,229
1977	22,679	743	3,394	5,643	1,050	14,254	16,336	12,628

Table 10.—U.S. imports for consumption of titanium concentrates, by country

Country	1975 Quantity (short tons)	1975 Value (thousands)	1976 Quantity (short tons)	1976 Value (thousands)	1977 Quantity (short tons)	1977 Value (thousands)
Ilmenite:						
Australia	98,352	$1,674	168,402	$2,646	309,902	$4,590
Canada	221	11	--	--	--	--
India	19,428	317	--	--	--	--
Netherlands[1]	--	--	--	--	25,088	1,087
Sri Lanka	4,010	57	--	--	--	--
Total	[2]122,010	2,059	168,402	2,646	334,990	5,677
Titanium slag:						
Canada	212,682	13,844	171,624	13,291	150,564	13,514
Rutile, natural:						
Argentina[1]	--	--	--	--	7,862	1,789
Australia	166,298	35,494	196,035	42,037	88,681	18,659
Austria[1]	--	--	--	--	23	3
Canada[1]	135	58	--	--	--	--
Netherlands[1]	--	--	--	--	673	489
Total	166,433	35,552	196,035	42,037	97,239	20,940
Rutile, synthetic:						
Australia	34,222	6,218	43,866	6,955	17,351	2,103
France[1]	--	--	--	--	([3])	1
India	6,614	900	11,011	1,668	5,500	750
Japan	16,878	3,599	26,363	3,193	3,691	682
Taiwan	353	92	4,437	996	19	5
Total	[2]58,066	[2]10,810	85,677	12,812	26,561	3,541
Titaniferous iron ore:[4]						
Canada	46,031	1,255	91,692	2,778	82,753	2,526

[1]Country of transshipment rather than country of production.
[2]Data do not add to total shown because of independent rounding.
[3]Less than 1/2 unit.
[4]Includes materials consumed for purposes other than production of titanium commodities, principally heavy aggregate and steel furnace flux.

Table 11.—U.S. imports for consumption of unwrought titanium and waste and scrap

Country	1975 Quantity (short tons)	1975 Value (thousands)	1976 Quantity (short tons)	1976 Value (thousands)	1977 Quantity (short tons)	1977 Value (thousands)
Australia	3	$5	--	--	3	$4
Belgium-Luxembourg	--	--	28	$24	15	36
Canada	154	230	219	291	190	393
France	41	92	29	49	89	238
Germany, Federal Republic of	69	185	153	317	793	709
Israel	--	--	--	--	1	7
Italy	--	--	--	--	7	10
Japan	2,545	9,882	1,659	6,114	1,882	7,166
Mexico	3	3	3	8	--	--
Netherlands	18	31	152	145	57	95
South Africa, Republic of	--	--	2	4	([1])	1
Spain	--	--	7	26	--	--
Sweden	4	11	61	57	--	--
Switzerland	--	--	--	--	2	6
U.S.S.R	1,698	4,326	742	1,289	2,321	3,783
United Kingdom	531	1,346	583	1,428	1,521	3,103
Total	5,066	16,111	3,638	9,752	6,881	15,551

[1]Less than 1/2 unit.

WORLD REVIEW

Australia.—Australia continued to dominate world markets in mineral sands, particularly ilmenite, rutile, and zircon. In 1977, ilmenite production increased 9% to 1,191,261 short tons, including an estimated 11,799 short tons of leucoxene. Rutile production was 357,557 short tons, 18% lower than in 1976. Exports of ilmenite

Table 12.—Titanium: World production of concentrates (ilmenite, rutile, and titaniferous slag), by country

(Short tons)

Country[1]	1975	1976	1977[p]
Ilmenite: [2]			
Australia[3]	[r]1,111,464	1,097,159	1,191,261
Brazil	5,066	16,110	[e]16,500
Finland	135,143	135,143	137,458
India[e]	90,000	[r]100,000	150,000
Malaysia[4]	123,732	198,410	169,388
Norway	580,549	845,101	913,108
Portugal	234	405	[e]410
Sri Lanka	70,559	61,524	[e]66,000
United States[5]	717,281	652,404	638,503
U.S.S.R.[e]	360,000	[r]420,000	440,000
Total	[r]3,194,028	3,526,256	3,722,628
Rutile:			
Australia	[r]383,990	435,791	357,557
Brazil	115	141	[e]145
India[e]	4,000	[r] [e]4,400	6,600
Sri Lanka	3,427	1,146	[e]1,200
United States	W	W	W
U.S.S.R.[e]	30,000	30,000	30,000
Total	[r]421,532	471,478	395,502
Titaniferous slag:			
Canada[6]	[r]826,563	907,201	783,742
Japan	4,942	3,843	1,354
Total	[r]831,505	911,044	785,096

[e]Estimate. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing individual company confidential data.
[1]In addition to the countries listed, the Republic of South Africa began to produce ilmenite and rutile concentrates in 1977, but output level is not quantitatively reported and available general information is inadequate to make reliable estimates of output levels.
[2]Ilmenite is also produced in Canada and reported separately in Canadian sources but is not reported here because it is almost entirely used in slag production (see below under titaniferous slag).
[3]Includes leucoxene as follows in short tons: 1975—18,597; 1976—11,616; 1977—11,799.
[4]Exports.
[5]Includes a mixed product containing ilmenite, leucoxene, and rutile.
[6]Contains 70% to 72% TiO_2.

including leucoxene were 1,207,274 short tons, up 14% from those of 1976, and rutile exports were 271,964 short tons, 29% lower than in 1976. Ilmenite exports went mainly to the United States, the United Kingdom, Japan, France, and Brazil; rutile was exported mostly to the United States, the United Kingdom, the Netherlands, Japan, Italy, and the Federal Republic of Germany.

Supply of beach sand minerals continued to exceed demand. Depressed markets for rutile and zircon, coupled with metallurgical problems, led to suspension of Western Mining Corp.'s mineral sands operation at Jurien Bay in Western Australia.

Following the withdrawal of export licenses for mineral concentrates mined from Fraser Island, Queensland, sands at yearend 1976, there was continued environmental pressure to further restrict mining of sand minerals. The Queensland State Government was reportedly considering allowing only 6% of Moreton Island to be mined, with all mining to cease by 1990 when the island is to become a national park. Among the companies involved on Moreton Island were Dillingham Minerals, Ltd., Associated Minerals Consolidated, Ltd., and Mineral Deposits, Ltd. In New South Wales, the State Government reportedly decided to permit sand mining to continue in national park areas for the next 5 years, after which time no mining is to be permitted in national parkland.

Mining applications were reported to have been rejected on environmental grounds for the first time by the Government of Western Australia. The applications involved plans for ilmenite dredging in Hardy Inlet at Augusta by Northwest Development Corp., Ltd.

Queensland Titanium Mines reportedly accepted the Australian Government's offer of $440,000 compensation for 1977 profits the company has been denied as a result of the Government's withdrawal of export licenses for Fraser Island mineral concentrates. However, the Dillingham-Murphyores Minerals consortium, whose operations were also halted, rejected a $4.4 million offer in late 1977, and was reportedly demanding $23.9 million settlement.

Mineral Deposits, Ltd., was reported to have deferred development of its planned $15 million Agnes Waters mineral sands project in Queensland, because of the uncertainty concerning future sand mining regulations.

Tioxide Australia Pty. Ltd. and Westralian Sands Ltd. agreed on a plan to merge the two firms. If approved, the merger will give Tioxide a 40% share in Westralian Sands, along with an option to increase this holding to 51% should Westralian Sands decide to proceed with plans to build a 110,000-ton-per-year ilmenite beneficiation plant. Westralian is traditionally a supplier to the Tioxide group. The merger will result in a combined ilmenite output from adjacent deposits of over 440,000 tons per year.

Dupont reportedly acquired an additional 25% interest in Allied Eneabba Pty., Ltd., through its subsidiary, Dupont (Australia) increasing the company's total equity in Allied Eneabba to 40%.

Brazil.—For development of the anatase reserves at Tapira and Salitre, Mineração Vale do Paranaiba (VALEP), a subsidiary of Companhia Vale do Rio Doce (CVRD), which owned the reserves, arranged for New Jersey Zinc Co. to develop suitable concentration technology. Based on preliminary studies, production of 220,000 tons per year of anatase is planned, which will be processed to 165,000 tons per year of titanium dioxide pigment and 6,600 tons of titanium metal. The investment required was estimated at $250 million, with New Jersey Zinc to be a minority participant. The phosphate with which the anatase is associated was to be recovered in a new plant scheduled to begin production in May 1978, with 1 million tons of titanium ore to be stockpiled during the first 2 years of phosphate production.

Titanio do Brazil S.A. (Tibras) reportedly was planning to increase the capacity of its titanium dioxide pigment plant from 25,000 to 55,000 tons per year.

Canada.—Shipments of Sorelslag by Quebec Iron and Titanium Corp. (QIT) were 784,000 tons, about 14% lower than in 1976. This reduction in shipments was due mainly to a 5-week strike over working conditions at the Sorel, Quebec, smelter. Shipments of Sorelmetal (a low-manganese pig iron) increased from 515,000 tons in 1976 to 560,000 tons in 1977, and shipments of Sorelflux (ilmenite used as a flux in electric steel furnaces) was down from 157,000 tons in 1976 to 134,000 tons in 1977. The Sorelslag was primarily exported to the United Kingdom, Western Europe, and the United States. About 13% of production was sold to Canadian Titanium Pigments, Ltd., Varennes, Quebec, a subsidiary of NL Industries; and Tioxide of Canada Ltd., Tracy, Quebec, a subsidiary of BTP Tioxide, Ltd., United Kingdom. Production from these plants, whose combined annual capacities total about 76,000 tons, was about the same as in 1976.

European Economic Community (EEC).—The EEC opened an inquiry into alleged Japanese dumping of wrought unalloyed titanium. Japanese exports reportedly held a 32% share of the EEC market in 1977, compared with 16% in 1974.

An EEC commission proposed a new titanium dioxide waste-control formula. No specific timetable was proposed for phasing out pollution from sulfate-process plants, except that it should be reduced or eliminated over a 10-year period. Anticipated means of reducing such pollution included increased use of higher grade feed materials, reprocessing or land storage of solids byproducts, and the neutralization or open-sea disposal of byproduct acids. It was proposed that all new capacity be based on the chloride process which produces less waste.

Italy.—A deposit of rutile in eclogite-type rock in the Liguria region around Genoa was reported to contain 3% to 5% rutile and to have proven reserves of about 165 million tons of ore and possible reserves of at least 440 million tons. Mineral rights for the deposit are owned by Mineraria Italiana S.p.A.

Plans by Montedison S.p.A for a 44,000-ton-per-year chloride process pigment plant at Crotone reportedly had to be changed because the area selected contains the ruins of an ancient Greek necropolis. An alternate possibility is that of building the chloride plant at Scarlino, the site of Montedison's sulfate process plant.

Spain.—The 50,000-ton-per-year titanium dioxide plant built by Titanio S.A. at Huelva was reported to have increased Spain's total TiO_2 production capacity to about 80,000 tons per year.

United Kingdom.—Laporte Industries (Holdings) said it planned a $6 million expansion of titanium dioxide facilities at Stallingborough. Both Laporte and BTP Tioxide, Ltd., reported first-half profits which reflected a slump in the titanium dioxide business. One source cited the problem of worldwide overcapacity, with world production capacity in mid-1977 at about 2.9 million tons per year and demand just under 2.2 million tons per year.

IMI Titanium, a division of Imperial Metal Industries, Ltd., reportedly invested £800,000 in its Swansea, Wales, plant for manufacturing seam-welded tubing used in condensers and heat exchangers. IMI reported in September the development of a new high-temperature, creep-resistant alloy, IMI-829, which was claimed to be capable of operating at temperatures up to 550° C (600° C in low-stress use) which the company says is 50° C higher than any other commercial titanium alloy available worldwide.

Israel.—Israel Chemicals Ltd. was reportedly trying to interest titanium dioxide pigment producers in building a 44,000-ton-per-year sulfate-process pigment plant next to its Timna copper mines near Eilat, Israel, which are now closed because of market conditions. The waste sulfuric acid effluent from the pigment plant would be used for leaching copper ore.

Japan.—Toho Titanium Co., Ltd., and Osaka Titanium Co., Ltd., produced 7,049 tons of sponge metal in 1977, about 1% more than in 1976. Japanese exports of sponge and mill products in 1977 were 2,535 tons and 1,248 tons, respectively; the United States received nearly 60% of the sponge; the Netherlands, the Federal Republic of Germany, France, and the United Kingdom received 40%. Domestic sales and internal plant consumption increased 10% to 5,193 tons.

Toho Titanium was reported to be increasing production of titanium metal sponge in October 1977 from the previous level of 287 tons per month to about 330 tons per month, which is about 70% of Toho's production capacity. Demand from both domestic and export markets was said to have improved, notably in the commercial airplane industry in the United States.

Malaysia.—Malaysian Titanium Corp. started production of synthetic rutile by the Benilite process at its new 60,000-ton-per-year plant at Ipoh, Perak, but shut the plant down after a few months of operation because of startup problems and the depressed condition of the rutile market.

Sierra Leone.—Sierra Rutile Ltd. (owned 85% by Bethlehem Steel Corp. and 15% by Nord Resources) was reported to be progressing on schedule with development of the former Sherbro Minerals property. Initial output was expected in late 1978, with a planned production rate of 110,000 tons per year of rutile concentrate.

South Africa, Republic of.—Shipments of rutile and zircon were started from the Richards Bay mineral sands operation in Natal. Richards Bay Minerals will manage the combined affairs of Tisand (Pty.) Ltd. and Richards Bay Iron and Titanium (Pty.) Ltd., the companies responsible for the operation of the new mine operations and the smelter, respectively. The high-TiO_2 slag, to be produced at the smelter beginning in March 1978, was expected to contain 85% TiO_2, and will be known as RB slag. Five Japanese titanium dioxide pigment producers have reportedly reached agreement to import 77,000 to 110,000 short tons per year of RB slag at a base price of $158 per short ton.

The planned annual production rates from Richards Bay Minerals were about 440,000 tons of the 85%-TiO_2 slag, 62,000 tons of rutile, 127,000 tons of zircon, and 239,000 tons of low-manganese pig iron. Most of the slag will go to sulfate-process TiO_2 producers, but significant quantities will go to chloride-process producers.[8]

U.S.S.R.—The U.S.S.R. was reportedly conducting feasibility tests on a high-grade titanium deposit, probably ilmenite, in the Yaregsk region of the northern Ural Mountains.

Production of titanium metal sponge in the U.S.S.R. was estimated at 39,000 tons, 9% higher than in 1976. Soviet technology for producing titanium sponge was being marketed by Southwire Corp., United Kingdom, and was reported to include upgrading of titanium-bearing concentrates, titanium tetrachloride production and purification, and titanium reduction.

TECHNOLOGY

Published results of Bureau of Mines research on titanium included papers on a zircon mold-casting process for static casting of small titanium or zirconium shapes;[9] stabilization of silver reflecting films with light undercoatings of oxides of Ti, Zr, and Cr;[10] nitrogen diffusion in the Ti-TiN phase system;[11] and coatings of semiconductor films of TiN_x and ZrN_x as selective solar absorbers.[12] A bulletin was published describing the electroslag melting process and its use for melting reactive metals including titanium, base metals, ferrous alloys, superalloys, and the refractory metals.[13]

Other Bureau of Mines research included the following programs pertaining to titanium: Physical beneficiation and smelting of domestic ilmenites to produce a high-titanium slag suitable for making titanium tetrachloride; recovery of byproduct rutile from domestic copper mill tailings; recovery of rutile, ilmenite, and other minerals from black sand concentrates that are byproducts of placer gold dredging, silica-clay operations, and sand and gravel operations on the West Coast; development of a vacuum-rolling technique for bonding titanium and other corrosion-resistant metals to steel; development of processes for utilizing low-cost molding materials, such as olivine foundry sand for making titanium castings; and electrodeposition of titanium diboride for protection of high-strength metals and alloys from oxidation, corrosion, or wear.

Laporte Industries, Ltd., published a paper[14] describing its patented ilmenite beneficiation process,[15] which involves a new variation of the oxidation-reduction pretreatment of ilmenite for acid leaching. By using a high temperature (900° to 950° C) for the oxidation treatment and controlling the reduction step so that the proportion of the iron in the ferrous state is about 86% to 92%, the treated ore is said to require only a single-stage leach with 18% HCl at atmospheric pressure for 3-1/2 hours for satisfactory removal of iron and other impurities. After washing and calcination, the beneficiate typically contains 95.5% TiO_2 and has the same particle size as the original ore.

An extensive discussion was published on the use of the Reichert cone gravity concentrator for recovery of mineral concentrates from low-grade ores.[16] Several patents were issued on various modifications of ilmenite beneficiation by reduction and leaching and by chlorination. In chlorine beneficiation, iron is usually removed selectively as iron chloride, but in one patent, the titanium content is largely chlorinated with substantially no net yield of iron chloride. The solid residue contains the iron content in the form of metallic iron.[17]

In titanium metal research, emphasis was on development of weight-saving and cost-saving techniques. Examples were papers on superplastic forming and diffusion bonding presented by representatives of McDonnell Aircraft Co., Rockwell International Corp., and the Air Force Materials Laboratory at the 1978 Annual Meeting of the AIME in Denver, Colo. Superplastic forming concurrently combined with diffusion bonding was described as a revolutionary process for fabricating sheet structures of Ti-6AL-4V alloy for various aerospace applications.[18]

Other cost-saving techniques being developed in 1977 included isothermal[19] or hot-die forging[20] which can produce complex shapes in a single cycle, hot isostatic pressing from powder,[21] vacuum hot pressing,[22] and cold isostatic pressing.[23] Bell Aerospace Textron division of Textron, Inc., working under an Air Force contract, found that shear spinning tank segments from titanium alloy sheet and plate cut scrap rates almost in half and reduced labor costs about 90% compared with the conventional machining of titanium forgings.[24]

The U.S. supersonic transport (SST) program resulted in significant developments in titanium metallurgical technology. A two-phase, follow-on program, funded by the U.S. Federal Aviation Administration was to document significant developments and to expand selected technological areas. A report was published that summarized the work conducted under this program.[25]

A comprehensive review of the use of titanium dioxide pigments for surface coatings was published by Metalgesellschaft AG.[26] This review covers applications, characteristics of white pigments, manufacturing processes, development, and technical service work.

The use of organotitanates in plastics was found to promote improved performance of plastic flame retardants. The organotitanate contains groups that couple to the inorganic surface of filler materials, such as TiO_2 in a hydrocarbon vehicle, and allows very high filler loadings to be used, greatly reducing the source of flammability, the organic polymer itself.[27]

---

[1]Physical scientist, Division of Nonferrous Metals.

[2]U.S. Geological Survey. Phosphate Rock, Titanium Deposits Found in South Carolina. U.S. Geol. Survey News Release, Oct. 13, 1977, 2 pp.

[3]Thompson, J. V. Appraising Large Diameter Core and Percussion Drilling for Bulk Samples. Eng. and Min. J., v. 178, No. 8, August 1977, pp. 80-82.

[4]Minkler, W. W. Titanium: Shipments Rise Despite Military Cutbacks. Eng. and Min. J., v. 179, No. 3, March 1978, pp. 137-138.

[5]Byrne, J. W. Diverse Markets Attracted by Resourceful Titanium. Am. Metal Market, v. 85, No. 133, July 12, 1977, p. 12A.

[6]Haflich, F. Innovation Takes Off; Cost Factor Mitigated by New Production Techniques. Am. Metal Market, v. 85, No. 133, July 12, 1977, pp. 3A-4A.

[7]Cavaseno, V. Outlook for Titanium Brightens With CPI Gains. Chem. Eng., v. 84, No. 27, Dec. 19, 1977, pp. 40, 42.
Work cited in footnote 5.
[8]Bartle, W. W. Mineral Sands Markets—The Impact of Richards Bay. Pres. at 3d Ind. Miner. Internat. Cong., Paris, Mar. 13-15, 1978, 6 pp.
[9]Koch, R. A., J. L. Hoffman, M. R. Transuc, and R. A. Beall. Casting Titanium and Zirconium in Zircon Sand Molds. BuMines RI 8208, 1977, 44 pp.
[10]Wood, F. W., and R. Blickensderfer. Stabilization of Absorber Stocks Containing Zr or Ti Compounds on Ag. Pres. at Internat. Conf. on Metal Coatings, San Francisco, Calif., Apr. 5-8, 1976. Thin Solid Films, Elsevier Sequoia, S.A., Lausanne, Switzerland, v. 39, No. 1, December 1976, pp. 133-142.
[11]Wood, F. W., and O. G. Paasche. Dubious Details of Nitrogen Diffusion in Nitrided Titanium. Thin Solid Films, Elsevier Sequoia S.A., Lausanne, Switzerland, v. 40, No. 1, January 1977, pp. 131-137.
[12]Blickensderfer, R., D. K. Deardorff, and R. L. Lincoln. Spectral Reflectance of TiNx and ZrNx Films as Selective Solar Absorbers. Solar Energy, v. 19, No. 4, 1977, pp. 429-432.
[13]Nafziger, R. H. and Others. The Electroslag Melting Process. BuMines Bull. 669, 1976, 219 pp.
[14]Robinson, M., F. Clamp, D. B. Mobbs, and R. V. Pearse. The Laporte High-Efficiency Ilmenite Beneficiation Process. The Inst. of Min. and Metallurgy symp. on Advances in Extractive Metallurgy, London, England, April 1977, pp. 89-96.
[15]Pearse, R. V., M. Robinson, F. Clamp, D. Aberdeen, and D. B. Mobbs. (assigned to Laporte Industries, Ltd.). Improvements In and Relating To the Beneficiation of Ilmenite Ores. Brit. Pat. 1,392,441, Apr. 30, 1975.
[16]Paterson, O. D. How Many Low-Grade Ores are Now Being Recovered by Gravity Concentration. World Min., v. 30, No. 8, July 1977, pp. 44-49.
[17]Glaeser, H. H. (assigned to E. I. du Pont de Nemours & Co.). Reduction and Chlorination of Ilmenite. U.S. Pat. 4,017,304, Apr. 12, 1977, 18 pp.
[18]Agrawal, S. P., and E. D. Weisert. An Advanced Titanium Fabrication Technique: The Concurrent SPF/DB Process. Pres. at AIME Ann. Meeting, Denver, Colo., Feb. 26-Mar. 2, 1978.
Dorr, J., and J. Williamson. SPF/DB F15 Nozzle Fairing. Pres. at AIME Ann. Meeting, Denver, Colo., Feb. 26-Mar. 2, 1978.
Tupper, N. G. Applications of Titanium Superplastic Forming to Future USAF Aircraft. Pres. at AIME Ann. Meeting, Denver, Colo., Feb. 26-Mar. 2, 1978.
[19]Iron Age. Isothermal Forging Makes a First Good Impression. V. 220, No. 18, Oct. 31, 1977, pp. 43-44.
[20]American Metal Market. Wyman-Gordon Hot-Die Forges Titanium Parts. V. 85, No. 108, June 6, 1977, p. 27.
[21]Work cited in footnote 19.
[22]Iron Age International. Vacuum Hot Pressing. March 1977, pp. 22-23.
[23]Van Cleave, D. Cold Pressing Opens the Door on Complex Shapes. Iron Age, v. 219, No. 18, May 9, 1977, pp. 39-41.
[24]American Metal Market. Bell Division Shear Spins Titanium Alloy and Cuts Scrap Rate Costs Sharply. V. 85, No. 152, Aug. 8, 1977, p. 28.
[25]Lindh, D. V., and D. T. Lovell. Titanium Structures Technical Summary. DOT/SST Phase I and Phase II. Boeing Commercial Airplane Co., Seattle, Wash., October 1974, 33 pp.
[26]Cremer, M., and E. Meyer-Galow. Titanium Dioxide Pigments for Surface Coatings. Review of the Activities. Metallgesellschaft A.G., Frankfurt, the Federal Republic of Germany, ed. 19, 1977, pp. 44-55.
[27]Monte, S. J., and G. Sugarman. Flame Retardant Plastics Through Use of Organotitanates. Pres. at Nat. Tech. Conf. on Safety and Health With Plastics, Soc. of Plastics Eng., Inc., Denver, Colo., Nov. 8-10, 1977. 7 pp.; available from Kenrich Petrochemicals, Inc., Bayonne, N.J.

Tungsten

By Philip T. Stafford[1]

Domestic production and consumption of tungsten concentrate increased 3% and 6% to 6 million pounds and 17.1 million pounds, respectively, compared with those of 1976. Almost 93% of this material was obtained from two mining operations, one in California and one in Colorado. Production of ammonium paratungstate (APT) rose 17% to 14.9 million pounds in 1977, and reported consumption of APT decreased slightly to 15.7 million pounds. Production and consumption of tungsten products increased 4% and 1%, respectively. Imports for consumption of tungsten concentrate rose 31% to 6.9 million pounds, but exports of tungsten concentrate, from sales of Government stockpile excesses, fell 26% to 1.3 million pounds of contained tungsten in 1977.

The reported price of tungsten concentrate, shipped from mines and custom mills, increased 44% and averaged $145 per short ton unit f.o.b.

Legislation and Government Programs.—During the year, the General Services Administration (GSA) Office of Stockpile Disposal continued to sell excess tungsten concentrate on the basis of monthly sealed bids. Regular offerings of excess concentrate were made at the disposal rate of 500,000 pounds of contained tungsten per month, of which 375,000 pounds was for domestic use and 125,000 pounds was for export. In January 1977, a single supplemental offering was made. Starting in March, supplemental offerings of concentrate were made on the basis of monthly

Table 1.—Salient tungsten statistics

(Thousand pounds of contained tungsten and thousand dollars)

	1973	1974	1975	1976	1977
United States:					
Concentrate:					
Mine production	7,575	7,381	5,588	5,830	6,008
Mine shipments	7,059	7,836	5,490	5,869	6,022
Value	$19,154	$37,413	$29,090	$37,266	$55,073
Consumption	15,386	16,298	14,012	16,107	17,100
Shipments from Government stocks	1,269	6,398	2,970	4,004	5,015
Exports[1]	90	1,187	1,316	1,729	1,283
Imports, general	11,047	11,786	6,908	5,802	6,847
Imports for consumption	10,834	11,096	6,570	5,301	6,919
Stocks, Dec. 31:					
Producer	225	529	531	150	124
Consumer	1,446	1,565	1,958	1,002	826
Employment[2]	535	540	525	540	945
Ammonium paratungstate:					
Production	13,012	14,707	10,282	12,808	14,940
Consumption	13,945	15,733	10,353	15,921	15,744
Stocks, Dec. 31: Producer and consumer	945	1,062	1,704	1,438	1,975
Primary products:					
Production	16,600	20,131	12,634	18,226	19,005
Consumption	17,984	20,556	12,934	16,799	16,905
Stocks, Dec. 31:					
Producer	3,523	3,628	3,976	3,390	3,139
Consumer	2,051	2,771	2,753	2,778	2,581
World: Concentrate:					
Production	83,612	82,832	r84,508	r91,767	93,630
Consumption	84,857	83,506	r73,949	r82,297	79,117

rRevised.
[1]Estimated tungsten content.
[2]Estimated number of persons at mines and mills, excluding office workers, at yearend.

sealed bids at the disposal rate of 200,000 pounds of tungsten per month, of which 150,000 pounds was for domestic use and 50,000 pounds was for export. As a result of the regular and supplemental offerings, concentrate sales totaled 3,631,958 pounds of tungsten, of which 2,692,329 pounds was for domestic use and 939,629 pounds was for export. Prices, ex-duty, of concentrate for domestic use ranged from $126.50 to $159.57 per short ton unit of WO_3. Prices, ex-duty, of concentrate for export ranged from $138.12 to $160.35 per short ton unit. Actual shipments of Government tungsten concentrate stockpile excesses were 5,014,934 pounds of contained tungsten.

On October 7, 1977, the Government stockpile goals, as revised on October 1, 1976, were reaffirmed (table 2), subject to annual review and revision. As of November 1, 1977, the Federal Preparedness Agency (FPA) of GSA decided to use excess tungsten concentrate containing 31,948,897 pounds of tungsten to offset shortfalls in the goals of ferrotungsten, tungsten metal powder, and tungsten carbide.

Hearings were held in July 1977 by the Trade Policy Staff Committee, Office of the Special Representative for Trade Negotiations, concerning the possible deletion or addition of items covered by the Generalized System of Preferences (GSP). In August 1977, the Office of the Special Representative formed an interagency task force to review and report confidentially on the status of the domestic tungsten products industry. The report of the task force had not been completed at yearend, and hence no action was taken on changes desired by the domestic tungsten industry concerning the GSP for tungsten products.

Table 2.—U.S. Government tungsten stockpile material inventories and goals

(Thousand pounds of contained tungsten)

Material	Goals[1]	Inventory by program, Dec. 31, 1977			
		National stockpile	DPA[2] inventory	Supplemental stockpile	Total[3]
Tungsten concentrate:					
Stockpile grade	8,823	64,850	1,917	3,196	69,962
Nonstockpile grade	--	32,369	359	1,043	33,772
Total	8,823	97,219	2,276	4,239	103,734
Ferrotungsten:					
Stockpile grade	17,769	841	--	--	841
Nonstockpile grade	--	1,185	--	--	1,185
Total[3]	17,769	2,025	--	--	2,025
Tungsten metal powder:					
Stockpile grade	3,290	1,567	--	--	1,567
Nonstockpile grade	--	332	--	--	332
Total	3,290	1,899	--	--	1,899
Tungsten carbide powder:					
Stockpile grade	12,845	842	--	1,080	1,922
Nonstockpile grade	--	112	--	--	112
Total[3]	12,845	953	--	1,080	2,033

[1]Goals established Oct.1, 1976 and reaffirmed in 1977.
[2]Defense Production Act (DPA).
[3]Data may not add to totals shown because of independent rounding.

DOMESTIC PRODUCTION

Domestic mine production and shipments of tungsten concentrate each increased 3% over those of 1976 and each totaled 6.0 million pounds of tungsten during 1977. Although 77 mines in Alaska and 9 Western States reported concentrate production and shipments, only 2 mines operated continuously throughout 1977: The Pine Creek mine and mill of the Metals Division, Union Carbide Corp. (UCC), located northwest of Bishop, Calif., in Inyo County; and the Climax mine and mill of Climax Molybdenum Co., a division of AMAX, Inc., at Climax, Colo., in Lake County. The major mineral value recovered at Pine Creek continued to be tungsten, with minor amounts of byproduct copper, gold, molybdenum, and silver. UCC processed the Pine Creek ore directly into APT, an intermediate tungsten product suitable for conversion to tungsten metal powder.

The UCC Emerson mine and mill at Tempiute, Lincoln County, Nev., about 150 miles north of Las Vegas, initiated operations in mid-1977. Scheelite ore was processed to a low-grade tungsten concentrate at the mill and shipped to UCC's Pine Creek facility, where it was converted to APT. The Emerson facility is scheduled to reach a production capacity of 2 million pounds of concentrate annually by 1979.

The major mineral value recovered at Climax was molybdenum. Concentrates of tungsten, tin, and pyrite were recovered as byproducts; the production rates of these minerals were largely dependent upon the molybdenum production rate.

Additionally, intermittent tungsten concentrate production and shipments were reported from east-central Alaska; Cochise, Pima, Pinal, and Yuma Counties, Ariz.; Fresno, Inyo, Kern, Los Angeles, San Bernadino, and Tulare Counties, Calif.; Boulder County, Colo.; Custer and Valley Counties, Idaho; Custer, Deer Lodge, and Granite Counties, Mont.; Churchill, Douglas, Elko, Esmeralda, Lincoln, Mineral, Nye, Pershing, Washoe, and White Pine Counties, Nev.; Baker County, Oreg.; Box Elder, Davis, Millard, Tooele, and Utah Counties, Utah; and Stevens County, Wash. The Tungsten Queen mine and mill of Ranchers Exploration & Development Corp., near Townsville, in Vance County, N.C., remained closed and on standby status throughout the year.

Data on tungsten shipped from domestic mines are presented in table 3.

Table 3.—Tungsten concentrate shipped from mines in the United States

Year	Quantity			Reported value, f.o.b. mine[1]		
	Short tons 60% WO_3 basis[2]	Short ton units WO_3[3]	Tungsten content (thousand pounds)	Total (thousands)	Average per unit of WO_3	Average per pound of tungsten
1973	7,418	445,051	7,059	$19,154	$43.04	$2.71
1974	8,233	494,012	7,836	37,413	75.73	4.77
1975	5,769	346,112	5,490	29,090	84.05	5.30
1976	6,168	370,069	5,869	37,266	100.70	6.35
1977	6,331	379,729	6,022	55,073	145.03	9.15

[1]Values apply to finished concentrate and are in some instances f.o.b. custom mill.
[2]A short ton of 60% tungsten trioxide (WO_3) contains 951.6 pounds of tungsten.
[3]A short ton unit equals 20 pounds of tungsten trioxide (WO_3) and contains 15.86 pounds of tungsten.

Table 4.—Major producers of tungsten concentrate and principal tungsten processors in 1977

Company	Location of mine, mill, or processing plant
Producers of tungsten concentrate:	
Climax Molybdenum Co., a subsidiary of AMAX Inc	Climax, Colo.
Union Carbide Corp., Metals Div. [1]	Bishop, Calif.; Tempiute, Nev.
Processors of tungsten:[2]	
Adamas Carbide Corp	Kenilworth, N.J.
Fansteel, Inc	North Chicago, Ill.
General Electric Co	Euclid, Ohio; Detroit, Mich.
GTE Sylvania, Inc., a subsidiary of General Telephone & Electronics Corp	Towanda, Pa.
Kennametal, Inc	Latrobe, Pa.; Fallon, Nev.
Li Tungsten Corp	Glen Cove, N.Y.
Teledyne Firth Stirling	McKeesport, Pa.
Teledyne Wah Chang Huntsville	Huntsville, Ala.
Union Carbide Corp., Metals Div	Niagara Falls, N.Y.
Westinghouse Electric Corp	Bloomfield, N.J.

[1]At its Pine Creek mine and mill in California, UCC processes ore "straight through" to APT.
[2]Major consumers of intermediate tungsten products.

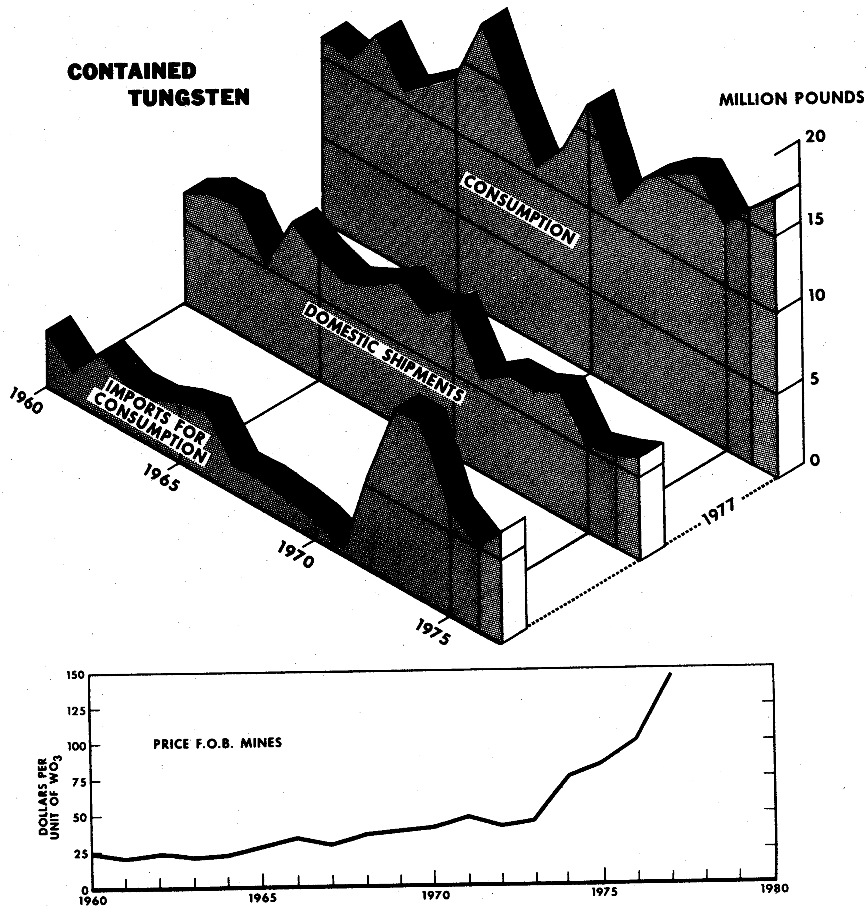


Figure 1.—Domestic shipments, imports, consumption, and average price of tungsten concentrate.

CONSUMPTION AND USES

Total domestic tungsten product consumption rose 1% to 16.9 million pounds of tungsten during 1977. The major end use continued to be in cutting and wear-resistant materials (65%), primarily as tungsten carbide. Other major end-use categories were mill products (15%), specialty steels (tool, alloy, and stainless) (9%), hardfacing rods and materials (5%), superalloys (3%), and chemicals (2%).

The consumption distribution in 1977 of intermediate tungsten products used to make end-use items was as follows: Tungsten carbide (including cemented, crushed and cast, and crystalline), 43%; tungsten metal powder, 39%; ferrotungsten, 5%; and scrap, 4%.

Figure 2 is a simplified tungsten flow diagram showing the major processing steps, intermediate products, and end-use items involved in the industry.

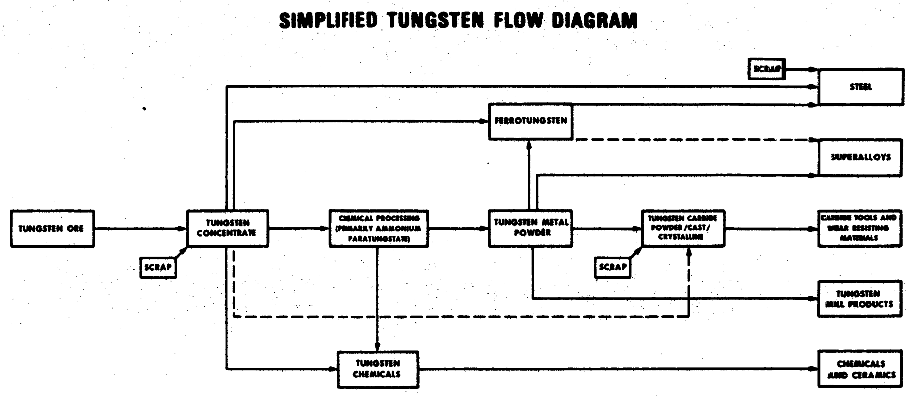


Figure 2.—Simplified tungsten flow diagram.

Table 5.—Production, disposition, 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[2]
		Made from metal powder	Crushed and crystal-line			
1976:						
Gross production during year	15,873	10,054	1,532	5,932	603	33,995
Used to make other products listed here	10,505	--	223	5,040	(3)	15,769
Net production	5,368	10,054	1,309	892	603	18,226
Disposition:						
To other processors	861	272	335	384	489	2,341
To end-use consumers	6,434	8,242	419	553	279	15,927
To make products not listed in this table	2,372	1,913	1,101	14	2	5,402
Producer stocks, Dec. 31	1,881	547	486	365	111	3,390
1977:						
Gross production during year	16,185	9,897	1,906	6,616	421	35,026
Used to make other products listed here	10,131	186	108	5,596	(3)	16,021
Net production	6,055	9,711	1,799	1,020	420	19,005
Disposition:						
To other processors	879	333	427	487	230	2,356
To end-use consumers	7,801	8,082	394	574	228	17,079
To make products not listed in this table	1,524	1,523	1,327	12	--	4,387
Producer stocks, Dec. 31	1,543	571	543	363	120	3,139

[1]Includes ferrotungsten, scheelite (produced from scrap), nickel-tungsten, and self-reducing oxide pellets.
[2]Data may not add to totals shown because of independent rounding.
[3]Less than 1/2 unit.

STOCKS

Producers' stocks of tungsten concentrate held at domestic mines were 17% less at yearend 1977 than at yearend 1976, and consumers' stocks held were 18% less. During 1977, combined producers' and consumers' stocks of APT increased 37%, and producers' and consumers' stocks of intermediate products each decreased 7%.

Table 6.—Consumption and stocks of tungsten products in the United States, by end use

(Thousand pounds of contained tungsten)

End use	Ferro-tungsten[1]	Tungsten metal powder[2]	Tungsten carbide powder	Other tungsten materials[3]	Total
1976:					
Steel:					
Stainless and heat-resisting	69	--	--	57	126
Alloy	97	--	--	147	244
Tool	682	--	--	451	1,133
Cast irons	4	--	--	--	4
Superalloys	90	137	W	208	435
Alloys (excludes steels and superalloys):					
Cutting and wear-resistant materials	--	3,744	6,081	577	10,402
Other alloys[4]	89	546	312	145	1,092
Mill products made from metal powder	--	2,432	W	--	2,432
Chemical and ceramic uses	--	--	W	704	704
Miscellaneous and unspecified	--	2	218	7	227
Total	1,031	6,861	6,611	2,296	16,799
Consumer stocks, Dec. 31	272	606	1,430	470	2,778
1977:					
Steel:					
Stainless and heat-resisting	94	--	--	81	175
Alloy	154	--	--	108	262
Tool	518	--	--	606	1,124
Cast irons	2	--	--	--	2
Superalloys	130	198	W	199	527
Alloys (excludes steels and superalloys):					
Cutting and wear-resistant materials	--	3,434	6,680	766	10,880
Other alloys[4]	50	441	274	129	894
Mill products made from metal powder	--	2,482	W	--	2,482
Chemical and ceramic uses	--	--	W	275	275
Miscellaneous and unspecified	1	3	268	12	284
Total	949	6,558	7,222	2,176	16,905
Consumer stocks, Dec. 31	193	460	1,459	469	2,581

W Withheld to avoid disclosing company proprietary data, included in "Miscellaneous and unspecified."
[1]Includes melting base self-reducing tungsten.
[2]Includes both carbon-reduced and hydrogen-reduced tungsten metal powder.
[3]Includes tungsten chemicals, natural and synthetic scheelite, tungsten scrap, and other.
[4]Includes welding and hard-facing rods and materials and nonferrous alloys.

PRICES AND SPECIFICATIONS

During 1977, the average value of tungsten concentrate shipped from domestic mines and mills, as reported to the Bureau of Mines, increased 44% to $145.03 per short ton unit of WO_3, compared with the 1976 value. In 1977, excess tungsten concentrate was purchased from GSA at prices, ex-duty, ranging from $126.50 to $159.57 per short ton unit for domestic use and from $138.12 to $160.35 per short ton unit for export.

As quoted in the Metal Bulletin (London), and reported in Metals Week, the European price of tungsten concentrate increased in the first part of the year, remained relatively stable during mid-year, and was erratic during the latter part of the year. Prices ranged from a low of $142.00 per metric ton unit ($128.82 per short ton unit) in January to a high of $186.50 per metric ton unit ($169.19 per short ton unit) in June. The average price of $155.03 per short ton unit of WO_3 was 50% higher than the 1976 average price of $103.68 per short ton unit.

The U.S. spot quotation of tungsten concentrate, published by Metals Week, ranged from a low of $116.00 per short ton unit in September to a high of $163.00 per short ton unit in May and June; quotes at yearend were $145 to $150 per short ton unit.

The Tungsten Ore Users' Index reported tungsten concentrate prices ranging from a low of $140.10 per metric ton unit ($127.10 per short ton unit) for the last half of January to a high of $175.43 per metric ton unit ($159.15 per short ton unit) for the first half of June.

The price of APT delivered to large volume contract customers was $155 per short ton unit at the beginning of 1977. From March through December it ranged from $165 to $190 per short ton unit, dropping to $180 per short ton unit at yearend.

The price of hydrogen-reduced tungsten metal powder (99.9% purity), f.o.b. shipping point, as quoted in Metals Week, rose from a range of $10 to $13 per pound of tungsten at the beginning of the year to a high range

Table 7.—Monthly price quotations of tungsten concentrate in 1977

Month	Wolframite, European market, dollars per metric ton unit of WO_3, 65% basis		Equivalent quotations, dollars per short ton unit of WO_3, 65% basis[1]			U.S. spot quotations, dollars per short ton unit of WO_3, 65% basis, c.i.f., U.S. ports[2]	
	Low	High	Low	High	Average[3]	Low	High
January	142.00	163.00	128.82	147.87	136.21	128.00	137.00
February	166.00	180.00	150.59	163.30	156.43	139.00	160.00
March	174.00	183.00	157.85	166.02	161.94	155.00	162.50
April	175.00	184.00	158.76	178.85	164.21	160.00	162.50
May	177.00	185.00	160.00	169.19	164.08	155.00	163.00
June	174.00	186.50	157.85	169.19	164.26	157.00	163.00
July	168.00	183.00	152.41	166.02	160.01	155.00	162.00
August	159.00	176.00	144.24	159.67	152.14	135.50	151.00
September	147.00	163.00	133.36	147.87	140.84	116.00	133.50
October	144.00	178.00	130.64	161.48	146.00	122.00	160.00
November	172.00	179.00	156.04	162.39	159.21	148.00	158.00
December	165.00	176.00	149.69	159.67	155.02	140.00	150.00

[1]Equivalent high and low quotations as reported in Metals Week from biweekly Metal Bulletin (London) data.
[2]U.S. spot quotations as reported in Metals Week.
[3]Monthly averages are arithmetic average of weekly low and high quotations. The equivalent 1977 average price, excluding duty, was $155.03 per short ton unit.

of $14.20 to $15.47 in April. At yearend, the price range was $13.90 to $15.00. Within these ranges, the price was primarily dependent upon the tungsten powder particle size (Fisher number).

The quoted price of UCAR, a proprietary high-purity ferrotungsten, rose from $9.25 per pound of tungsten at the beginning of the year to $10.50 on February 1 and a high of $12.75 on June 1. The price was reduced to $12.10 on September 1 and to $10.10 on October 1. It was increased to $12.10 on December 1 for the remainder of the year.

The price of scheelite concentrate (calcium tungstate) for direct addition to steel melts was believed to be comparable to the prices reported in table 7.

FOREIGN TRADE

Exports.—Tungsten concentrate exports during 1977 decreased 26% to 1.3 million pounds of tungsten. Ferrotungsten exports were 3,062 pounds of tungsten compared with none in 1976. APT exports were 22% less than in 1976 and totaled 146,287 pounds of tungsten, of which 65% went to the United Kingdom. Exports of tungsten carbide powder decreased 6% to 1.2 million pounds of tungsten compared with those of 1976. The principal recipients were Canada (34%), the Federal Republic of Germany (11%), Italy (8%), and Denmark and Mexico (7% each).

Exports of unwrought tungsten metal and alloys in crude form, waste, and scrap decreased 32% compared with those of 1976 to 746,284 pounds, gross weight, valued at $4,350,299. This material was shipped primarily to the Federal Republic of Germany (38%), Canada (22%), the United Kingdom (16%), and Belgium (6%). Tungsten and tungsten alloy powder exports were 26% less than in 1976 and totaled 768,549 pounds of tungsten valued at $11,457,147, with Israel (65%) as the main recipient.

Exports of tungsten and tungsten alloy wire fell 3% from those of 1976 to 188,306 pounds, gross weight, valued at $8,607,172 and were shipped primarily to Canada (24%), Mexico and the U.S.S.R. (13% each), and Brazil and Japan (11% each). Wrought tungsten and tungsten alloy exports increased 3% compared with those of 1976 to 248,576 pounds, gross weight, valued at $4,417,968. Most of these materials were shipped to the Federal Republic of Germany (46%), the United Kingdom (13%), Mexico (12%), Austria (8%), and Canada (7%).

Imports.—Imports for consumption of tungsten concentrate increased 31% compared with those of 1976, and totaled 6.9 million pounds of contained tungsten. The major sources of these imports were Canada (30%), Bolivia (23%), Mexico and Peru (9% each), and Thailand and the People's Republic of China (7% each).

In 1977, tungsten carbide imports decreased 20% compared with those of 1976 to 156,404 pounds of contained tungsten valued at $2,404,935, and came principally from the Federal Republic of Germany

(74%), Sweden (12%), and Canada and France (6% each). Imports of waste and scrap containing over 50% tungsten increased 104% compared with 1976 to 305,737 pounds of contained tungsten valued at $2,452,178. The major sources of these imports were Israel (55%), the Federal Republic of Germany (12%), Canada (10%), and Japan and Sweden (8% each). Imports of unwrought tungsten (except alloys), in lump, grain, and powder decreased 90% compared with 1976 to 37,169 pounds of contained tungsten valued at $454,866 and were supplied principally by the Federal Republic of Germany and Singapore (34% each) and by Mexico (17%). Wrought tungsten imports in 1977 rose 173% compared with 1976, and totaled 117,254 pounds, gross weight, valued at $3,243,246. Canada (80%), Austria (11%), and Japan (6%) were the major sources.

Imports of tungsten material classified as "metal-bearing materials in chief value of tungsten" decreased 32% from those of 1976 to 257,838 pounds of contained tungsten valued at $2,098,461. The imports were principally from Chile (46%), Bolivia (21%), the Republic of Korea (20%), and Switzerland (10%), and were believed to be mostly synthetic scheelite. Ferrotungsten imports decreased 40% from those of 1976 to 504,761 pounds of contained tungsten valued at $4,564,848. This material came mostly from Austria (56%), the United Kingdom (24%), and Brazil (8%).

Ammonium paratungstate imports decreased 36% compared with those of 1976 to 370,010 pounds of contained tungsten valued at $3,701,946, and was supplied solely by the Republic of Korea. Imports of calcium tungstate increased 90% over those of 1976 to 36,187 pounds of contained tungsten valued at $666,090 and was received entirely from the Federal Republic of Germany. There were no reported imports of sodium tungstate in 1977.

Table 8.—U.S. exports of tungsten ore and concentrate, by country

(Thousand pounds and thousand dollars)

Country	1976			1977		
	Gross weight	Tungsten content[1]	Value	Gross weight	Tungsten content[1]	Value
Austria	56	29	141	--	--	--
Belgium-Luxembourg	30	16	79	--	--	--
France	122	63	600	--	--	--
German Democratic Republic	--	--	--	94	48	265
Germany, Federal Republic of	965	498	2,973	1,890	975	8,559
Japan	505	260	1,751	--	--	--
Netherlands	1,216	628	4,225	57	29	246
South Africa, Republic of	--	--	--	100	52	562
Spain	--	--	--	12	6	24
Sweden	11	6	30	--	--	--
Switzerland	30	15	89	(2)	(2)	3
United Kingdom	344	177	1,052	237	122	1,299
U.S.S.R	72	37	249	98	51	442
Total	3,351	1,729	11,189	[3]2,487	1,283	11,400

[1]Tungsten content estimated by multiplying the gross weight by a factor of 0.516 equal to 0.65 (to convert from 65% to 100% WO_3 basis) times 0.7931 (to convert from WO_3 to W basis).

[2]Less than 1/2 unit.

[3]Data do not add to total shown because of independent rounding.

Table 9.—U.S. exports of ammonium paratungstate, by country

Country	1976 Gross weight (pounds)	1976 Tungsten content[1] (pounds)	1976 Value	1977 Gross weight (pounds)	1977 Tungsten content[1] (pounds)	1977 Value
Argentina	--	--	--	339	240	$1,349
Belgium-Luxembourg	--	--	--	2,390	1,689	9,560
Canada	40,000	28,264	$253,865	24,054	16,997	166,193
El Salvador	200	141	3,347	--	--	--
Ethiopia	--	--	--	1,153	815	4,611
France	--	--	--	749	529	2,040
Germany, Federal Republic of	4,556	3,220	30,660	19,981	14,119	151,676
Guatemala	--	--	--	316	223	1,352
Italy	--	--	--	311	220	2,803
Netherlands	--	--	--	22,050	15,581	17,520
Pakistan	--	--	--	1,200	848	2,400
Peru	--	--	--	2,300	1,625	1,244
Philippines	137	97	1,000	--	--	--
United Kingdom	220,650	155,911	1,412,000	132,186	93,403	1,112,833
Venezuela	1,029	727	4,410	--	--	--
Total	266,572	188,360	1,705,282	207,029	[2]146,287	1,473,581

[1]Tungsten content estimated by multiplying gross weight by 0.7066.
[2]Data do not add to total shown because of independent rounding.

Table 10.—U.S. exports of tungsten carbide powder, by country

Country	1976 Gross weight (pounds)	1976 Tungsten content[1] (pounds)	1976 Value	1977 Gross weight (pounds)	1977 Tungsten content[1] (pounds)	1977 Value
Argentina	10,574	8,248	$167,010	715	558	$20,551
Australia	13,181	10,281	108,222	5,570	4,345	77,502
Austria	63,153	49,259	591,013	88,540	69,061	707,655
Belgium-Luxembourg	57,225	44,635	214,521	34,345	26,789	244,918
Bermuda	--	--	--	90	70	648
Brazil	22,754	17,748	253,662	44,832	34,969	510,829
Canada	381,760	297,773	2,223,783	521,054	406,422	5,130,181
Chile	2,653	2,069	25,000	3,166	2,469	35,260
Colombia	57	44	2,695	242	189	4,084
Czechoslovakia	--	--	--	110	86	1,300
Denmark	5,483	4,277	51,260	105,338	82,164	948,564
Finland	50	39	726	4,311	3,363	52,590
France	7,702	6,008	58,071	19,149	14,936	189,931
Gabon	1,000	780	10,800	1,500	1,170	20,925
Germany, Federal Republic of	171,397	133,690	1,436,085	164,259	128,122	1,546,569
Guatemala	--	--	--	750	585	4,361
Hong Kong	8,881	6,927	3,998	--	--	--
India	--	--	--	80	62	1,138
Iran	91,445	71,327	18,251	187	146	1,428
Ireland	1,722	1,343	24,896	3,829	2,987	67,331
Israel	30,000	23,400	4,320	22,786	17,773	156,962
Italy	57,955	45,205	454,980	121,390	94,684	1,299,153
Japan	82,836	64,612	771,183	38,545	30,065	372,528
Mexico	428,988	334,611	437,209	110,505	86,194	403,642
Netherlands	29,387	22,922	261,485	44,759	34,912	524,109
Nigeria	--	--	--	8,996	7,017	8,060
Norway	643	502	7,105	8,818	6,878	121,760
Peru	2,000	1,560	4,280	--	--	--
Philippines	2,395	1,868	1,032	406	317	5,540
Portugal	110	86	1,374	--	--	--
Romania	--	--	--	1,306	1,019	16,983
Saudi Arabia	--	--	--	54,114	42,209	9,135
Singapore	82	64	1,184	--	--	--
South Africa, Republic of	1,856	1,448	26,723	8,890	6,934	145,250
Spain	2,057	1,604	33,278	3,429	2,675	61,956
Sweden	94,253	73,518	501,356	13,824	10,783	78,672
Switzerland	17,350	13,533	110,250	26,347	20,551	277,197
Taiwan	30	23	780	740	577	10,312
Thailand	--	--	--	50	39	1,600
Turkey	100	78	2,320	100	78	1,902
United Arab Emirates	5,000	3,900	10,231	--	--	--
United Kingdom	29,465	22,983	127,242	50,156	39,122	625,780
Venezuela	398	310	3,813	110	86	4,008
Yugoslavia	--	--	--	8,882	6,928	86,520
Total	1,623,942	1,266,675	7,950,138	1,522,220	[2]1,187,332	13,776,834

[1]Tungsten content estimated by multiplying gross weight by 0.78.
[2]Data do not add to total shown because of independent rounding.

Table 11.—U.S. exports of tungsten and tungsten alloy powder, by country

Country	1976			1977		
	Gross weight (pounds)	Tungsten content[1] (pounds)	Value	Gross weight (pounds)	Tungsten content[1] (pounds)	Value
Argentina	--	--	--	825	660	$11,296
Australia	434	347	$4,354	2,958	2,366	14,159
Austria	37,321	29,857	253,933	28,867	23,094	383,816
Belgium-Luxembourg	2,705	2,164	24,166	250	200	11,076
Brazil	1,243	995	14,300	924	739	12,249
Canada	67,554	54,043	706,460	42,842	34,274	593,718
Chile	--	--	--	82	66	4,697
Denmark	--	--	--	15,500	12,400	123,300
Finland	4,312	3,450	40,918	24,443	19,554	301,080
France	1,501	1,201	16,726	29,125	23,300	297,721
Germany, Federal Republic of	28,417	22,734	181,987	26,276	21,021	274,740
Ireland	3,308	2,646	41,443	28,796	23,037	415,850
Israel	457,074	365,659	1,202,601	739,851	591,881	8,732,308
Italy	2,005	1,604	18,920	470	376	2,970
Japan	1,915	1,532	10,623	426	341	2,604
Korea, Republic of	--	--	--	100	80	2,962
Mexico	6,959	5,567	63,237	1,152	922	14,013
Netherlands	236	189	1,128	10,103	8,082	116,414
South Africa, Republic of	--	--	--	2,607	2,086	32,719
Spain	330	264	5,625	880	704	17,695
Sweden	28,109	22,487	260,455	--	--	--
Switzerland	118	94	1,104	--	--	--
Taiwan	3,051	2,441	49,778	2,217	1,774	36,796
Turkey	13,411	10,729	136,294	137	110	1,980
United Kingdom	99,709	79,767	775,089	1,855	1,484	52,984
Venezuela	3,860	3,088	27,530	--	--	--
Total	763,572	610,858	3,836,671	960,686	[2]768,549	11,457,147

[1]Tungsten content estimated by multiplying gross weight by 0.80.
[2]Data do not add to total shown because of independent rounding.

Table 12.—U.S. general imports of tungsten ore and concentrate, by country

(Thousand pounds and thousand dollars)

Country	1976			1977		
	Gross weight	Tungsten content	Value	Gross weight	Tungsten content	Value
Australia	311	172	864	251	128	1,081
Bolivia	1,753	963	4,900	2,644	1,475	12,062
Brazil	4	2	11	169	96	912
Burma	232	123	582	--	--	--
Burundi	7	3	16	--	--	--
Canada	4,101	1,343	7,656	6,384	2,046	18,191
Chile	--	--	--	73	39	281
China, People's Republic of	717	384	2,289	866	466	4,256
France	--	--	--	87	43	146
Germany, Federal Republic of	--	--	--	([1])	([1])	1
Hong Kong	78	43	121	--	--	--
Korea, Republic of	357	202	1,054	115	69	514
Malaysia	105	61	284	341	193	1,224
Mexico	927	440	2,279	1,694	647	3,494
Netherlands	--	--	--	7	4	36
Peru	1,458	839	4,450	1,094	626	5,235
Portugal	714	420	2,386	340	199	1,702
Rhodesia, Southern	--	--	--	128	58	406
Rwanda	71	38	169	--	--	--
Singapore	19	10	59	--	--	--
South Africa, Republic of	26	15	69	13	7	51
South-West Africa, Territory of	--	--	--	65	36	262
Spain	36	21	119	--	--	--
Sweden	--	--	--	19	10	113
Thailand	1,314	655	3,266	1,115	576	4,849
Uganda	--	--	--	16	9	84
United Kingdom	--	--	--	108	51	411
Zaire	125	68	376	128	70	576
Total[2]	12,355	5,802	30,950	15,656	6,847	55,886

[1]Less than 1/2 unit.
[2]Data may not add to totals shown because of independent rounding.

Table 13.—U.S. imports for consumption of tungsten ore and concentrate, by country

(Thousand pounds and thousand dollars)

Country	1976			1977		
	Gross weight	Tungsten content	Value	Gross weight	Tungsten content	Value
Argentina[1]	23	10	46	--	--	--
Australia	311	172	864	251	128	1,081
Bolivia[1]	1,062	580	2,649	2,831	1,581	12,264
Brazil[1]	4	2	11	191	108	1,024
Burma[1]	232	123	581	--	--	--
Burundi[1]	7	3	16	--	--	--
Canada	4,101	1,343	7,656	6,384	2,046	18,191
Chile[1]	--	--	--	73	39	281
China, People's Republic of	703	377	2,256	866	466	4,256
France	--	--	--	87	43	146
Germany, Federal Republic of	--	--	--	(2)	(2)	1
Korea, Republic of[1]	357	202	1,054	115	69	514
Malaysia[1]	86	49	207	360	204	1,302
Mexico[1]	883	417	2,166	1,694	647	3,494
Netherlands	--	--	--	7	4	36
Peru[1]	1,501	863	4,564	1,094	626	5,235
Portugal[1]	714	420	2,386	340	199	1,702
Rhodesia, Southern	--	--	--	128	58	406
Rwanda[1]	70	38	169	--	--	--
Singapore[1]	19	10	59	--	--	--
South Africa, Republic of	26	15	69	13	7	51
South-West Africa, Territory of	--	--	--	65	36	262
Spain	36	21	118	--	--	--
Sweden	--	--	--	19	10	113
Thailand[1]	1,193	588	3,073	1,015	518	4,498
Uganda	--	--	--	16	9	84
United Kingdom	--	--	--	108	51	411
Zaire[1]	125	68	376	128	70	576
Total	11,453	5,301	28,320	15,785	6,919	[3]55,927

[1]Section 504(c) of the Trade Act of 1974 establishes a Generalized System of Preferences for the entry of tungsten from designated beneficiary developing countries. The program began Jan. 1, 1976.

[2]Less than 1/2 unit.

[3]Data do not add to total shown because of independent rounding.

Table 14.—U.S. imports for consumption of ferrotungsten, by country

Country	1976			1977		
	Gross weight (pounds)	Tungsten content (pounds)	Value	Gross weight (pounds)	Tungsten content (pounds)	Value
Austria	313,704	260,191	$1,744,103	339,411	281,555	$2,565,631
Brazil	--	--	--	57,435	41,268	389,239
France	312,172	246,447	1,502,085	--	--	--
Germany, Federal Republic of	64,588	52,920	292,170	22,023	18,293	195,799
India	39,262	32,077	251,209	--	--	--
Korea, Republic of	4,409	3,349	18,959	--	--	--
Portugal	17,636	14,741	86,445	51,588	42,744	313,399
Sweden	24,692	20,001	147,831	--	--	--
United Kingdom	265,431	214,545	1,408,443	148,334	120,901	1,100,780
Total	1,041,894	844,271	5,451,245	618,791	504,761	4,564,848

Table 15.—U.S. import duties on all forms of tungsten

Tariff classification	Article	Rate of duty effective Jan. 1, 1978: Prevailing[1]	Rate of duty effective Jan. 1, 1978: Statutory
601.5400	Tungsten ore	25 cents per pound on tungsten content.	50 cents per pound on tungsten content.
603.4500	Other metal-bearing materials in chief value of tungsten.	21 cents per pound on tungsten content and 10% ad valorem.	60 cents per pound on tungsten content and 40% ad valorem.
607.6500	Ferrotungsten	21 cents per pound on tungsten content and 6% ad valorem.	60 cents per pound on tungsten content and 25% ad valorem.
629.2500	Waste and scrap containing by weight not over 50% tungsten.	do	Do.
629.2600	Waste and scrap containing by weight over 50% tungsten.	10.5% ad valorem	50% ad valorem.
629.2800	Unwrought tungsten, except alloys, in lump, grain, and powder.	21 cents per pound on tungsten content and 12.5% ad valorem.	60 cents per pound on tungsten content and 50% ad valorem.
629.2900	Unwrought tungsten, ingots and shot.	10.5% ad valorem	50% ad valorem.
629.3000	Unwrought tungsten, n.e.c	12.5% ad valorem	60% ad valorem.
629.3200	Tungsten alloys, unwrought, containing by weight over 50% tungsten.	21 cents per pound on tungsten content and 6% ad valorem.	60 cents per pound on tungsten content and 25% ad valorem.
629.3300	Tungsten alloys, unwrought, containing by weight not over 50% tungsten.	12.5% ad valorem	60% ad valorem.
629.3500	Wrought tungsten	do	Do.
416.4000	Tungstic acid	21 cents per pound on tungsten content and 10% ad valorem.	60 cents per pound on tungsten content and 40% ad valorem.
417.4000	Ammonium tungstate	do	Do.
418.3000	Calcium tungstate	do	Do.
420.3200	Potassium tungstate	do	Do.
421.5600	Sodium tungstate	do	Do.
422.4000	Tungsten carbide	21 cents per pound on tungsten content and 12.5% ad valorem.	60 cents per pound on tungsten content and 50% ad valorem.
422.4200	Other tungsten compounds	21 cents per pound on tungsten content and 10% ad valorem.	60 cents per pound on tungsten content and 40% ad valorem.
423.9200	Mixtures of two or more inorganic compounds in chief value tungsten.	do	Do.

[1]Not applicable to most centrally planned economy countries.

WORLD REVIEW

During April 1977, a special United Nations Conference on Trade and Development (UNCTAD) board meeting was held in Geneva, Switzerland, at which it was decided that a group of experts on tungsten be formed to examine and assess proposals for the stabilization of the world tungsten market. In July 1977, the UNCTAD ad hoc Intergovernmental Group of Experts on Tungsten (IGET) met at Geneva and agreed to make detailed studies of the various areas affecting price and trade of tungsten as a framework for a possible international arrangement to increase the stability of the market. Different countries made studies on specific subjects relating to the tungsten market. At a November-December 1977 meeting of IGET in Geneva, these various studies were presented. It was concluded that the analyses to date, plus their continuing review and updating by governments before the next meeting of IGET, should permit completion and presentation of this work at the 11th special session of the Committee on Tungsten in February 1978. No agreement was reached between tungsten-producing and tungsten-consuming countries.

The second annual general meeting of the Primary Tungsten Association (PTA) was

Table 16.—Tungsten: World mine production, by country

(Thousand pounds of contained tungsten)[1]

Country	1975	1976	1977[p]
North and Central America:			
Canada[2]	2,584	3,792	3,994
Guatemala	2	--	--
Mexico	611	518	421
United States	5,588	5,830	6,008
South America:			
Argentina	190	207	183
Bolivia	[3]5,661	[4]6,700	[4]6,572
Brazil	2,496	[r] [e]2,160	[e]2,200
Peru	1,283	1,303	1,160
Europe:			
Austria	798	1,193	2,460
Czechoslovakia[e]	175	175	175
France	1,367	1,775	[e]1,870
Portugal	3,139	2,813	2,227
Spain	774	611	595
Sweden	315	428	[e]440
U.S.S.R.[e]	17,200	17,600	18,100
United Kingdom	22	22	[e]22
Africa:			
Burundi	2	4	[e]4
Nigeria	([5])	([5])	[e]--
Rhodesia, Southern[6]	84	55	[e]55
Rwanda	761	952	[e]990
South-West Africa, Territory of[7]	[r]15	[e]18	[e]18
Uganda[e]	240	240	240
Zaire	547	[e]530	[e]550
Asia:			
Burma	[r]1,091	1,032	983
China, People's Republic of[e]	19,800	19,800	19,800
India	[r]44	51	49
Japan	1,693	1,795	1,704
Korea, North[e]	4,740	4,740	4,740
Korea, Republic of	5,298	5,655	5,573
Malaysia	234	141	218
Thailand	3,609	4,180	4,486
Turkey	--	2,046	[e]2,650
Oceania:			
Australia	[r]4,145	5,401	5,143
Total	[r]84,508	91,767	93,630

[e]Estimate. [p]Preliminary. [r]Revised.

[1]Conversion factors: WO_3 to W, multiply by 0.7931; 60% WO_3 to W, multiply by 0.4758.

[2]Producer's shipments; actual production data are not officially reported.

[3]Data presented are sum of production reported by COMIBOL and exports credited to medium and small mines and other unspecified exporters (including COMIBOL). Total national output is not reported.

[4]Actual recorded total national output. Not available for prior years.

[5]Less than 1/2 unit.

[6]Production of Beardmore mine only.

[7]Production of Brandberg West mine of South West Africa Company, Ltd. only. Data are for calendar years.

held in July 1977 at Divonne-les-Bains, France.[2] A. B. Statsgruver of Sweden and R. B. Mining Pty. Ltd. of Australia were elected as new members. In August 1977, the UNCTAD board accepted PTA on a consultative status that allows PTA to be represented at all UNCTAD committee and board meetings concerning tungsten.

Australia.—King Island Scheelite Pty., Ltd., a subsidiary of Peko-Wallsend Ltd., continued to produce most of Australia's tungsten concentrate. For the fiscal year ending July 5, 1977, production increased 36% from that of the previous 12 months to 1.8 million pounds of contained tungsten. Mill recovery was 78.9% compared with 75.4% for the previous fiscal year. Advanced development in the Bold Head and Dolphin mines was maintained with the objective of reaching the bottom of both ore bodies in the 1978-79 fiscal year. The construction of the artificial scheelite plant to produce a molybdenum-free calcium tungstate product from the flotation concentrate was well advanced.[3]

Bolivia.—Production of tungsten concentrate in Bolivia in 1977 totaled 6.6 million pounds of tungsten, of which Corporacíon Minera de Bolivia (COMIBOL) produced 2.3 million pounds, mainly from the Kami and Bolsa Negra mines. COMIBOL's reserves were estimated at 12.5 million pounds of tungsten.

International Mining Co., a subsidiary of Estalsa, S.A., operated three mines— Chambillaya, Chojlla, and Enramada. During

Table 17.—Tungsten: World concentrate consumption, by country[1]

(Thousand pounds of contained tungsten)

Country[2]	1975	1976	1977[p]
Actual consumption:			
Australia	88	88	88
Austria	2,008	3,505	3,184
Canada	269	639	e 3 550
Czechoslovakia[e 3]	2,700	2,700	2,800
France	3,179	3,139	2,207
Japan	4,773	5,677	4,667
Mexico	106	71	130
Portugal	780	595	302
Sweden	3,629	3,761	e 3 3,800
United Kingdom	4,967	4,251	4,046
United States	r 14,012	16,107	17,100
Apparent consumption:[4]			
Argentina	121	137	e 3 130
Belgium-Luxembourg	90	401	57
Brazil	613	e 3 620	e 3 620
China, People's Republic of[e 3]	r 4,630	r 4,740	5,100
German Democratic Republic[3 e]	550	600	600
Germany, Federal Republic of	2,551	4,464	2,943
Hungary[e]	1,320	1,320	3 1,320
India	287	615	e 3 660
Italy[e]	280	125	3 110
Korea:			
North[e 3]	3,500	3,500	3,500
Republic of[e 5]	1,500	1,600	1,600
Netherlands	2,465	2,593	e 3 2,650
Poland	3,549	4,231	3,935
South Africa, Republic of[e]	550	550	3 550
Spain	132	168	168
U.S.S.R.[e 3]	15,300	16,100	16,300
Total	r 73,949	82,297	79,117

[e]Estimate. [p]Preliminary. [r]Revised.

[1]Source, unless otherwise specified, is the Quarterly Bulletin of the UNCTAD Committee on Tungsten. Tungsten Statistics. V. 12, No. 3, July 1978, 57 pp.

[2]In addition to the countries listed, Bulgaria, Denmark, Finland, Israel, Norway, Romania, Switzerland, and Yugoslavia may consume tungsten concentrate, but consumption levels are not reported and available general information is inadequate to permit formulation of reliable estimates of consumption levels.

[3]Estimated by U.S. Bureau of Mines. (All estimates not so footnoted are reported in the primary source.)

[4]Production plus imports minus exports. For a few countries where data were available, variations in stocks were used in determining consumption.

[5]Data represents tungsten content of concentrate consumed to make ammonium paratungstate at APT plant adjacent to Sangdong mine and mill.

1977, work was done on mine expansion, a new camp, and a 660-short-ton-per-day mill at Enramada. Completion was scheduled for late 1978. Trackless mining was introduced at Chojlla to counter declining production caused by lowering grades.

Empresa Nacional de Fundiciones (ENAF) formed a joint venture with International Mining Co. to produce 2,200 short tons of APT per year. The project was suspended in 1977 awaiting action on a request for reduction or elimination of duties on APT imports into the United States, which is the principal market for this product. ENAF also plans to issue a construction contract for a ferrotungsten plant in August 1978, which will supply the Andean Common Market.

Brazil.—Four tungsten producers and five consumers in Brazil reached an agreement that the domestic price for scheelite concentrate (70% WO_3) was to be based on the weighted quotes of the previous month's Metal Bulletin (London) tungsten price with a ceiling of $180 per short ton unit. The tungsten consumers earlier had asked the Government to embargo concentrate shipments because they felt they were being penalized by paying higher prices than those sought for export by the tungsten producers.[4]

Canada.—Tungsten concentrate produced by Canada Tungsten Mining Corp. Ltd. from tbe Flat River mine and mill at Tungsten, Northwest Territories, near the Yukon border, increased 5% compared with that of 1976 to 4 million pounds of tungsten. Overall, WO_3 recovery was 82.2% compared with 81.6% in 1976. The concentrator was operational 98.6% of the time and averaged 535 tons of ore per day.

Construction work for the expansion of mine and mill capacity from 500 to 1,000 tons of ore per day commenced in June 1977. Exploration and diamond drilling added reserves of ore containing 4.9 million pounds of tungsten. At yearend, reserves totaled 103 million pounds of tungsten.[5]

Korea, Republic of.—The Korea Tungsten Mining Co., Ltd. (KTMC), 8.6% owned by the Republic of Korea, decreased production of tungsten concentrate by 8%, but accounted for 90% of the country's tungsten output. KTMC produced 3.1 million pounds of APT, the entire production of the country.

Mexico.—A four-part study of the tungsten industry in Mexico and the world was published during 1977 and early 1978.[6] Part 1 of the study analyzes tungsten production, consumption, reserves, commerce, prices, and foreign trade in Mexico. Part 2 covers world production, consumption, reserves, and prices of tungsten concentrate. Part 3 concerns commerce, foreign trade, and international cooperation to stabilize world prices. Part 4 refers to world trade and the prices of certain tungsten-based intermediate goods, ending with conclusions on the entire study. In the study, the reserves of contained tungsten in Mexico as of May 1977 were estimated to be 44 million pounds. The most recent published estimates prior to the study were 2 million pounds.

Portugal.—Tungsten concentrate production by the major Portugese tungsten producer, Beralt Tin & Wolfram (Portugal) SARL, at the Panasqueira mine decreased 19% to 1.7 million pounds of tungsten in 1977, due, according to the company, mainly to absenteeism, reduction of the work week from 6 to 5 days, and labor unrest. Lower grade of ore fed to the mill also contributed to the lower production. Production improved in the last quarter of the year. Byproduct production of copper and tin concentrates declined in line with the reduction of tungsten concentrates.

Excavation continued on an inclined shaft scheme to service the new Level 2, except for the period of May through September when work was suspended due to a shortage of labor. The revised commissioning target for the new shaft is early 1981. The heavy-media separation plant at Barroca Grande and the mill at Rio operated satisfactorily throughout the year.[7]

According to the Portuguese State Secretary of Planning, the reserves at the Panasqueira mine were 38 million pounds of tungsten in early 1977.[8]

Sweden.—The Sandvik Group increased research and development work aimed at reducing the company's dependence on the type of raw materials previously used. The Coromant factory in Stockholm was trying in 1977 to evolve substitute materials and to find ways of recycling indexable inserts and other items made of cemented carbide. During the year, Sandvik obtained minority interest in Queensland Wolfram Pty. Ltd. in Australia, which planned to mine and concentrate ore starting in 1978.[9]

Turkey.—Etibank's scheelite mine at Uludag near Bursa was expected to start APT production of 6.6 million pounds of tungsten in mid-1978. A fire and technical difficulties delayed the start of production for more than 1 year. In 1977, Turkey's reserves were estimated at 170 million pounds of contained tungsten in ore averaging 0.51% WO_3.

United Kingdom.—In 1977, exploration for tungsten and tin in the Hemerdon area near Plymouth was begun by AMAX Exploration of U. K., Inc., a subsidiary of AMAX Inc., under a joint venture agreement with Hemerdon Mining and Smelting Ltd. of Bermuda (HMSL) and its subsidiary, Hemerdon Mining and Smelting (U. K.) Ltd. HMSL had already completed the first phase of a drilling program, having confirmed earlier estimates that the known part of the ore body contained 5.6 million short tons of ore averaging 0.18% WO_3.

TECHNOLOGY

A technique capable of removing tungsten from the complex brines of Searles Lake, Calif., was demonstrated by the Bureau of Mines during 1977. The tungsten is adsorbed on a specially synthesized, ion-exchange resin and stripped by using an alkaline solution. Tungsten can be recovered either as a marketable iron-tungsten product or as tungstic acid concentrate. Available commercial ion-exchange resins proved ineffective for recovering tungsten from the alkaline brines, so the Bureau developed a unique resin for that purpose. Research at yearend was directed toward providing information for operating an expanded-scale process research unit and appraising the process economics. The Searles Lake brines are estimated to contain 135 million pounds of tungsten, compared with present U.S. reserves of 275 million pounds.

The Bureau of Mines continued to conduct research on new and improved methods for the economic recovery of tungsten and associated valuable metals and minerals from domestic tactite ores and hot springs deposits. Studies were also continued on the recovery of tungsten from processing sludges and scrap.

The National Institute for Occupational Safety and Health of the U.S. Department of Health, Education, and Welfare presented criteria in a recommended standard for occupational exposure to tungsten and cemented tungsten carbide in workplaces that produce cemented tungsten carbide.[10] Cemented tungsten carbides consume about 68% of tungsten production and are made by binding with cobalt and/or other metals, including nickel. The criteria for tungsten, its compounds, and the cobalt and nickel that are used as binders in making cemented carbides are based on the health effects (chiefly on the respiratory and dermal systems) of exposure to these materials.

Canada Tungsten Mining Corp. Ltd. described the changing of a tungsten mining and milling operation in the harsh climate of northern Canada from a seasonal open pit mine with a limited life to an underground mine with 20 years' reserves.[11]

Improved technology in mineral processing, constituting a major breakthrough in tungsten processing at the Mount Carbine mine and mill in Australia, was announced by R. B. Mining Pty. Ltd. The process involves photometric sorting of metallic ore from gangue at high speed and in large volume. The successful use of photometry for low-grade tungsten resources could markedly increase present estimates of tungsten reserves.[12]

The tensile properties of chemically vapor-deposited (CVD) tungsten were studied to establish the reason for its reportedly poor high-temperature ductility and to compare its tensile properties with powder metallurgy tungsten.[13]

The latest technology available in Europe and the United States was used by Wolfram-Bergbau & Hüettengesellschaft mbH to overcome an array of geographic and metallurgical obstacles to development of integrated tungsten mining and processing facilities in Austria.[14]

---

[1]Physical scientist, Division of Ferrous Metals.
[2]Primary Tungsten Association (London). Quarterly Bull., No. 2, September 1977, p. 1.
[3]Peko-Wallsend Ltd. (Sydney, Australia). 1976-77 Annual Report. 33 pp.
[4]Metals Week. V. 48, No. 48, November 28, 1977, p.6.
[5]Canada Tungsten Mining Corp. Ltd. (Toronto, Canada). 1977 Annual Report. 12 pp.
[6]Uriarte, M. A., and A. B. Partida. Tungsten and Compounds. Comercio Exterior de Mexico, v. 23, No. 7, July 1977, pp. 280-287.
———. Tungsten and By-Products. Comercio Exterior de Mexico, v. 23, No. 8, August 1977, pp. 319-324.
———. Tungsten and By-Products. Comercio Exterior de Mexico, v. 23, No. 10, October 1977, pp. 409-415.
———. Tungsten and By-Products. Comercio Exterior de Mexico, v. 24, No. 2, February 1978, pp. 87-91.
[7]Beralt Tin and Wolfram Ltd. (London). 1977 Annual Report. 20 pp.
[8]State Secretary of Planning (Lisbon). Productive Structures. Medium-Term 77/80; Summary Report. EC-Economic and Social Questions, n-9, June-July 1977.
[9]Sandvik (Sweden). 1977 Annual Report. 40 pp.
[10]U.S. National Institute for Occupational Safety and Health. Criteria for a Recommended Occupational Exposure to Tungsten and Cemented Tungsten Carbide. 1977, 174 pp.
[11]Cummings, W. W., and D. E. Bruce. Canada Tungsten—Change to Underground Mining & Description of Mine-Mill Procedures. Canadian Min. and Met. Bull., v. 70, No. 784, August 1977, pp. 94-101.
[12]Metal Bulletin (London). Photometry and W. No. 6188, May 3, 1977, p. 21.
[13]Bryant, W. A. Chemically-Deposited Tungsten: Its High Temperature Strength and Ductility. J. Less-Common Metals, v. 53, No. 1, May 1977, pp. 35-42.
[14]Walsh, T. New Technology Overcomes Obstacles in the Alps. Am. Metal Market, v. 86, No. 3, Jan. 5, 1978, pp. 9, 16.

Uranium (Depleted)

By William S. Kirk[1]

Depleted uranium hexafluoride (UF_6), resulting from the enrichment of natural uranium for nuclear applications by the Department of Energy (DOE), was the sole source of uranium for nonenergy applications. The quantity of depleted UF_6 that can be made available greatly exceeds current demand. DOE converts some of the UF_6 to the tetrafluoride (UF_4 or greensalt) which is shipped to several domestic companies and a company in Canada for reduction to uranium metal for use in ordnance applications. This use is believed to account for about 90% of total consumption. Commercial sales of depleted UF_6 or UF_4 for use in containers for spent nuclear reactor residues, other radiation shielding applications, as counterweights and ballast for aircraft and ships, and in research, accounted for the remaining 10% of demand.

Legislation and Government Programs.—Depleted uranium, though less radioactive than the enriched product, is treated as a source material in the Code of Federal Regulations and is referred to in sections 10 CFR 40.25 and 10 CFR 110.23.[2]

DOMESTIC PRODUCTION

DOE is the sole domestic processor of uranium to produce a uranium product that is enriched in the isotope uranium 235 (U_{235}) used for nuclear applications. About 4.5 tons of depleted UF_6, which still contains some U_{235}, is generated for each ton of commercial power reactor-grade enriched UF_6 produced. If a more enriched product is required, such as for weapons use, a considerably larger quantity of depleted uranium product is generated for each ton of the enriched product. Expressed as uranium equivalent, DOE, in 1977, generated 32,140 tons of depleted UF_6, 0.25% of which was the hexafluoride of U_{235}, and 526 tons of depleted UF_6, 0.30% of which was the hexafluoride of U_{235}. In 1977, 2,764 tons (uranium equivalent) of depleted UF_6 was converted by DOE to UF_4, 0.25% of which was the tetrafluoride of U_{235}.

CONSUMPTION AND USES

Expressed as the uranium equivalent, 7,974 tons of depleted UF_4 was shipped in 1977 for eventual conversion to metal. Some 90% of depleted uranium metal is used in ordnance applications. Due to its high density and pyrophoricity, depleted uranium metal is used by the Army for 120-mm antitank ammunition, by the Air Force for 30-mm ammunition on the A-10 aircraft, and by the Navy in its Phalanx antimissile system. Depleted uranium metal ammunition is reported to be more effective than tungsten alloy ammunition. Depleted uranium metal is also used in making containers for spent nuclear reactor residues and other radiation shielding applications. Other uses are as ballast and counterweights on aircraft control surfaces and research.

PRICES AND STOCKS

The price of depleted UF_6 charged by DOE since August 14, 1973, was $2.50 per kilogram, or about $1.25 per pound. The price of depleted uranium metal was about $2.50 per pound.

The yearend inventory of depleted UF_4, expressed as the uranium equivalent, held by DOE dropped 7% from 1976, from 79,085 to 73,423 tons. DOE stocks of depleted UF_6 rose 8.7% in the same period, from 180,466 to 196,205 tons. Depleted UF_6 held by DOE at the end of 1977 by assay was: 0.20% U_{235}, 76,417 tons; 0.25% U_{235}, 77,725 tons; 0.30% U_{235}, 42,063 tons.

WORLD REVIEW

The United Kingdom had some 15,000 to 20,000 tons of depleted uranium in various forms on hand. The quantity of depleted UF_6 reported to be held by the Netherlands was several thousand tons. Data on stocks of depleted uranium products in other countries with enriching facilities, such as France and the Federal Republic of Germany, were not available.

TECHNOLOGY

Uranium ore is mined and sent to milling plants where it is mechanically and chemically processed to upgrade the uranium content. The product from the milling plant is called yellow cake (uranium oxide or U_3O_8). The yellow cake is converted to UF_6, which is a gas at about 56°C at atmospheric pressure. The UF_6 is shipped to any one of three DOE enrichment facilities (Oak Ridge, Tenn., Paducah, Ky., or Portsmouth, Ohio), where it is enriched by a process known as gaseous diffusion. Gaseous diffusion operates on the principle that the average velocities of gas molecules at a given temperature depend on their molecular mass. The molecules of the lighter isotopes of uranium will contact the walls of a porous containment vessel more frequently than the molecules of the heavier isotopes. The molecules of the lighter isotopes will therefore diffuse through the containment vessel faster than those of the heavier isotopes. The barrier contains hundreds of millions of submicroscopic openings per square inch. The degree of enrichment in a single stage is very small, but the desired enrichment level is achieved by repeating the process through hundreds of stages arranged in cascade. A portion of the enriched UF_6 is shipped in 2-1/2-ton steel containers to facilities where it is converted to uranium oxide (UO_2) for use in power reactors. A portion of the depleted UF_6 is converted to UF_4 and reduced to depleted uranium metal by using magnesium metal.

[1]Physical scientist, Nonferrous Metals Section.

[2]U.S. Code of Federal Regulations. Title 10—Energy; Chapter I—Nuclear Regulatory Commission; Sections 40.25, 110.23, under General Licenses.

Vanadium

Grace N. Broderick[1]

The supply of vanadium in 1977 exceeded requirements, although reported consumption of intermediate products increased 11% over that of 1976, and vanadium oxide recovered from domestic sources decreased 16%. Union Carbide Corp., the principal producer of vanadium oxide in the United States, announced in November 1977 that it was reducing its vanadium operations at Hot Springs, Ark., because of the depressed demand for vanadium, and that it would shutdown the Arkansas mine and mill in the first quarter of 1978 for an indefinite period. Arkansas, however, continued to be the leading vanadium-producing State for the sixth consecutive year. Exports of ferrovanadium were down in 1977, but exports classified as ores, concentrates, oxides, and vanadates increased considerably over those of the previous year. Vanadium pentoxide (anhydride) imports and imports of residues and slags were both less than in 1976. Ferrovanadium imports for consumption, however, were higher than those of any other year except 1968.

Table 1.—Salient vanadium statistics

(Short tons of contained vanadium)

	1973	1974	1975	1976	1977
United States:					
Production:					
Ore and concentrate:					
Recoverable vanadium[1]	4,377	4,870	4,743	7,376	6,504
Value (thousand dollars)	$26,611	$38,266	$49,329	$81,279	$74,488
Vanadium oxides recovered[2]	4,864	5,368	4,859	6,197	5,208
Consumption	6,393	7,200	5,501	4,720	5,261
Exports:					
Ferrovanadium and other vanadium alloying materials (gross weight)	1,416	1,335	1,018	1,210	658
Vanadium ores, concentrates, oxides, and vanadates	232	203	215	99	192
Imports (general):					
Ferrovanadium (gross weight)	303	225	179	433	558
Ores, slags, residues	2,600	2,485	2,895	2,998	2,812
Vanadium pentoxide (anhydride)	([3])	533	1,275	668	444
World production	21,653	20,762	r28,471	r31,271	33,317

rRevised.
[1]Recoverable vanadium contained in uranium and vanadium ores and concentrates received at mills, plus vanadium recovered from ferrophosphorus derived from domestic phosphate rock.
[2]Produced directly from all domestic sources and includes metavanadates.
[3]Less than 1/2 unit.

Legislation and Government Programs.—As of December 31, 1977, the physical inventory of the U.S. Government stockpile remained at 540 tons of contained vanadium, all in the form of vanadium pentoxide. The stockpile goals for vanadium announced by the General Services Administration on October 1, 1976 were reaffirmed in October 1977, subject to annual review and revisions; these goals for vanadium were 10,095 tons of ferrovanadium and 2,576 tons of vanadium pentoxide.

The National Institute for Occupational Safety and Health (NIOSH), U.S. Department of Health, Education, and Welfare, recommended in a document sent to the

Occupational Safety and Health Administration (OSHA), U.S. Department of Labor, that occupational exposure to vanadium carbide and metallic and alloyed forms of vanadium be limited to 1.0 milligram per cubic meter of air measured on a 10-hour, time-weighted concentration. It also recommended that exposure to all other vanadium compounds be limited to a 15-minute ceiling concentration of 0.05 milligram per cubic meter of air. OSHA's current standards for vanadium are: For vanadium pentoxide dust, a maximum exposure not exceeding 1.0 milligram per cubic meter of air; for vanadium pentoxide in fume form, a maximum of 0.1 milligram per cubic meter of air; and for ferrovanadium, 1.0 milligram per cubic meter of air based on an 8-hour, time-weighted average.

DOMESTIC PRODUCTION

The same four mills that recovered vanadium oxide from domestic sources in 1976 continued as the producers in 1977: Union Carbide Corp., Rifle, Colo., and Hot Springs, Ark.; Atlas Corp., Moab, Utah; and Kerr-McGee Corp., Soda Springs, Idaho. Colorado Plateau uranium-vanadium ores, Arkansas vanadium ore, and Idaho ferrophosphorus constituted the domestic raw materials that were run through the mills. Other feed materials included vanadium-bearing slags from Chile, the U.S.S.R., and the Republic of South Africa; spent catalysts, and vanadium residues. Vanadium recovered from imported vanadium-bearing materials is not included in any of the production figures shown in the tables, nor is the vanadium recovered directly from slags or residues as ferrovanadium or similar products.

Gulf Chemical and Metallurgical Corp. continued to recover vanadium oxide from foreign materials at its Texas City, Tex. plant. Ranchers Exploration & Development Corp.'s Durita project at Naturita, Colo., which involves the leaching of old uranium-vanadium mill tailings and treatment of the leaching liquors to recover both uranium and vanadium, came onstream in December 1977. Additional production from uranium-vanadium ores of the Colorado Plateau will be forthcoming with the completion of Cotter Corp.'s Canon City, Colo. facility, expected to be onstream in 1979, and Pioneer Uravan, Inc.'s mill in Colorado, which has a target startup date for early 1981. Kaiser Engineers, Inc. was selected for the engineering design of Pioneer Uravan's projected mill, which will be located in Disappointment Valley near Slick Rock, Colo.

Vanadium continued to be produced as a byproduct of the burning of Venezuelan oil in power-generating operations. Long Island Lighting Co. (LILCO) sold vanadium-bearing material recovered from this source. Niagara Mowhawk Power Corp. also sold vanadium-bearing ash and slag from its two oil-fired generating stations at Albany and Oswego, N.Y. Several other power stations burning vanadium-bearing Venezuelan residual oil located along the east coast of the United States contributed residues from which vanadium was extracted.

Table 2.—Mine production and recoverable vanadium of domestic origin produced in the United States

(Short tons of contained vanadium)

Year	Mine production[1]	Recoverable vanadium[2]
1973	4,117	4,377
1974	5,240	4,870
1975	5,213	4,743
1976	8,076	7,376
1977	7,565	6,504

[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 3.—Production of vanadium oxides in the United States[1]

(Short tons)

Year	Gross weight	Oxide content[2]
1973	8,226	8,683
1974	9,304	9,583
1975	8,597	8,674
1976	10,836	11,063
1977	9,341	9,297

[1]Produced directly from all domestic sources; includes metavanadates.
[2]Expressed as equivalent V_2O_5.

Producers of vanadium additives used by the steel and titanium industries were Engelhard Minerals & Chemicals Corp., Strasburg, Va.; Foote Mineral Co., Cambridge, Ohio; Reading Alloys, Inc., Robesonia, Pa.; Shieldalloy Corp. (a division of Metallurg, Inc.), Newfield, N.J.; and Union Carbide Corp. at Marietta, Ohio, and Niagara Falls, N.Y.

CONSUMPTION AND USES

Domestic consumption of vanadium, reported by type of material in table 4 and by end use category in table 5, increased 11% over the 4,720 tons consumed in 1976. Approximately 88% of the vanadium consumed went to the production of steel, and all of the steel end use categories registered increases. The most significant gain in 1977 was for carbon steel, which increased more than 35%. High-strength low-alloy steels, with extensive use in structural steels, large-diameter natural gas and oil transmission pipelines, and automotive industry applications, continued to be the largest end use.

Ferrovanadium consumption (including proprietary vanadium-iron-carbon ferroalloys), compared with data for 1976, rose 13%; oxide consumption decreased 18%; and ammonium metavanadate consumption increased 5%. Consumption of other vanadium materials, consisting principally of vanadium-aluminum alloys and small quantities of other vanadium alloys, was 6% above that of 1976.

Table 4.—Consumption and consumer stocks of vanadium materials in the United States

(Short tons of contained vanadium)

Type of material	1976		1977	
	Consumption	Ending stocks	Consumption	Ending stocks
Ferrovanadium[1]	4,144	924	4,693	669
Oxide	175	50	143	34
Ammonium metavanadate	41	9	43	14
Other[2]	360	97	382	128
Total	4,720	1,080	5,261	845

[1]Includes other vanadium-iron-carbon alloys.
[2]Consists principally of vanadium-aluminum alloy, plus relatively small quantities of other vanadium alloys and vanadium metal.

Table 5.—Consumption of vanadium in the United States, by end use

(Short tons of contained vanadium)

End use	1977
Steel:	
Carbon	715
Stainless and heat resisting	28
Full alloy	1,425
High-strength low-alloy	1,834
Electric	W
Tool	603
Cast irons	47
Superalloys	19
Alloys (excluding steels and superalloys):	
Cutting and wear resistant materials	W
Welding and alloy hard-facing rods and materials	9
Nonferrous alloys	350
Other alloys[1]	W
Chemical and ceramic uses:	
Catalysts	180
Other[2]	W
Miscellaneous and unspecified	51
Total	5,261

W Withheld to avoid disclosing individual company confidential data, included in "Miscellaneous and unspecified."
[1]Includes magnetic alloys.
[2]Includes pigments.

STOCKS

In addition to the consumers' stocks shown in table 4, producers' stocks of vanadium as fused oxide, precipitated oxide, metavanadate, metal, alloys, and chemicals totaled 3,518 tons of contained vanadium at yearend 1977, compared with 3,018 tons at yearend 1976.

PRICES

The price for domestic 98% fused vanadium pentoxide (metallurgical grade) quoted by Metals Week remained at $2.75 to $3.35 per pound of contained V_2O_5 throughout 1977, and that for technical-grade, air-dried vanadium pentoxide (chemical grade) remained at $2.75 to $3.54 per pound of contained V_2O_5 throughout the year.

On July 15, 1977, Foote Mineral Co. resumed production of 70% to 80% vanadium-grade ferrovanadium, which had been discontinued about 5 years earlier when the company decided to concentrate on its proprietary Ferovan grade (42.6% vanadium). Price for the 70% to 80% grade was $5.85 per pound of contained vanadium. Shieldalloy Corp., effective July 25, 1977, reduced the price of its 80% vanadium-grade ferrovanadium from $6.10 to $5.85 per pound of contained vanadium. U.S. price quotations for Carvan and Ferovan of $5.60 per pound of contained vanadium stayed the same throughout the year.

Union Carbide Corp., effective September 1, 1977, raised the price of VQ 65% vanadium-aluminum from $8.27 to $9.25 per pound of contained vanadium and, effective December 1, 1977, reduced this to $8.95 per pound of contained vanadium. In December, the company resumed production of VQ 50% vanadium-aluminum, which had been discontinued in September 1977; its price was set at $9.25 per pound of contained vanadium, an increase from the previous price of $8.60. The price for vanadium-aluminum alloys sold by Reading Alloys, Inc., effective December 1, 1977, was $8.95 per pound of contained vanadium for 65% to 35% vanadium-aluminum, and $9.25 per pound of contained vanadium for 50% vanadium-aluminum.

FOREIGN TRADE

Exports of ferrovanadium totaled 1.3 million pounds (gross weight) in 1977, 46% less than in 1976. Exports of ores, concentrates, and oxides, however, were at a much higher level than in 1976, rising from 197,000 pounds of contained vanadium to 384,000 pounds, an increase of 95%. The average declared value for exports of ores, concentrates, and technical-grade oxides was $2.86 per pound of contained vanadium pentoxide in 1977, compared with $2.11 per pound in 1976. The average declared value for exports of ferrovanadium was $3.76 per pound of alloy in 1977, compared with $3.79 in 1976.

Imports classified as vanadium ore and concentrates, the first to be reported since 1973, were received from Canada in December 1977. The quantity imported had a vanadium pentoxide content of 14,000 pounds, valued at $15,698. Imports classified as vanadium carbide totaled 3,452 pounds (gross weight), 2,800 pounds of which came from Canada and 652 pounds from the Federal Republic of Germany. Imports of vanadium-bearing materials (such as ashes and slags) totaled 5.6 million pounds of contained vanadium, compared with 6.0 million pounds of contained vanadium in 1976. In both years, the Republic of South Africa, Chile, and the U.S.S.R. continued to be the major sources of this supply. Vanadium pentoxide (anhydride) imports for consumption decreased from 2,184,241 pounds (gross weight) in 1976 to 1,598,571 pounds in 1977. Imports of ammonium vanadate (gross weight) were 10,069 pounds from the Federal Republic of Germany and 5,630 pounds from the United Kingdom; sodium vanadate imports amounted to 55,115 pounds (gross weight), all of which came from the United Kingdom. Ferrovanadium imports, shown in table 7, in terms of general imports were the highest since 1972, and in terms of imports for consumption were higher than any other year except 1968.

Table 6.—U.S. exports of vanadium, by country

(Thousand pounds and thousand dollars)

Destination	Ferrovanadium and other vanadium alloying materials containing over 6% vanadium (gross weight)				Vanadium ore, concentrates, pentoxide, vanadic acid, vanadium oxide, and vanadates (except chemically pure grade) (vanadium content)			
	1976		1977		1976		1977	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Argentina	40	172	84	343	--	--	--	--
Belgium-Luxembourg	110	394	--	--	--	--	--	--
Canada	780	3,236	507	2,240	65	206	212	543
El Salvador	--	--	1	3	--	--	--	--
Finland	33	122	--	--	--	--	--	--
Germany, Federal Republic of	41	128	--	--	--	--	--	--
Hong Kong	--	--	26	110	--	--	--	--
India	1	3	(1)	3	23	100	12	49
Indonesia	--	--	5	11	--	--	--	--
Italy	--	--	--	--	5	20	--	--
Japan	718	2,414	579	1,858	--	--	--	--
Korea, Republic of	--	--	2	6	--	--	--	--
Malaysia	1	4	--	--	--	--	--	--
Mexico	16	57	104	348	50	233	30	103
Netherlands	132	527	--	--	--	--	--	--
New Guinea	--	--	--	--	(1)	1	--	--
Peru	--	--	--	--	1	1	--	--
Philippines	--	--	2	10	--	--	--	--
Poland	107	399	--	--	--	--	--	--
Spain	230	934	--	--	53	181	6	22
Sweden	121	504	5	17	--	--	--	--
Switzerland	70	204	--	--	--	--	--	--
Taiwan	--	--	1	5	--	--	--	--
Venezuela	--	--	--	--	--	--	124	1,242
Yugoslavia	22	82	--	--	--	--	--	--
Total	2,422	9,180	1,316	4,954	197	742	384	1,959

[1]Less than 1/2 unit.

Table 7.—U.S. imports of ferrovanadium, by country

(Thousand pounds and thousand dollars)

Country	1976			1977		
	Gross weight	Vanadium content	Value	Gross weight	Vanadium content	Value
General imports:						
Austria	55	45	219	12	10	53
Canada	91	69	371	416	319	1,658
Germany, Federal Republic of	323	238	1,200	169	114	597
Norway	353	166	656	407	186	901
Sweden	44	36	172	111	90	443
Total[1]	866	553	2,618	1,116	719	3,652
Imports for consumption:						
Austria	55	45	219	12	10	53
Canada	91	69	371	416	319	1,658
Germany, Federal Republic of	279	202	1,029	169	114	597
Norway	353	166	656	304	140	687
Sweden	44	36	173	111	90	443
Total	822	518	2,448	1,012	673	3,438

[1]Data may not add to totals shown because of independent rounding.

Table 8.—U.S. imports of vanadium pentoxide (anhydride), by country

Country	1976			1977		
	Gross weight (pounds)	Vanadium content (pounds)	Value	Gross weight (pounds)	Vanadium content (pounds)	Value
General imports:						
Denmark	--	--	--	24,339	13,635	$24,000
Finland	--	--	--	162,754	91,175	321,344
South Africa, Republic of	2,383,754	1,335,379	$3,766,686	1,397,515	782,888	2,372,358
United Kingdom	665	373	2,851	6	3	1,201
Total	2,384,419	1,335,752	3,769,537	1,584,614	887,701	2,718,903
Imports for consumption:						
Denmark	--	--	--	24,339	13,635	24,000
Finland	--	--	--	162,754	91,175	321,344
South Africa, Republic of	2,183,576	1,223,239	3,478,196	1,411,472	790,706	2,398,292
United Kingdom	665	373	2,851	6	3	1,201
Total	2,184,241	1,223,612	3,481,047	1,598,571	895,519	2,744,837

WORLD REVIEW

In addition to the nations listed in table 9, some others had relatively small vanadium production from secondary, waste, or byproduct sources. Japan and the Federal Republic of Germany produced vanadium from several such sources.

World capacity to produce vanadium has increased considerably with the result that it now exceeds the rate of world vanadium consumption. Oversupply, along with accumulated inventories, led to announcements of production curtailments by Highveld Steel and Vanadium Corp., Ltd. (HSV); Ucar Minerals Corp.; Rautaruukki Oy; and Elkem-Spigerverket A/S.

Australia.—It was reported that a vanadium/pig iron project planned by Garrick Agnew, a mining entrepreneur whose company, Agnew Clough, Ltd., owns a charcoal pig iron plant at Wundowie in Western Australia, would cost about $28,000,000. Subsidies would be granted by the Western Australian Government to Agnew Clough, Ltd., when the company undertakes construction of a facility to produce vanadium pentoxide from vanadiferous magnetite deposits at the rate of 1.2 million pounds of contained vanadium per year.

Austria.—Treibacher Chemische Werke A.G. continued to produce ferrovanadium from imported vanadium material. Austrian trade statistics do not record exports of ferrovanadium separately, but imports reported by the U.S. Bureau of Census indicate that the United States received from Austria 55 tons (gross weight) of ferrovanadium in 1976 and 12 tons in 1977.

Brazil.—Import barriers against vanadium pentoxide were dropped by the Brazilian Government at midyear, thus making it possible for Brazil's ferroalloy producers to import this material at an attractive price level.

Finland.—The new Mustavaara mine and plant of Rautaruukki Oy, in combination with their Otanmäki mine and plant, have greatly increased Finland's capacity to produce vanadium. The company developed its own extraction process, which is used at both plants. In this process, after magnetic concentration of vanadiferous magnetite, soda is added to the concentrate and the concentrate is pelletized. Wet pellets are charged to sintering furnaces that convert the magnetite to hematite; meanwhile, under the influence of the soda, vanadium forms a water-soluble compound that can be leached from the pellets with hot water. Vanadium is precipitated from the leaching solution as ammonium trivanadate, which is then fused into vanadium pentoxide. The Mustavaara deposit is located at the border area of Taivalkoski and Posio, about 90 miles north of Otanmäki and 43 miles southeast of Rovaniemi.

India.—Ferrovanadium production was 99 tons in 1977, compared with 58 tons in 1976. Plans for the construction of a ferrovanadium plant in the State of Orissa were under consideration by Ipicol.

Norway.—Elkem-Spigerverket A/S, a company formed by the merger of Elkem A/S and Christiania Spigerverk in 1972, produced ferrovanadium at its Bremenger

Table 9.—Vanadium: World production from ores and concentrates, by country

(Short tons of contained vanadium)

Country	1975	1976	1977[p]
Chile[e] [1]	660	1,199	950
Finland (in vanadium pentoxide product)	1,405	1,649	2,055
Norway[e]	510	580	600
South Africa, Republic of:[2]			
Content of pentoxide and vanadate product[e]	5,300	3,931	4,900
Content of vanadiferous slag product[e]	6,434	6,954	7,488
Total	11,734	10,885	12,388
South West Africa, Territory of (in lead vanadate concentrate)[3]	619	782	[e]820
U.S.S.R. [e]	[r]8,800	[r]8,800	10,000
United States (recoverable vanadium)	4,743	7,376	6,504
Total	[r]28,471	31,271	33,317

[e]Estimate. [p]Preliminary. [r]Revised.
[1]Based on U.S. imports of vanadium bearing slag.
[2]The Republic of South Africa officially reports the undistributed total production of vanadium in pentoxides and vanadate products as well as in vanadium bearing slags. Data on vanadium content of vanadium slag are estimated on the basis of a reported tonnage of vanadium bearing slag (gross weight) multiplied by an assumed grade of 14% vanadium. Vanadium content of pentoxide and vanadate products represents the difference between the reported total and the calculated estimate for vanadium in slag.
[3]Data represent output of South West Africa Co. Ltd. for the years ending June 30 of that stated.

smelter at Svelgen. Christiania Spigerverk was a producer and exporter of vanadiferous slag and vanadiferous pig iron for some years, but in 1966 changed over to the production of ferrovanadium for export. The titaniferous magnetite ore of the Rodsand mine was, and continues to be, the source of the vanadium. It was reported in September 1977 that Elkem-Spigerverket A/S was not producing vanadium-titanium pig iron at that time.

Poland.—The Polish Government was reportedly studying the feasibility of a project to recover vanadium, titanium, and iron ore from a large titaniferous magnetite deposit in eastern Poland.

South Africa, Republic of.—South Africa continued to be the world's largest producer of vanadium with an estimated production in 1977 of 22,113 tons, as V_2O_5 equivalent, for the combined forms— slag, polyvanadate and metavanadate, and fused pentoxide. During the fiscal year ending June 30, 1977, HSV, the country's and the world's leading producing company in vanadium, produced at its Witbank plant a total of 53,482 tons (gross weight) of vanadium-bearing slag, compared with 49,571 tons in fiscal year 1976. The company's Vantra division, as a result of lowered vanadium demand, curtailed its production of vanadium pentoxide and operated only one of its eight roasting units during the latter part of calendar year 1977.

Ucar Minerals Corp. continued to operate its vanadium plant at Bon Accord and brought onstream its new plant at Brits. Planned cutbacks in production at these plants and of its mining operations at Brits were announced by the company, because of current oversupply of vanadium resulting from increased world production capacity coupled with weakened demand.

The shareholding of Otavi Mining Co. (Pty.) Ltd. in Transvaal Alloys (Pty.) Ltd. was acquired in 1976 by Norddeutsche Affinerie. Modifications of the vanadium pentoxide plant and equipment were implemented and full annual output capacity was indicated to be about 1,120 tons of contained vanadium. Sales, handled on a long-term contractual basis by Brandeis Goldschmidt & Co., Inc., were mainly to Europe but also to South America and Japan.

South-West Africa, Territory of.—The South-West Africa Co., Ltd., (SWACO), continued to produce lead vanadate concentrate from the Berg Aukas mine, near Grootfontein. As of November 24, 1976, the company became a wholly owned subsidiary of Kiln Products Ltd.; SWACO is administered by Gold Fields of South Africa Ltd.

Rössing Uranium, Ltd., reportedly, has a source of vanadium raw material available in the tailings from its uranium mining and this material may be stockpiled against future use.

Turkey.—Prospecting teams of the Mining Research and Prospecting Institute of Turkey (MTA) reported the discovery of vanadium mineralization near Keban.

U.S.S.R.—The U.S.S.R., which has large vanadium resources, continued to produce vanadium-rich slag, a coproduct with iron from the titaniferous magnetites of the Kachkanar open pits in the Ural Mountains and iron ore from Lisakovsk in Kazakhstan. A unit for vanadium recovery from waste, commissioned in 1976 by the Ust'-Kamenogorsk titanium-magnesium complex in Kazakhstan, began production in 1977. Vanadium pentoxide has been recovered as a byproduct of the production of alumina from bauxite at the Dneprovsk aluminum plant. At Tula, a city south of Moscow, a relatively large vanadium oxide plant, with a reported capacity of 20 million pounds of V_2O_5 per year, was said to have been completed.

Yugoslavia.—Vanadium and titanium reportedly have been discovered in Yugoslavia. The ore bodies, located in the Jastebec Mountains west of Nis, were estimated to contain 50,000 tons of vanadium pentoxide and 2,000 tons of titanium oxide.

TECHNOLOGY

Research projects sponsored by the Vanadium International Technical Committee (Vanitec) included research on the properties of vanadium-nitrogen steels at the National Physical Laboratory in England, the weldability of vanadium steels at The Welding Institute in England, the properties of dual phase HSLA steels at the Swedish Institute for Metal Research, vanadium steels for line pipe at Italsider S.p.A. and Centro Sperimentalie Metallurgico in Italy, vanadium steels for rails at the University of Ghent in Belgium, the strength-toughness balance of vanadium line pipe steels at the British Steel Corp., and precipitation reactions in vanadium steels at the Massachusetts Institute of Technology.

Several experimental programs were conducted on vanadium steels and vanadium-columbium steels with emphasis on developing a composition suitable for Arctic-grade line pipe. Results from these programs were presented and supplemented by recent data on commercial trials with vanadium-columbium microalloyed steels.[2]

A superformable, high-strength sheet steel, GM 980X, developed by metallurgists at General Motors Research Laboratories, was described.[3] The steel is characterized by a low yield strength, a continuous stress-strain curve with no yield point elongation, a high work hardening rate and tensile strength, and a large total elongation. It is basically a commercially available vanadium-strengthened SAE 980X that has been heated at 790° C for 3 minutes and then air-cooled to room temperature.

A patent was issued on a process for recovering vanadium from a magnetite concentrate produced during the beneficiation of titaniferous magnetite, for example, the ilmenite-magnetite deposits of the Adirondack Mountains in New York. A finely divided magnetite concentrate was screened, and the minus 250-mesh fraction mixed with a sodium compound; the mixture was roasted at a temperature of 1,000° to 1,300° C. to form a water-soluble sodium-vanadium compound, which was then removed by leaching with water. The magnetite end product contained as low as 0.3% sodium and no more than about 1.0% SiO_2 and was suitable for use as feed material for blast furnaces in the production of metallic iron.[4]

Two patents for recovering vanadium from a vanadium-bearing source were assigned to UOP Inc. One process leached vanadium-bearing material with an ammoniacal solution at a temperature of 50° to 300° C. and pressure up to 200 atmospheres. The resulting ammonium vanadate solution was separated from insoluble metal impurities and cooled to below 50° C to precipitate ammonium vanadate, and the precipitate separated and calcined to form vanadium pentoxide.[5] The second process leached vanadium-bearing material with a solution of sodium hydroxide or sodium carbonate. The leach liquor was separated from insoluble impurities and treated with ammonia and carbon dioxide to precipitate ammonium vanadate. The precipitate was separated and calcined to form vanadium pentoxide. The spent caustic solution was stripped with steam to remove ammonia, the steam-ammonia mixture recycled to the precipitation step, and the stripped caustic solution recycled to the leaching step.[6]

Other patents issued in 1977 included one for recovery of vanadium, as vanadium pentoxide, from a solution of sodium vanadate obtained during processing of vanadium-containing sludge in the production of alumina. Solution at a pH value of from 4.0 to 6.0 and at a temperature lower than 40° C was treated with ammonium chloride or ammonium sulfate to precipitate ammonium-sodium decavanadate. The precipitate was separated and dissolved in hot water, the aqueous solution treated with a mineral acid and heated to precipitate ammonium polyvanadate, and the precipitate calcined.[7]

Another patent was for the recovery of vanadium pentoxide from vanadium-containing metallurgical slag. Ground slag was roasted in an oxidizing medium, the calcine leached with phosphoric acid at a temperature of 50° to 100° C for a period of 30 to 120 minutes to solubilize vanadium as vanadium pentoxide, the leach liquor filtered off, and the vanadium pentoxide recovered from the solution.[8]

---

[1]Physical scientist, Division of Ferrous Metals.

[2]Goetz, G. J. New X70-X80 HSLA Steels for Structural and Line Pipe Use. J. Metals, v. 29, No. 8, August 1977, pp. 12-18.

[3]Baxter, D. F., Jr. GM Develops a Superformable HSLA Steel. Metal Prog., v. 112, No. 3, August 1977, pp. 44-48.

[4]Nilsen, A. E. (assigned to NL Industries, Inc.). Method for Recovering Vanadium from Magnetite and Forming a Magnetite Product Low in Sodium and Silica. U.S. Pat. 4,023,959, May 17, 1977.

[5]Morgan, K. A., and R. R. Frame (assigned to UOP Inc.). Recovery of Vanadium Values. U.S. Pat. 4,061,711, Dec. 6, 1977.

[6]Morgan, K. A., and M. Miller (assigned to UOP Inc.). Recovery of Vanadium Values. U.S. Pat. 4,061,712, Dec. 6, 1977.

[7]Nasyrov, G. Z., and I. V. Ravdonikas (assigned to Vsesojuzny Nauchno-Issledovatelsky i Proektny Institut Aljuminievoi and Magnievoi i Elektrodni Promyshlennosti). Method of Preparing Vanadium Pentoxide. U.S. Pat. 4,039,582, Aug. 2, 1977; Can. Pat. 1,022,727, Dec. 20, 1977.

[8]Slotvinsky-Sidak, N. P., and N. V. Grinberg. Method of Preparing Vanadium Pentoxide from Metallurgical Slags Containing Vanadium. U.S. Pat. 4,039,614, Aug. 2, 1977.

Vermiculite

By Stanley K. Haines[1]

Domestic production of crude vermiculite reached 359,000 tons, slightly below the record of 365,000 tons in 1973. Output of exfoliated vermiculite increased to 321,000 tons, 19% above the revised 1976 total. The average value per ton continued to climb, reaching $157.42. Exfoliating plants processed ore from Montana, South Carolina, Texas, and South Africa. The principal end uses were as loose-fill and block insulation; in concrete aggregate; in premixes for acoustic, fireproofing, and other applications; and for agricultural purposes. World production of crude vermiculite was 569,879 tons, a decrease of 1% from 1976.

Table 1.—Salient vermiculite statistics

(Thousand short tons and thousand dollars)

	1973	1974	1975	1976	1977
United States:					
Sold or used by producers:					
Crude	365	341	330	304	359
Value	$9,464	$10,120	$13,761	$14,032	$18,579
Average value per ton	$25.93	$29.68	$41.70	$46.16	$51.75
Exfoliated	293	275	235	r270	321
Value	$31,186	$30,916	$36,345	r$42,255	$50,108
Average value per ton	$106.44	$112.42	$154.66	r$156.40	$157.42
Exports to Canada	36	44	45	41	45
Imports from the Republic of South Africa	30	42	33	40	40
World: Production, crude	549	557	r588	r577	570

rRevised.

DOMESTIC PRODUCTION

Crude Vermiculite.—Output of vermiculite concentrate, commonly called crude, increased 18%, from 304,000 tons in 1976 to 359,000 tons. The principal mining operations were W. R. Grace & Co.'s mines and beneficiating plants in Libby, Mont. and Enoree, S.C. Crude vermiculite was also produced by Patterson Vermiculite Co. in Lanford, S. C., and Volite, Inc., Llano, Tex.

At yearend Virginia Vermiculite Co. had obtained commercial financing for its mine, beneficiation plant, and exfoliation plant in Louisa County, Va. Mining was planned for late 1978.

Exfoliated Vermiculite.—Production of exfoliated vermiculite increased 18% in quantity and 19% in value in 1977. The five leading producing States were Ohio, South Carolina, Texas, Florida, and New Jersey. W. R. Grace & Co., Construction Products Div., the principal producer of crude and exfoliated vermiculite, operated 30 plants in 24 States. Vermiculite was produced by 22 companies with 52 plants in 29 States. Crude vermiculite from the Republic of South Africa was exfoliated at about 10 domestic plants.

Table 2.—Exfoliated vermiculite sold or used, by end use

Use	1976 Short tons	1976 Percent of total	1977 Short tons	1977 Percent of total
Aggregates:				
Concrete	67,710	25	65,920	21
Plaster	3,099	1	3,599	1
Premixes[1]	39,450	15	30,130	9
Total[2]	110,300	41	99,650	31
Insulation:				
Loose fill	39,050	14	74,900	23
Block	39,310	15	50,980	16
Packing	390	--	168	--
Total[2]	78,750	29	126,000	39
Agriculture:				
Horticulture and soil conditioning	36,380	13	40,780	13
Fertilizer carrier	[r]37,450	14	47,580	15
Total[2]	[r]73,830	27	88,360	28
Miscellaneous	7,334	3	6,797	2
Grand total[2]	[r]270,200	100	320,800	100

[r]Revised.
[1]Includes vermiculite used in premixes for acoustic and fireproofing purposes, decorative textures, moisture sealant, etc.
[2]Data may not add to totals shown due to independent rounding.

Table 3.—Vermiculite exfoliating plants in the United States in 1977

Company	State	County	Nearest city or town
J. P. Austin Assoc., Inc	Pennsylvania	Allegheny	Beaver Falls.
J. J. Brouk & Co., Inc	Missouri	St. Louis	St. Louis.
Cleveland Builders Supply Co., Cleveland Gypsum Co. Div.	Ohio	Cuyahoga	Cleveland.
Diversified Insulation, Inc	Minnesota	Hennepin	Minneapolis.
W. R. Grace & Co., Construction Products Div.	Arizona	Maricopa	Phoenix.
	Arkansas	Pulaski	North Little Rock.
	California	Alameda	Newark.
	do	Los Angeles	Los Angeles.
	do	Orange	Santa Ana.
	Colorado	Denver	Denver.
	Florida	Broward	Pompano Beach.
	do	Duval	Jacksonville.
	do	Hillsborough	Tampa.
	Illinois	DuPage	West Chicago.
	Kentucky	Campbell	Newport.
	Louisiana	Orleans	New Orleans.
	Maryland	Prince Georges	Muirkirk.
	Massachusetts	Hampshire	Easthampton.
	Michigan	Wayne	Dearborn.
	Minnesota	Hennepin	Minneapolis.
	Missouri	St. Louis	St. Louis.
	Nebraska	Douglas	Omaha.
	New Jersey	Mercer	Trenton.
	New York	Cayuga	Weedsport.
	North Carolina	Guilford	High Point.
	Oklahoma	Oklahoma	Oklahoma City.
	Oregon	Multnomah	Portland.
	Pennsylvania	Lawrence	New Castle.
	South Carolina	Greenville	Kearney.
	do	do	Travellers Rest.
	Tennessee	Davidson	Nashville.
	Texas	Bexar	San Antonio.
	do	Dallas	Dallas.
	Wisconsin	Milwaukee	Milwaukee.
Hyzer & Lewellen	Pennsylvania	Bucks	Southampton.
International Vermiculite Co	Illinois	Macoupin	Girard.
Koos, Inc	Wisconsin	Kenosha	Kenosha.
La Habra Products, Inc	California	Orange	Anaheim.

Table 3.—Vermiculite exfoliating plants in the United States in 1977 —Continued

Company	State	County	Nearest city or town
MacArthur Co	Minnesota	Ramsey	St. Paul.
Mica Pellets, Inc	Illinois	DeKalb	DeKalb.
Patterson Vermiculite Co	South Carolina	Laurens	Lanford.
Robinson Insulation Co	Montana	Cascade	Great Falls.
	North Dakota	Ward	Minot.
Schmelzer Sales Associates, Inc	Florida	Hillsborough	Tampa.
The Schundler Co	New Jersey	Middlesex	Metuchen.
O. M. Scott	Ohio	Union	Marysville.
Strong-Lite Products	Arkansas	Jefferson	Pine Bluff.
Supreme Perlite Co	Oregon	Multnomah	Portland.
Vermiculite of Hawaii, Inc	Hawaii	Honolulu	Honolulu.
Vermiculite-Intermountain, Inc	Utah	Salt Lake	Salt Lake City.
Vermiculite Products, Inc	Texas	Harris	Houston.
Volite, Inc	do	Llano	Llano.

CONSUMPTION AND USES

The end-use pattern shifted substantially, through a large increase in loose-fill insulation and a drop in premixes. The principal end-use categories were insulation, 39% (up 10 percentage points); aggregate, 31% (down 10 percentage points); agriculture, 28%; and miscellaneous, 2%. One explanation for the increase in demand for loose-fill insulation is that U.S. consumers became convinced of the need to insulate their homes, causing an increase in demand for all forms of home insulation. Some of the other insulating materials underwent a period of tight supply, thereby throwing more business to the vermiculite industry. Additionally, about 21,000 tons of crude vermiculite was consumed for various end uses without exfoliation.

PRICES

According to the Bureau of Mines canvass, the average value of domestic crude vermiculite increased 12%, from $46.16 per ton in 1976 to $51.75 in 1977. The average value of exfoliated vermiculite increased $1.02 per ton to $157.42 in 1977, f.o.b. mine or plant.

Engineering and Mining Journal quoted nominal yearend prices for crude vermiculite as follows: Per short ton, f.o.b. mine, domestic crude, $48 to $75; c.i.f. Atlantic ports, Republic of South Africa crude, $60 to $80.

FOREIGN TRADE

Exports of crude vermiculite to Canada increased to 45,000 tons in 1977. The vermiculite was shipped primarily from Libby, Mont. About 40,000 tons of crude vermiculite was imported duty free from the Republic of South Africa.

WORLD REVIEW

Canada.—A total of 59,471 tons of crude vermiculite was imported in 1977, from the United States and the Republic of South Africa. The Provinces receiving the most vermiculite were Quebec, 23,800 tons; Ontario, 15,000 tons; Alberta, 9,700 tons; Manitoba, 6,000 tons; and British Columbia, 4,500 tons. The end-use pattern for 1976 was as follows: Loose-fill insulation, 71.9%; horticulture, 8.8%; insulating concrete, 7.3%; plaster, 2%; and other uses (including fireproofing and barbecue base), 10%.[3]

Japan.—Production of crude vermiculite in Japan in 1977 was 15,000 tons, compared with 14,000 tons in 1976. The deposits are generally of lower quality vermiculite. The primary producing companies were Sinsei Nekken Kogyo Co., Ltd., U. S. Industry Co., Toyo Hiruishi Kogyo Co., and Nihon Hiruishi Kabuishiki Kaisha. The principal deposits are in Fukushima Prefecture in the northeast, and in Fukui Prefecture in central Japan.

About 80,000 tons of vermiculite per year is imported into Japan, mainly from the Republic of South Africa with a small quantity from the United States and Kenya. Most of the vermiculite is consumed by the construction industry.[3]

South Africa, Republic of.—Total production of crude vermiculite was 182,343 short tons. Local usage amounted to 7,485 tons, and exports were 163,800 tons.

[1]Physical scientist, Division of Nonmetallic Minerals.
[2]Stonehouse, D. H. Lightweight Aggregate, 1976. Canada Dept. Energy, Mines, and Resources (Ottawa), 1976, 5 pp.
[3]Industrial Minerals (London). No. 119, August 1977, p. 22.

Table 4.—Vermiculite: World production, by country[1]

(Short tons)

Country[1]	1975	1976	1977[p]
Argentina	[e]4,400	4,517	4,600
Brazil[2]	882	1,111	[e]1,200
Egypt[e]	(3)	(3)	--
India	[r]2,327	4,600	2,954
Japan[e]	13,000	14,000	15,000
Kenya	8,249	3,954	4,762
South Africa, Republic of	228,761	244,798	182,343
Tanzania[e]	20	20	20
United States (sold or used by producers)	330,000	304,000	359,000
Total	[r]587,639	577,000	569,879

[e]Estimate. [p]Preliminary. [r]Revised.
[1]Excludes production by centrally planned economy countries.
[2]Production for Brazil in previous editions of the Minerals Yearbook has been estimated owing to the absence of reliable source materials. Official Brazilian output data for the years 1967 to 1974 that has become available since the last edition of the Minerals Yearbook was published as follows in short tons: 1967, 239; 1968, 186; 1969, 18; 1970, 9; 1971, 104; 1972, 622; 1973, 51; and 1974, 7.
[3]Revised to zero.

Zinc

By V. Anthony Cammarota, Jr.[1] and John M. Lucas[1]

The zinc industry in 1977 was marked by production cutbacks, lower consumption, falling prices, and labor strikes. Mine production of recoverable zinc fell 7%, primary slab zinc production dropped 10%, and slab zinc consumption decreased 3%. Several mine closures and strikes adversely affected both mine and smelter production. Primary producers announced cutbacks in production rates to about 70% of capacity in the second half of the year. Stocks of both consumers and producers fell 21%.

Mine development continued in middle Tennessee, while several mines in Arizona, Maine, Tennessee, and Washington closed due to ore depletion or low zinc prices. A 4-month strike at a mine in Tennessee cut production in that State, and a 5-month strike at a smelter in Idaho affected mine production in several Western States.

U.S. primary and secondary smelters produced 500,756 tons of slab zinc, down 12% from that of 1976. A strike, mechanical problems at several smelters, and cutbacks in production to bring it more in line with demand were reasons for the decline. The construction of a new 90,000-ton-per-year zinc plant in Tennessee was nearly half-completed by yearend.

Consumption of slab zinc was 1.1 million

Table 1.—Salient zinc statistics

	1973	1974	1975	1976	1977
United States:					
Production:					
Domestic ores, recoverable content short tons	478,850	499,872	469,355	484,513	449,620
Value thousands	$197,861	$358,908	$366,097	$358,541	$309,338
Slab zinc:					
From domestic ores short tons	399,119	346,993	307,959	381,872	355,174
From foreign ores do	184,360	208,195	130,092	116,983	94,971
From scrap do	83,187	78,535	57,886	r68,555	50,611
Total	666,666	633,723	495,937	r567,410	500,756
Secondary zinc[1] do	300,073	259,947	225,315	r304,336	313,128
Exports of slab zinc do	14,566	19,062	6,897	3,513	237
Imports (general):					
Ores (zinc content) do	199,634	240,043	144,987	97,115	122,808
Slab zinc do	592,046	539,538	380,437	714,489	576,736
Stocks, December 31:					
At producer plants do	25,947	39,720	74,676	r96,950	92,387
At consumer plants do	114,317	211,158	107,276	121,154	80,941
Government stockpile do	677,009	391,600	385,714	385,192	383,415
Reprocessed GSA zinc[2] do	109,333	42,850	3,442	--	--
Consumption:					
Slab zinc do	1,503,938	1,287,696	925,330	1,134,141	1,101,765
All classes do	1,931,925	1,673,013	1,231,815	r1,536,890	1,507,635
Price: Prime Western, cents per pound (delivered)	20.66	35.95	38.96	37.01	34.39
World:					
Production:					
Mine short tons	6,293,484	6,371,590	r6,448,041	r6,357,626	6,682,951
Smelter[3] do	5,876,535	6,182,680	r5,526,379	r5,907,566	6,040,834
Price: Prime Western grade, London cents per pound	38.55	56.13	33.76	32.38	26.71

rRevised.
[1]Excludes redistilled slab zinc.
[2]Included in total amount withdrawn from Government stockpile.
[3]Primary metal production only; includes secondary metal production where inseparably included in country total.

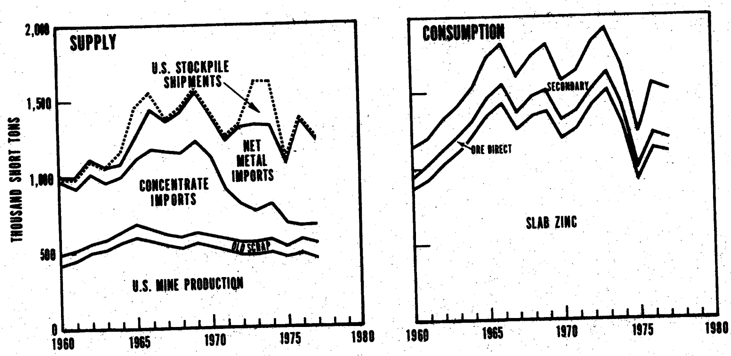


Figure 1.—Trends in supply and consumption in the United States.

tons. Consumption for brass and bronze was down 15%, followed by zinc-base alloy, down 5%. Consumption for galvanizing increased 9%; for zinc oxide, 9%; and for rolled zinc, 1%. The continuing decline in the amount of zinc used in diecastings by the automotive industry was an important factor in lowering consumption.

Secondary slab zinc production was 50,611 tons, 26% less than in 1976. Production of zinc dust from secondary materials was 39,674 tons, down slightly from that of 1976. Producer and consumer stocks fell consistently through the year to finish at 173,328 tons. No sales of zinc were made from the Government stockpile in 1977.

With a high stock position by the producers, weak demand, and a continued strong level of imports, zinc prices fell in May, October, and November by a total of 6.5 cents, so that by yearend producers were quoting 30.5 cents per pound for Prime Western Grade zinc. The average price for the year was 34.4 cents compared with 37 cents per pound in 1976. On the London Metal Exchange (LME) prices generally declined through the year to less than 25 cents per pound by yearend.

General imports of zinc in ores and concentrates were 26% over those of 1976. Major sources were Canada, Honduras, and Mexico. General imports of slab zinc were 576,736 tons, down 137,753 tons from those of 1976. Canada, Finland, Mexico, and Yugoslavia provided about one-half of the imports in 1977 compared with three-fifths in 1976. Imports from Yugoslavia dropped 88% from those of 1976. The European Economic Community provided 23% of U.S. imports of zinc metal, up from 19% in 1976.

Legislation and Government Programs.—On October 7, the President reaffirmed the major elements of the strategic and critical materials stockpile policy developed in 1976. The overall long-range goals will be reviewed at least annually and revised whenever appropriate. The goal for zinc was 1,313,000 tons. Total inventory in storage was 383,415 tons, and uncommitted inventory was 374,159 tons at the end of 1977.

A bill, H.R. 9911, was introduced in Congress to continue until June 30, 1981, the suspension of duties on zinc concentrates and waste and scrap as provided by Public Law 94-89. The bill had not passed by yearend.

The Commodity Futures Trading Commission approved trading of zinc futures contracts on the Commodity Exchange Inc. of New York. The zinc contract calls for delivery of 60,000-pound units of slabs weighing 40 to 60 pounds each with a purity of at least 99.99% zinc, which corresponds to Special High Grade zinc. Trading was expected to begin in February 1978.

The International Lead and Zinc Study Group (ILZSG) held its 21st session in Geneva, Switzerland, Sept. 12-16, 1977, 2 months earlier than usual, because of the uncertain international zinc situation. It was noted that until the zinc market recovered, producers would attempt to maintain zinc metal output at 1976-77 levels. Ireland became the 31st member of ILZSG. Earlier in the year ILZSG moved its headquarters from the United Nations in New York to London.

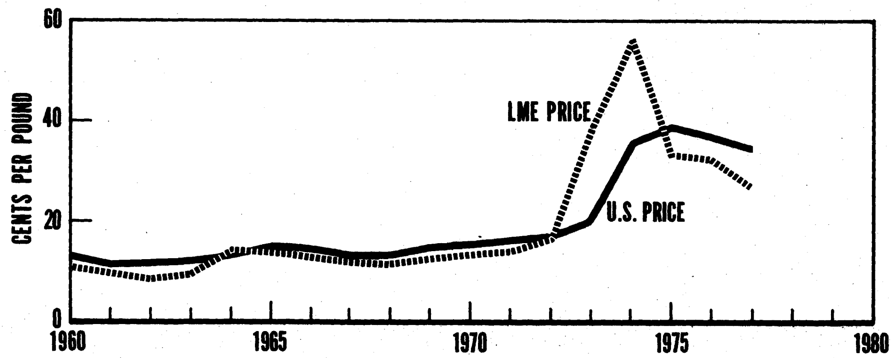


Figure 2.—Trends in average London Metal Exchange (LME) and domestic zinc prices.

DOMESTIC PRODUCTION

MINE PRODUCTION

U.S. mine production of zinc from 18 States was 449,620 tons, 7% below that of 1976. The major producing States were Tennessee (20%), Missouri (18%), New York (16%), Colorado (9%), and New Jersey (7%). Production in Idaho was down 33% compared with that of 1976, largely as the result of a prolonged labor strike.

Table 5 shows sources of zinc production in 1977 according to ore type. Zinc ore accounted for 59% of the total zinc production, followed by lead ore (19%), zinc-lead ore (16%), copper-zinc, copper-lead, and copper-lead-zinc ores (5%), and other ores, (1%).

The 25 leading U.S. zinc mines (table 6) accounted for 87% of the recoverable domestic zinc mined in 1977. The 10 leading mines accounted for 57% of the total U.S. mine production.

Tennessee was the foremost producer of zinc during 1977 and despite a 4-month strike at the Cities Service Co. Copperhill mine, production of zinc from mines within the State rose 10% above that of 1976. Seven mines produced zinc from zinc ores; and one mine, Copperhill, produced zinc from copper-zinc ore. Jersey Minière Zinc Co., a 60-40 joint venture of The New Jersey Zinc Co. and Union Minière, S.A., of Belgium, continued development of the Gordonsville and Stonewall mines. During its first full year of operation, production at the Elmwood mine increased to 3,000 tons of ore per day. New Jersey Zinc continued construction and development at its Lost Creek and Beaver Creek properties and began production at the Idol mine.

In eastern Tennessee, ASARCO Incorporated suspended mining operations at two mines and reduced production at the remaining two, thus reducing production to 62% of capacity. Production from the four mines totaled 41,620 tons of zinc compared with 42,700 tons in 1976. The zinc concentrate is used mainly for the production of zinc oxide at ASARCO's own plants in Ohio and Illinois. At the Young mill, construction was completed in April on a new concentrate drying and loading facility.

St. Joe Minerals Corp., in a joint venture with a subsidiary of Freeport Minerals Co., reported that significant zinc mineralization was encountered on its property near Carthage, Tenn. A shaft is being sunk to evaluate further the discovery. Detailed drilling to evaluate the potential of a large low-grade zinc prospect at Fountain Run, Ky., was also conducted by St. Joe during the year.

Zinc production as a coproduct from eight lead mines in Missouri declined 2% from that of 1976. The Buick mine near Boss, Mo., owned 50% each by Homestake Mining Co. and AMAX Inc., produced 176,788 tons of zinc concentrate from ore assaying 8.6% lead and 3.4% zinc. Ore reserves were given as 54 million tons assaying 7% lead and 2% zinc. The program to increase mine production to 1.8 million tons of ore annually through improved techniques continued through 1977.

At St. Joe Zinc Co.'s Balmat and Edwards mines in New York, production declined nearly 4% compared with the 1976 level. During 1977, 1.19 million tons of ore averaging 6.79% zinc was mined at the complex with the Balmat mine retaining its position as the Nation's largest zinc producer. The company stated that the decline in ore production resulted from optimizing the grade of concentrate produced and reducing unit operating costs through improved labor schedules.

In Colorado, zinc production from 13 mines was 40,267 tons, down 20% compared with that of 1976. Idarado Mining Co., owned 80.1% by Newmont Mining Co., treated 301,000 tons of ore grading 3.89% zinc, 2.22% lead, 0.42% copper, and 0.035 and 0.95 ounces of gold and silver per ton, respectively. Ore reserves were 3.4 million tons grading about 4.4% zinc. Resurrection Mining Co., wholly owned by Newmont Mining Corp., milled 186,000 tons of ore grading 8.13% zinc from the Leadville mine, which is managed by ASARCO. Ore reserves were 1.9 million tons grading 10.11% zinc and 5.01% lead. Homestake Mining Co. produced some coproduct zinc from its Bulldog silver mine near Creede. In December, New Jersey Zinc suspended zinc mining operations at its high-cost mine at Gilman, Colo.

Zinc mine production was reported from 21 mines in Idaho, where production during the year declined to just under 31,000 tons of zinc. At the Bunker Hill mine of The Bunker Hill Co., a wholly owned subsidiary of Gulf Resources & Chemical Corp., a 5-month labor strike resulted in a 42% reduction in crude ore production compared with 1976. Production from the Star-Morning unit area, owned 30% by Hecla Mining Co., increased about 4%. Proven and probable reserves of lead-zinc ore at these mines were 3.8 million tons containing 3.3% zinc and 2.4% lead. Ore grade of the Star mine averaged 7.8% zinc, 6.9% lead, and 4.0 ounces of silver per ton, all of which were higher than 1976 grade levels. Production from several veins was maintained throughout most of the year with principal production coming from the deeper levels of the mine. Preparation of new stoping areas on the 7,700-foot level assured adequate production for the next year. Lateral development continued at the 7,900-foot level. Hecla's wholly-owned Lucky Friday mine produced 182,412 tons of ore compared with 186,520 tons mined during 1976. Ore grade was 1.39% zinc and 10.57% lead, with 14.73 ounces of silver per ton. Calculated ore reserves at the end of 1977 were 510,000 tons compared with 475,000 tons at the end of 1976. Operating costs increased about 13%, compared with about a 5% increase during 1976. Development continued on the west end of the Lucky Friday vein on both the 4,050- and 4,250-foot levels. The main shaft was deepened to 262 feet below the 4,660-foot level. A new shaft, offset 550 feet from the existing main shaft, has been planned to increase hoisting capacity and provide access to a depth of 9,700 feet. Intermountain Mining Engineers, with equal participation by U.S. Antimony Corp., produced some zinc together with lead, silver, and gold from its recently rehabilitated Nabob mine located in the Pine Creek area of the Coeur d'Alene mining district.

Utah production of zinc from three mines was 17,759 tons, 21% less than that of 1976. Park City Ventures, a joint venture owned 60% by The Anaconda Company and 40% by ASARCO, mined 116,000 tons of ore at its leased lead-zinc-silver Ontario mine. Ore reserves at the Ontario mine were reported to be 1.1 million tons grading 9.9% zinc, 7.4% lead, and 6.2 ounces of silver per ton.

Zinc ore production from one mine in Virginia increased 18% over that of 1976. Piedmont Mineral Associates, a joint venture of Callahan Mining Corp. (49%) and New Jersey Zinc (51%), terminated its underground exploration program at the Cofer mine at Mineral, Va., but continued exploration for base metals on a reduced basis elsewhere in central Virginia.

Two mines produced zinc in Washington during the year compared with four in 1976. Bunker Hill's Pend Oreille mine, which was closed in June as a result of the labor strike at the Bunker Hill facility in Idaho, was subsequently placed on a care and maintenance basis pending improvement in the zinc market. Callahan Mining and its two partners terminated work on their Washington Zinc Unit, formerly known as the Van Stone mine; a new owner was being sought.

In Maine, mining operations were suspended in October at the Blue Hill joint venture, 60% owned by Kerr Addison, Ltd., and 40% by Kerramerican, Inc. Mine production during the year to the time of suspension amounted to 143,200 tons of ore that averaged 5.7% zinc and 1.1% copper. The mine openings were sealed with concrete, and all mine and plant equipment was prepared for storage.

Mine production of zinc in southwestern Wisconsin increased 3% over that of 1976 despite closure of one of the two operating mines earlier in the year. Exxon Company, U.S.A., a division of Exxon Corp., continued evaluating its large zinc-copper discovery near Crandon in northern Wisconsin. The deposit was reported to contain 70 million tons of ore grading 5% zinc and 1% copper, with lesser amounts of lead, gold, and silver. Eagle-Picher Industries, Inc., deferred opening its Elmo No. 3 and Crawhall mines pending improvement in the price of zinc.

Arizona zinc production from four mines was 4,380 tons, down 54% from that of 1976. Because of low copper prices Cyprus Mines Corp. shut down its Bruce mine near Bagdad, Ariz. The mine had about a 1-year reserve of ore remaining. Ore production up to the time of closure in July amounted to 40,710 tons grading 13.5% zinc and 3.97% copper and yielded concentrates containing 3,618 tons of zinc and 1,428 tons of copper.

Zinc production in Nevada increased 16% over that of 1976. As a consequence of the labor strike at its Kellogg, Idaho, facility, Bunker Hill curtailed exploration at the recently acquired Pan American mine near Pioche. Milling operations at the nearby Caselton concentrator, leased by Bunker Hill, were also suspended from July to December.

In Alaska, a joint venture of Houston Oil & Minerals Corp. and General Crude Oil Co. reported the discovery of significant lead-zinc mineralization in the Western Brooks Mountain range 80 miles north of Kotzebue. Preliminary drilling indicated some values ranging in excess of 8% lead and 14% zinc combined with cadmium and silver.

SMELTER AND REFINERY PRODUCTION

U.S. slab zinc production at 6 primary plants and 13 secondary plants was 500,756 tons in 1977, a decrease of 12% from that of 1976. Primary and secondary metal production at primary plants was 479,299 tons, for a capacity utilization of nearly 69%. The portion of domestic slab zinc production from domestic ore was 71%; from foreign ore, 19%; and scrap, 10%. Zinc produced from foreign ore decreased 19% from that of 1976, production from domestic ore decreased 7%, and from scrap, 26%. Producer stocks at the smelter decreased from 96,950 tons to 92,387 tons during the year.

Primary slab zinc produced at electrolytic refineries during 1977 decreased 9% compared with that of 1976 and was 47% of the total slab zinc produced. Zinc produced at retort plants was down 11% and comprised 43% of the total. Redistilled slab zinc from secondary materials produced at primary smelters decreased 23% and contributed 6% of the total; redistilled slab zinc at secondary smelters decreased 31% and comprised 4% of the total. Distribution of slab zinc production, by grades, was Prime Western, 56%; Special High Grade, 33%; High Grade, 9%; and Intermediate, 2%.

The new 350-ton-per-day acid plant at ASARCO's Corpus Christi, Tex., electrolytic zinc plant came onstream in March. About two-thirds of the concentrate came from ASARCO's mines or those of affiliated companies. The company's $26.3 million program aimed at modernizing the leaching and electrolyte purification systems and air quality controls was 20% complete by yearend. A labor strike at the El Paso, Tex., smelting complex interrupted the flow of zinc fume to the Corpus Christi refinery. Because of the poor outlook for zinc, ASARCO again deferred construction of a 180,000-ton-per-year zinc plant in Kentucky.

AMAX Zinc Co., Inc.'s Sauget, Ill., electrolytic zinc plant produced 66,100 tons of refined zinc compared wth 70,000 tons in 1976. Bunker Hill produced 52,000 tons of slab zinc in Idaho, down 48,000 tons from the previous year due to a 5-month strike, an area-wide flood, and a major power outage. Following settlement of the strike in September, production was resumed at 70% of capacity through yearend. During 1977, approximately 40% of Bunker Hill's zinc production was Special High Grade zinc and the remaining 60% was galvanizing grades and zinc alloys. Sales of zinc metals were handled by The Bunker Hill Sales Co. in Kellogg, Idaho. The company filed a petition in late 1975 for a judicial review of the Environmental Protection Agency (EPA) decision to disapprove the Idaho plan for control of sulfur dioxide emissions; in July 1977 the case was remanded to EPA for reconsideration. In August, the company completed construction on two tall smelter stacks to reduce sulfur dioxide pollution of the ambient air. In December, EPA filed a civil action against Bunker Hill for alleged failure to control the emission of particulate matter into the ambient air.

Construction continued on Jersey Minière's $97 million, 90,000-ton-per-year zinc plant at Clarksville, Tenn., scheduled for completion by late 1978. Concentrate from the Tennessee mines being developed by the partnership will be transported to the plant by river barge.

During 1977, St. Joe Zinc's production of slab zinc at its Monaca, Pa., smelter fell 18% to 134,907 tons. Zinc concentrates from the Balmat and Edwards mines comprised almost half of the smelter feed, with the balance being obtained from other domestic and foreign suppliers. St. Joe financed a $21.1 million pollution control project at the Monaca smelter through the issuance of pollution control revenue bonds. Approximately $4.6 million of the proceeds from the bond sale was expended during 1977. St. Joe expects to spend approximately $15.8 million over the next 3 years to reduce the level of sulfur oxide and particulate emissions. Construction began on the demonstration citrate unit at the St. Joe powerplant in Monaca, Pa., that supplies electricity to the electrothermic smelter. The unit, scheduled for completion in the fall of 1978, is designed to scrub sulfur dioxide from the coal-fired powerplant stack gas.

Secondary Zinc Smelters.—Zinc recovered from zinc-bearing scrap was 363,739 tons in 1977, a 2% decrease compared with that recovered in 1976. Zinc-base scrap accounted for 57% of the total compared with 59% in 1976; zinc recovered from copper-base scrap was 43% compared with 41% in 1976. Recovery of zinc from both new and old scrap declined from that of 1976. Zinc recovered from old scrap accounted for 25% of the total compared with 26% during 1976. Of the total zinc recovered from scrap, 25% was recovered as zinc metal, 58% as alloys (mostly brass and bronze), and 17% as compounds (mostly zinc oxide). Australian Mining & Smelting Ltd. bought Pacific Smelting Co., one of the largest secondary zinc plants in the United States.

Slag-Fuming Plants.-Slag-fuming plants processed hot and cold lead blast furnace slags and residues to produce zinc oxide fume. The oxide was either sold and used as oxide or sent to smelters and refineries for processing into metallic zinc. Three plants operated in 1977 as in 1976: ASARCO at El Paso, Tex., and East Helena, Mont., and Bunker Hill at Kellogg, Idaho.

Byproduct Sulfuric Acid.—In 1977, seven plants roasted zinc sulfide concentrates and produced sulfuric acid, with one plant operating solely to produce calcine for processing to zinc oxide or slab zinc. In 1977, production of byproduct sulfuric acid from zinc plants was 737,781 tons, down from 799,773 tons produced in 1976.

Zinc Dust.—Production of zinc dust increased 3% over that of 1976 to 47,594 tons in 1977. Zinc dust from distilled scrap accounted for 39,674 tons.

CONSUMPTION AND USES

In 1977, slab zinc consumption, at 1,101,765 tons, decreased 3% from that of 1976 in spite of higher automotive output and housing starts. Some of the loss of zinc consumption for die casting in the transportation industry was made up through increased use of galvanized steel or steel protected with a zinc-based coating. The zinc content of the ore used directly in galvanizing or compounds was 95,339 tons, down from 101,241 tons in 1976. The zinc content of secondary materials to make alloys, zinc dust, and compounds was 310,531 tons, up from 301,508 tons in 1976. Total consumption of zinc for all classes was 1,507,635 tons, a decrease of 2% from that of 1976.

Slab zinc used for galvanizing accounted for 436,998 tons (39%); zinc-base alloys, 404,691 tons (37%); brass products, 141,438 tons (13%); zinc oxide, 42,454 tons (4%); rolled zinc, 30,210 tons (3%); and other, 45,974 tons (4%).

Slab zinc consumption distributed by grade was Special High Grade, 543,047 tons (49%); High Grade, 100,302 tons (9%); Intermediate, 21,874 tons (2%); Brass Special, 111,483 tons (10%); Prime Western, 323,710 tons, (30%); and Remelt, 1,349 tons (0.1%). Consumption of all grades of slab zinc except Brass Special decreased from that of 1976.

Slab zinc consumed at rolling mills was 30,210 tons in 1977, an increase of 1% over that of 1976. Production of rolled zinc products decreased 7% to 27,932 tons. Strip and foil accounted for 77%. Exports of wrought zinc increased 18% to 2,681 tons, and imports decreased from 209 tons to 205 tons. Production of rolled zinc from scrap was 24,268 tons in 1977, yielding a total of 52,200 tons of rolled zinc during the year, compared with 54,504 tons in 1976.

The leading zinc-consuming States in 1977 were Illinois with 165,470 tons (15%); Ohio, 139,945 tons (13%); Pennsylvania, 131,019 tons (12%); New York, 117,194 tons, (11%); Michigan, 109,401 tons, (10%); and Indiana, 98,930 tons, (9%). Ohio ranked highest in galvanizing and Michigan was the leader in diecasting.

The Zinc Institute Inc. conducted a survey of 460 diecasters to determine the market distribution of the 418,319 tons of zinc die castings shipped by these companies in 1977. The results showed that automotive components accounted for 49.3% of the total; builders' hardware, 22.4%; domestic appliances, 5.4%; industrial, agricultural, and commercial machinery, 5.9%; electrical components, 9.3%; sporting goods and toys, 2.5%; scientific and professional equipment, 1.4%; sound and television equipment, 1.4%; and miscellaneous, 2.4%. Since inception of the survey in 1974, the data indicate that builders' hardware and electrical components increased their market share from 25.5% to 31.7%, while the share taken by domestic appliances and industrial, agricultural, and commercial machinery declined from 16.0% to 11.3%.

ZINC PIGMENTS AND SALTS

Production.—Production of zinc oxide in 1977, at 207,725 tons, increased 7% over that of 1976. Shipments were 1% higher than production. The source of domestic zinc oxide production was 54% from ore and concentrate (American process), 26% from slab zinc (French process), and 20% from secondary material. Total French-process zinc oxide, including that from remelt and scrap, was 33% of the total. Lead-free zinc oxide was produced at 13 plants in the United States, and leaded zinc oxide was produced at 1 plant.

Zinc sulfate production, at 38,818 tons from nine companies, showed an increase of 12% over that of 1976. Zinc sulfate production came from secondary material and from ore or intermediate products. Zinc chloride production from four companies was 13,913 tons; 14,007 tons was shipped.

St. Joe produced 50,201 tons of zinc oxide, down 4% from that of 1976, and ASARCO, with plants at Columbus, Ohio, and Hillsboro, Ill., produced about 32,000 tons, down 11% from that of 1976. New Jersey Zinc also produced zinc oxide from ores or concentrates, and slab zinc. Other major zinc oxide producers such as the Eagle-Picher, Hillsboro, Ill., plant and the Sherwin-Williams Co., Coffeyville, Kans., plant, used calcines, fume, and secondary materials as raw materials. New Jersey Zinc and St. Joe were the two largest of the six producers of French-process zinc oxide.

Consumption and Uses.—The apparent consumption of zinc oxide increased 5% in 1977 to about 224,000 tons. Analysis of domestic shipments by industry usage showed the largest consumers to be the rubber industry with 54% of the total; chemicals, 14%; photocopying, 11%; and paints, 7%. The use of zinc oxide increased for rubber, agriculture, and miscellaneous uses. Photocopying declined 3%, continuing the downward trend of recent years. Among miscellaneous uses, zinc oxide was used in floor coverings, fabrics, lubricants, plastics, and rayon manufacturing. Agriculture was the chief use for zinc sulfate with lesser amounts assigned to rayon, flotation reagents, and chemicals. Leaded zinc oxide was used in rubber, and lithopone was used mainly in paints. Most of the zinc chloride was used in soldering fluxes and batteries.

Prices.—List prices at the beginning of the year were 40 cents per pound for American-process, lead-free, pigment grade, 41.5 cents for French process, regular, 43 to 44 cents for electrophotographic grade, and 38 cents for zinc oxide, leaded, 12%. With the reduction in the price of zinc metal in May, U.S. producers lowered zinc oxide prices to 37.5 cents per pound for American-process zinc oxide, 39 cents for French-process, 40.5 to 41.5 cents for electrophotographic grade, and 35.5 cents for leaded zinc oxide. Again in October prices were lowered 1 cent per pound for all grades except leaded zinc oxide, which dropped 1.25 cents per pound. The price of zinc sulfate, granular monohydrate industrial, 36% zinc, bags in carload lots, was quoted at $24 to $26.50 per 100 pounds throughout the year. The price of technical-grade zinc chloride, 50% solution, in tank-car quantities, was quoted at $15.25 per 100 pounds in January and at $10 to $17.55 at yearend.

Foreign Trade.—Exports of zinc oxide increased 40% over those of 1976 to 6,771 tons, of which 4,043 tons was pigment grade. Canada and the Federal Republic of Germany received 71% of the total. Lithopone exports decreased 44% to 435 tons. Imports of all classes of zinc compounds increased in 1977 to a total of 30,154 tons, an 8% gain. As in 1976, zinc oxide was the major component of imports of zinc compounds. Mexico and Canada supplied 93% of the zinc oxide; other European Economic Community countries contributed most of the remainder.

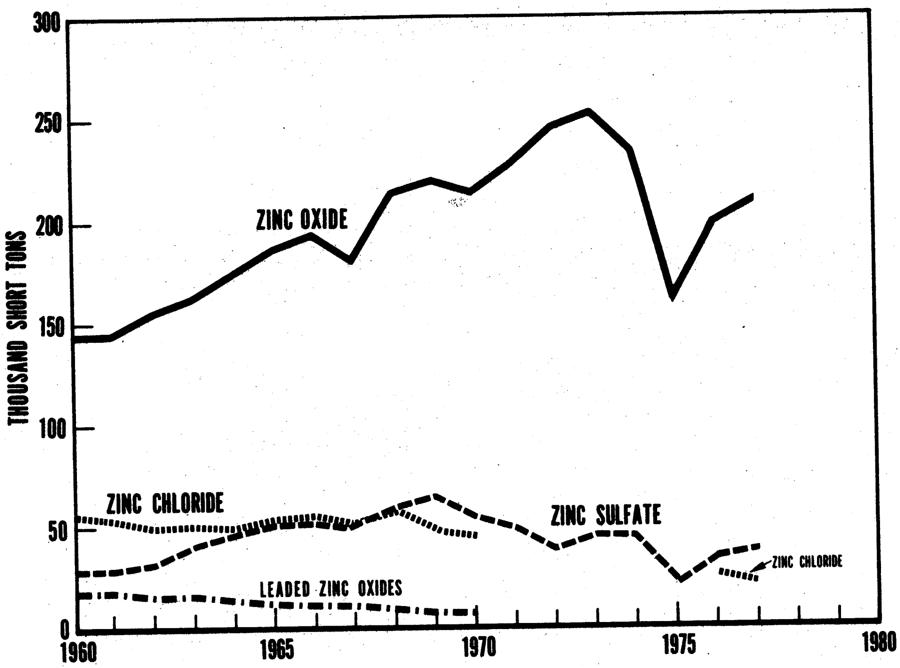


Figure 3.—Trends in shipment of zinc pigments.

STOCKS

Producer Stocks.—Stocks of slab zinc at producer plants at the beginning of the year were 96,950 tons, decreasing to 92,387 tons by yearend. Beginning with yearend 1977, producer stocks include stocks at plants, warehouses, and other locations, but continued to exclude stocks on consignment to consumers. The American Bureau of Metal Statistics Inc. (ABMS) reported that producer stocks at smelters dropped in the first quarter, increased in the second quarter, but by yearend showed a reduction of 26%.

Consumer Stocks.—Slab zinc inventories at consumer plants were 121,154 tons at the beginning of the year, but by yearend consumer stocks had dropped to 80,941 tons. In the first 6 months, consumer stocks declined to less than 90,000 tons, falling to the 1977 low of about 76,000 tons in November.

PRICES

Effective May 17, ASARCO lowered the price for Prime Western and High Grade zinc by 3 cents to 34 cents per pound, a move soon followed by the other producers. Special High Grade and Continuous Galvanizing Grade zinc were priced at 34.5 cents per pound. Producers cited the high rate of imports as the reason behind the price cuts. Foreign producers selling zinc in the United States matched the new U.S. list price.

National Zinc Co. took the lead on October 3 by lowering its price for Prime Western and High Grade zinc 2 cents to 32 cents per pound. Bunker Hill followed but cut the price to 31 cents per pound for all grades of zinc, thereby eliminating the normal premium pricing system. The remainder of the industry, however, reduced prices for Prime Western and High Grade zinc to 32 cents per pound, 32.25 cents for Controlled Lead, and 32.5 cents for Continuous Galvanizing Grade and Special High Grade zinc. Most producers reiterated their belief that increased foreign competition had forced the price reductions that were causing worker layoffs and production cuts.

St. Joe lowered its list price for all grades of zinc to 31 cents per pound effective November 1. All other United States and Canadian producers did the same except National Zinc, which reestablished the premium pricing system by posting a 0.5-cent-per-pound premium for Continuous Galvanizing Grade over Prime Western zinc. National's new prices became 30.5 cents for Prime Western and High Grade zinc, 30.75 cents for Controlled Lead Grade, and 31 cents per pound for Continuous Galvanizing Grade. By monthend, all producers were quoting these prices for U.S. sales.

In May, Cominco Ltd. announced a reduction in its European price to $700 per metric ton (31.8 cents per pound) from the previous price of $795 per metric ton (36.1 cents per pound), and most other European producers immediately followed. This price held until October when first the Australians reduced it to $630 per metric ton (28.6 cents per pound), and in November when other producers lowered it still further to $600 per metric ton (27.2 cents per pound). Weak market conditions and lower LME prices forced the move. Nonintegrated mine producers, who are paid for their concentrate depending on the list price of zinc metal, claimed the lower price could lead to mine closures.

On the LME, prices rose during the first quarter from £399 per metric ton (30.9 cents per pound) to £412 (32.1 cents per pound). Several producers had announced production cutbacks and absorbtion of some of the uncommitted North Korean zinc flowing to Europe. By August the LME price fell further to £295 (23.3 cents per pound) in the face of weak zinc demand. By yearend LME prices had leveled at about £290 (24.7 cents per pound). LME stocks dropped 27,172 tons during the year to 71,127 tons on December 30.

U.S. dealer prices for Special High Grade zinc were steady at about 35.3 to 35.8 cents per pound during the first quarter, but as LME quotes fell during the year, so did dealer prices. By yearend, dealers were quoting 28.5 to 28.8 cents per pound.

On December 20, the Lead-Zinc Producers Committee petitioned the U.S. International Trade Commission for temporary import relief in the form of a tariff-rate quota on excessive imports of slab zinc. The Committee suggested that for the first year of a 5-year period, higher import duties of an additional 7 cents per pound apply to imports in excess of 350,000 tons. Adjustments would be made in the next 4 years, depending on market conditions.

According to documents from the Australian Trade Practices Commission that became public in July, Australia's major lead and zinc producers were linked to an international cartel, including some producers in Europe and Canada. A trading concern, Blenden Pty., Ltd., had been organized to support zinc prices since 1965. News of the cartel's operations weakened LME prices at midyear.

FOREIGN TRADE

Exports of unwrought zinc and alloys were 1,228 tons in 1977, a 76% decrease from those of 1976. Canada received 37% of the exports; Guatemala, 11%; and Egypt, 9%. Wrought zinc and zinc alloy exports were 7,837 tons in 1977, of which 47% went to Canada and 29% to Belgium-Luxembourg. Exports of lead and zinc ores and concentrates decreased from 148,787 tons (gross weight) in 1976 to 128,056 tons in 1977 valued at $28.75 million.

General imports of zinc in ore were 122,808 tons in 1977, an increase of 26% over those of 1976. Canada supplied 48%, Honduras 14%, and Thailand, 13%. General imports of zinc metal were 576,736 tons, a decrease of 19% from those of 1976. Canada supplied 42% of the total; Belgium-Luxembourg and the Federal Republic of Germany, 7% each; and Zaire, 6%. Belgium-Luxembourg, Finland, France, the Federal Republic of Germany, Peru, and Spain increased their share of U.S. imports to 31% compared with 25% in 1976. Among the major suppliers, Canada, Italy, Mexico, and Yugoslavia accounted for a smaller share of the total compared with that of the previous year. In 1977, developed market economy countries provided 84% of the total, developing market economy countries, 15%; and centrally planned economy countries, 1%; compared with 78%, 17%, and 5%, respectively, in 1976.

Imports of concentrate for consumption were 120,457 tons in 1977, a decrease of 35,346 tons from those of 1976. Metal imports for consumption were 555,147 tons in 1977, 20% less than in 1976.

The U.S. Department of the Treasury placed an additional 4% ad valorem duty on imports of zinc metal from Spain to offset the rebate given to exporters by the Spanish Government.

There were no changes in the basic tariff rates in 1977 for slab zinc at 0.7 cent per pound, and zinc dust at 0.3 cent per pound. The duty rate for unwrought alloys of zinc, which include diecasting alloys, was 19% ad valorem.

WORLD REVIEW

Preliminary data from the World Bureau of Metal Statistics (WBMS)[2] indicated that the world consumption of slab zinc decreased 1.5% from that of 1976. Consumption in centrally planned economy (CPE) countries increased 1%, but Canadian consumption declined 8%; Australia, 7%; and Japan, 4%; Western Europe was unchanged. Bureau of Mines data showed world mine production up 5%, and slab zinc production up 2%, over 1976 levels. In mining, increases were especially noted in Bolivia, Canada, France, India, the Republic of Korea, Japan, Australia, Ireland, and Southwest Africa. Production in most other countries showed little change from the previous year. Mine production in the CPE countries gained 1%. Significant increases in primary smelter production occurred in Canada, Belgium, Japan, the Federal Republic of Germany, India, the Republic of South Africa, Finland, the Republic of Korea, the United Kingdom, and Turkey. Production in the United Kingdom recovered from the strike-affected 1976 level. Primary zinc metal production in CPE countries decreased less than 1% from that of 1976; total world production gained 2%. At yearend, many producers announced cutbacks in an attempt to avoid stock buildup and keep supply and demand in closer balance.

Smelter production of secondary zinc has been separated from primary zinc production where information is available, and is shown in table 40. Substantial quantities of secondary slab zinc are produced in France, Japan, the United States, and the U.S.S.R.

Stocks in LME warehouses decreased from 98,299 tons on January 1 to 71,127 tons by yearend. Most of the decrease occurred in the last half of the year, although by yearend stocks began to increase somewhat. Producer stocks worldwide increased 21% to about 912,000 tons during the year. European producers held about 278,000 tons and Japanese producers about 189,000 tons. Consumer stocks were about 183,000 tons, a decrease of 24%.[3]

World mine capacity was estimated to be 8.43 million tons of zinc annually. Major expansions occurred in Ireland and Spain; a number of mines closed in Canada and the United States.

World smelter capacity for slab zinc increased slightly to 7.71 million tons per year. Hindustan Zinc Ltd. expanded its plant in India by 30,000 tons. Asturiana de Zinc S.A. increased capacity at its San Juan de Nieva plant in Spain by 77,000 tons, and Cia. Mineira de Metais in Brazil by 14,000 tons. All new capacity was electrolytic. U.S. capacity was revised upward to 699,000 tons.

The European Zinc Institute, with headquarters in Paris, was formed during the year. Its purpose is to provide statistical information on zinc, especially production.

Australia.—About one-half of the zinc mined is sold as concentrate to smelters in Japan and Europe; about two-thirds of the zinc metal produced is exported, mainly to Southeast Asia, India, New Zealand, and the United States. Zinc production from the Mount Isa mine in Queensland, operated by Mount Isa Mines Ltd., was 111,900 tons, down from 123,800 tons in 1976. ASARCO will have 27,000 tons of concentrate from Mount Isa toll refined each year for the next 3 years at two Japanese smelters. The zinc content of the ore dropped from 6.7% in 1976 to 6.0% in 1977. Reserves at the mine increased to 63 million tons of ore assaying 6.5% zinc. At the Hilton lead-zinc-silver mine, underground diamond drilling continued in order to confirm ore reserves. The company began operating a 55-ton-per-day pilot plant at the McArthur River lead-zinc-silver deposit in the Northern Territory as part of the feasibility study.

At the West Coast mines in Tasmania, EZ Industries Ltd. produced 73,047 tons of zinc from ore grading 12.5% zinc. The company also treated zinc-rich tailings at the site. Reserves were given as 8.3 million tons of ore. An exploratory shaft was sunk at the Elura prospect near Cobar, New South Wales. Australian Mining & Smelting Ltd., through The Zinc Corp., Ltd., and New Broken Hill Consolidated Ltd., milled 2.3 million tons of ore grading 10.9% zinc and 8.2% lead. In addition, some mine tailings were treated.

EZ Industries produced 187,283 tons of

zinc metal and 6,980 tons of zinc dust from its Risdon smelter in the fiscal year ending June 30, 1977. Work began on a pollution abatement program to meet the requirements of the Tasmanian Environment Protection Act of 1974. Production at the Cockle Creek smelter of Sulfide Corporation Pty. Ltd., which operated at about 80% capacity most of the year, was about 64,000 tons. The Broken Hill Associated Smelters Pty. Ltd. produced about 37,500 tons of zinc in 1977 at its Port Pirie smelter.

St. Joe Minerals, Phelps Dodge Corp., and Australian Mining & Smelting began mine development at the Woodlawn zinc-lead-silver-copper deposit in New South Wales. The open pit mine, which was to be operational in mid-1978, was expected to produce 77,000 tons of zinc, 25,000 tons of lead, 15,000 tons of copper, and 880,000 ounces of silver annually.

Minerals, Mining and Metallurgy expanded its Blackwoods silver-lead-zinc mine in New South Wales to about 220,000 tons of ore per year.

Bolivia.—Corporación Minera de Bolivia (COMIBOL) produced 38,551 tons of zinc in 1977, up from 37,529 tons in 1976. The Matilde mine, the largest in Bolivia with a mill capacity of 1,100 tons per day, produced about 21,100 tons of zinc. The Medium Miners Association produced about 25,700 tons, mainly from the Porco mine and New Jersey Zinc's Huari-Huari mine. Low prices for zinc led to lower production and curtailment of expansion plans by medium and small miners.

Brazil.—Zinc production came from two open pit mines in the Vazante area of western Minas Gerais. Reserves at these deposits, which are mainly willemite and hemimorphite, are about 11 million tons grading 25% zinc. Cia. Mineira de Metais planned to upgrade the ore in a beneficiation process to produce about 40,000 tons per year of zinc oxide, with additional expansion to 80,000 tons by 1979. Exploration activities were centered in the Vazante-Paracatú region of Minas Gerais, where Noranda, New Jersey Zinc, and United States Steel Corp. have been surface drilling, in Bahia, and in western Rio de Janeiro State. In southwestern São Paulo State, St. Joe Minerals, among others, has uncovered large areas of sulfide mineralization. Paraibuna de Metais began construction of a 27,000-ton-per-year electrolytic zinc plant which will be operational in 1979.

Canada.—Mine output, at 1,433,223 tons from about 30 mines, was 14% higher than that of 1976. The average grade of ore processed assayed 5.3% zinc with an average recovery rate at the mill of 84%. Mill capacity at producing mines declined to 101,700 tons of ore per day because several mines closed.[4]

The leading producing provinces were Ontario with 28% of the total zinc production, followed by Northwest Territories, 16%; New Brunswick, 15%; British Columbia, 11%; and Quebec, 10%. Data for the principal producing mines are given in table 2. Slab zinc output was 545,521 tons, up 5% over that of 1976.

Texasgulf Inc. completed the transition from open pit to underground mining at the Kidd Creek mine in Timmins, Ontario. The program to increase mine capacity to 5 million tons of ore per year by the addition of the No. 2 underground mine and fourth concentrator circuit was delayed, with completion expected in 1978. Mattagami Lake Mines, Ltd. suspended all development work at Lyon Lake pending a more favorable market outlook for zinc. Willroy Mines Ltd. closed its Manitouwadge mine because it could not be operated economically, and sold a portion of the plant.

In New Brunswick, Brunswick Mining & Smelting Corp. Ltd. delayed the planned expansion of the No. 12 mine. The company experienced a total operating cost per ton of ore milled of $18.75,[5] compared with $20.06 in 1976 at its No. 12 underground mine. Labor productivity increased significantly, and zinc recovery at the mill improved from 75% in 1976 to 80% in 1977. With the beginning of underground mining, the cost was $13.30 at the open pit mine, up from $11.84 in 1976.

On Baffin Island in the Northwest Territories, Nanisivik Mines Ltd., in which Texasgulf has a 35% net-profits interest, completed the first full year of production at the Nanisivik mine. Texasgulf continued drilling at Izok Lake but made no plans to mine the deposit in view of its remote location and the poor world market for zinc. Drilling at the Great Slave Reef project, a joint venture between Western Mines Ltd. and DuPont of Canada Exploration Ltd., resulted in an increased reserve estimate of 3.8 million tons grading 9.1% zinc and 3.3% lead.

In Quebec, Mattagami milled less ore than in 1976 and the ore grade declined, but metal recovery improved. The Sullivan Mining Group Ltd. ceased operations in January. Orchan Mines Ltd. suspended operations in December at the Orchan

Table 2.—Principal Canadian zinc producers in 1977

Company	Mine	Mill capacity (thousand tons of ore per day)	Recoverable metals	Ore milled, (thousand tons per day)	Zinc content of ore, percent	Reserves: Ore (thousand tons)	Reserves: Zinc (percent)
British Columbia:							
Cominco Ltd	Sullivan	8,000	Zinc, lead	[1]2,419	3.8	55,000	[2]11.1
Do	H. B	1,200	do	394	3.9		
Northair Mines Ltd.[3]	Brandywine	300	Zinc, lead, gold, silver	79	2.0	338	4.1
Western Mines Ltd	Lynx and Myra	1,100	Zinc, lead, copper, silver, gold.	297	NA	1,460	7.5
Kam Kotia Mines Ltd	Silmonac	120	Zinc, lead, silver	17	6.1	NA	NA
Manitoba:							
Hudson Bay Mining & Smelting Co., Ltd	Flin Flon-Snow Lake area.	8,500	Zinc, lead, gold, silver, copper.	1,822	2.8	[4]17,500	2.7
Sherritt Gordon Mines, Ltd	Fox	3,000	Zinc, copper	890	1.9	7,000	2.1
Do	Ruttan	10,000	do	2,487	2.0	30,400	1.3
New Brunswick:							
Brunswick Mining & Smelting Corp. Ltd	Bathurst	10,000	Zinc, lead, silver, copper.	3,455	7.8	108,000	9.2
Heath Steele Mines Ltd	Newcastle	4,000	do	1,270	3.9	30,500	4.4
Nigadoo River Mines Ltd.[5]	Robertville	1,100	do	NA	NA	--	--
Newfoundland:							
ASARCO Incorporated	Buchans	1,250	Zinc, lead, silver	192	12.0	474	12.0
Teck Corp. Ltd.[6]	Daniel's Harbor	1,500	Zinc	543	9.4	3,200	8.4
Ontario:							
Texasgulf Canada Ltd	Kidd Creek	10,000	Zinc, lead, silver, copper.	3,636	7.3	108,000	5.0
Selco Mining Corp. Ltd	South Bay	500	Zinc, copper	182	9.9	460	10.8
Sturgeon Lake Mines Ltd	Sturgeon Lake	1,200	Zinc, lead, copper, silver.	423	[e]9.6	904	9.2
Mattabi Mines Ltd	Mattabi	3,000	do	1,030	8.4	5,100	7.2
Noranda Mines Ltd	Geco Division	5,000	do	1,754	2.6	25,600	3.7
Willroy Mines Ltd.[7]	Manitouwadge division.	1,600	do	63	NA	NA	NA

Quebec:							
Falconbridge Copper Ltd	Lake Dufault	1,500	Zinc, copper	430	3.7	4,000	2.9
Mattagami Lake Mines Ltd	Mattagami	3,850	Zinc, copper, silver, gold.	1,043	6.6	8,600	7.2
Orchan Mines Ltd	Garon Lake	1,900	Zinc, copper, silver	560	6.4	[8]3,800	5.3
Société Miniére Louvem Inc	Louvem	450	Zinc, copper	306	6.0	1,400	6.3
Lemoine Mines Ltd	Lemoine	300	do	122	10.6	430	10.0
Northwest Territory:							
Nanisivik Mines Ltd	Nanisivik	1,500	Zinc, lead, silver	580	13.3	7,000	14.1
Pine Point Mines Ltd	Pine Point	10,000	Zinc, lead	3,443	5.3	37,000	5.4
Yukon Territory:							
Cyprus Anvil Mining Corp	Faro	10,000	Zinc, lead, silver	3,435	4.9	41,000	5.6
United Keno Hill Mines Ltd	Elsa, Husky, No Cash.	500	do	91	NA	126	[e]1.2

[e]Estimate. NA Not available.
[1]Ore produced.
[2]Combined lead and zinc content.
[3]10 months to Nov. 30, 1977.
[4]Recoverable.
[5]Closed late 1977.
[6]Fiscal year ending Sept. 30, 1977.
[7]Closed March 1977.
[8]Includes the Norita and P. D. Divisions.

Source: Company Annual Reports and Department of Energy, Mine and Resources, Ottawa, Canada.

and Norita mines because of low zinc prices. Site preparation at the low-grade zinc-copper deposit acquired from Phelps Dodge of Canada was postponed until market conditions improved. Noranda formed a new company for the West Macdonald zinc deposit, Les Mines Gallen, but active development was to await improved market conditions.

In Manitoba, ore production by Hudson Bay Mining & Smelting Co., Ltd. was 258,563 tons more than that of 1976, but ore grade was lower. The Centennial mine was brought into full production in midyear, and the Westarm and White Lake mines were expected to be in production in early 1978. Construction began on a 3,800-ton-per-day mill adjacent to the Stall Lake mine to process ore from five mines in the Flin Flon-Snow Lake area. Production at the Ruttan mine of Sherritt Gordon Mines Ltd. decreased owing to operating problems and lower ore grade, but production at the Fox mine improved through higher ore grade and increased mill efficiency.

Zinc production in the Yukon Territory from the Faro mine of Cyprus Anvil Mining Corp. recovered to 112,385 tons, about double that of strike-affected 1976. Sales agreements with Japan and the Federal Republic of Germany for the concentrates expired in late 1977, but new ones were being negotiated. Pilot plant runs were made on ore from the Grum zinc-lead-silver deposit, in which Kerr Addison held a 60% interest. It was found that acceptable concentrates could be produced, and the company began site design and evaluation of the mining method.

Production at ASARCO'S Buchans mine in Newfoundland continued to decline, and the company stated that since no economic deposits were found, operations may end in 2 years.

Texasgulf Canada Ltd. produced 91,100 tons of zinc metal at its smelter in Ontario, down from 107,700 tons in 1976. The company installed labor-saving mechanical devices and began work on an automated cathode stripping line. Cominco Ltd. produced about the same amount as in 1976, 223,000 tons, at Trail, British Columbia. The company announced plans to increase plant capacity to 300,000 tons of zinc through modernization over the next 3 years. Canadian Electrolytic Zinc, at its Valleyfield, Quebec, plant, produced 155,550 tons of metal in 1977 compared with 125,800 tons in 1976. Hudson Bay Mining & Smelting Co., Ltd., produced 75,910 tons of zinc.

Canadian zinc reserves on January 1, 1977, were given as 30 million tons at the producing mines and deposits under development, with the Provinces of New Brunswick and Ontario containing about one-half of the total.

Greenland.—Production of ore by Vestgron Mines Ltd. declined 8% to 610,000 tons grading 15.1% zinc because of a 6-week strike. Exploration uncovered an amount of new ore approximately equal to production. Ore reserves at yearend totaled 3.6 million tons grading 12.4% zinc and 4.6% lead.

Honduras.—Production from the El Mochito mine of Rosario Resources Corp. was 359,216 tons yielding 29,257 tons of zinc in concentrates. Reserves in all ore bodies of the mine were 6.5 million tons averaging 8.2% zinc and 4.9% lead. Ore reserves increased as a result of development work in the San Juan orebody, which was to contribute to production in 1978. The mill was also being expanded.

Ireland.—Tara Mines Ltd. commenced operation of its concentrator at the Navan zinc-lead mine. A total of 789,700 tons of ore grading 9.9% zinc and 2.0% lead was treated yielding 71,200 tons of zinc and 10,700 tons of lead in concentrates. Mining was interrupted by a 6-week strike in the fourth quarter with the result that 58% of mill feed came from stockpile. Ore reserves total about 67 million tons grading 11% zinc and 2.4% lead. New Jersey Zinc announced it would study the feasibility of a 110,000-ton-per-year zinc smelter to process the Navan concentrate.

Irish Base Metals, a subsidiary of Northgate Exploration Ltd., treated 616,388 tons of ore from the Tynagh mine, County Galway. The ore grade was 3% zinc and 3.6% lead, with some silver and copper. Metallurgical recovery of zinc was 81% compared with 77% in 1976. Direct operating costs per ton of ore mined during 1977 were $14.74, compared wth $12.02 in 1976. Ore reserves were given at 1.5 million tons assaying 4.2% lead, 3.3% zinc, 0.2% copper, and 1 ounce of silver per ton. Almost 700,000 tons of material was excluded from reserve estimates because the zones were reevaluated and found to be uneconomical. The company stated that operations at Tynagh were unlikely to continue beyond 1979.

Mogul of Ireland, in which Kerr Addison has a 75% interest, mined 931,000 tons of ore grading 6.7% zinc and 2.5% lead. Operating costs increased 21% over those of 1976, mainly for power, transportation, and labor. Metal recovery of zinc was 87%. Ore reserves after dilution were 5.1 million tons grading 5.4% zinc and 2.7% lead.

Japan.—An increased stockpile program was initiated by the Metallic Minerals Stockpile Association to buy an additional 100,000 tons of zinc. When the program is completed in February 1978, the total metal purchased will be 122,000 tons of zinc. Falling prices allowed the increased purchase.

Dowa Mining Co. Ltd. began the development of the Ezuri mine with reserves of 3 million tons of ore grading 10.1% zinc, 3.3% lead, and smaller amounts of copper, silver, and gold. Initial production in 1979 will be 10,000 tons of ore per month.

Sumitomo Metal Mining Co. Ltd. completed a plant to extract crude zinc oxide from flue dust for use in its Imperial smelting furnace. Nisso Smelting Co., Ltd. began to process only zinc residues from steel plants. Toho Zinc Co. Ltd. announced plans to recover more than 22,000 tons of zinc per year from zinc leach residue using the jarosite process. A plant to process the residue was being constructed at the Annaka zinc refinery. Toho also began construction of a plant at its Chigirishima lead refinery to produce 4,000 tons of distilled zinc per year from the lead slag. Toho will be using a process already in operation at the Tamioka plant of Mitsui Mining & Smelting Co. Ltd.

Japan imported 29,680 tons of zinc from North Korea in 1977; that country used zinc in settlement for imported material from Japan. Japan exported 77,278 tons of refined zinc. Of the million tons of imported concentrate, Canada supplied 30%; Peru, 31%; Australia, 21%; and the Republic of Korea, 5%.

Nicaragua.—Neptune Mining Co., owned 51.8% by ASARCO, treated 230,672 tons of ore averaging 9.1% zinc and 0.8% lead. Reserves were estimated at 970,000 tons grading 5.8% zinc, and 0.8% lead, with lesser amounts of copper, silver, and gold.

Peru.—Empresa Minera del Centro del Perú (Centromin) accounted for 49% of the country's zinc production. Other principal zinc-producing mines were San Ignacio, 47,300 tons; Sta. Luisa, 32,600 tons; Huaron, 28,200 tons; Volcan, 22,300 tons; and Atacocha, 21,100 tons. Basic engineering work began on the construction of a 110,000-ton-per-year zinc refinery to be built at Cajamarquilla.

Cia. Minera del Madrigal, a division of Homestake Mining, milled 286,708 tons of copper-lead-zinc ore to produce 20,158 tons of zinc concentrate. Ore reserves totaled 1 million tons grading 5.4% zinc, 2.3% lead, and 1.2% copper. ASARCO, through Northern Peru Mining Corp., produced 9,100 tons of zinc from the Quiruvilca mine.

South Africa, Republic of.—Phelps Dodge Corp. reached an agreement with Gold Fields of South Africa Ltd. for the development of the Broken Hill deposit near Aggeneys in northern Cape Province. Gold Fields will manage the project, which is expected to cost about $191 million. Beginning in mid-1980, the annual production from the mine was expected to be about 99,000 tons of lead, 20,000 tons of zinc, and byproduct copper and silver.

Anglo American Corp. of South Africa took a 45% interest in the Gamsberg project, with Newmont Mining Corp. and O'okiep Copper Co. Ltd. owning equally the remaining 55%. Reserve estimates were expanded to 146 million tons grading 7.1% zinc and 0.6% lead. Drilling was to continue at the site, but development of the ore body was deferred because of the depressed zinc market.

South-West Africa, Territory of.—At the Tsumeb mine, Tsumeb Corp. Ltd. mined and milled 490,211 tons of ore grading 2.0% zinc, 7.8% lead, and 4.7% copper, about the same as in 1976. Zinc in concentrates was 1,200 tons. As deeper ore was mined, the lead content decreased. Ore reserves at the mine at yearend were estimated at 4.9 million tons containing 7.1% lead, 4.4% copper, and 1.9% zinc. Open pit mining will give way to underground operations at the Rosh Pinah mine of Imcor Zinc (Pty.) Ltd. Exploration proved a reserve of over 1 million tons grading 8.1% zinc and 2.3% lead.

A small amount of zinc concentrate was produced and stockpiled by Johnnies' Otjihase Mining Company (Pty.) Ltd. from its copper mine near Windhoek.

Spain.—The Rubiales zinc-lead mine of Exploración Minera Internacional España, S.A. began operations. Cominco Europe NV is the major stockholder with 47.48%. The underground mine has reserves of about 12 million tons grading 8.1% zinc and 1.5% lead, and a capacity of 2,750 tons of ore per day. Both the zinc and lead concentrates are smelted in Spain. Cia. Andaluza de Piritas continued construction work on its open pit mine where reserves were estimated at 45 million tons of pyrite ore grading 3.3% zinc, 1.7% lead, and lesser quantities of copper, silver, and gold, with an additional 35 million tons of ore overlying the pyrite ore body. A small pilot plant has been operating for a year to provide design data for the mill.

Thailand.—In July, the Thai Government and Thai Zinc, Ltd., signed an agreement under which Thai Zinc will receive a concession for the Mae Sot zinc deposit. Thai

Zinc was expected to have its smelter near Tak operational in 1980.

Zambia.—Nchanga Consolidated Copper Mines Ltd. may start operations at the Star mine if the oxide ore can be suitably treated in the Waelz kilns. The company began recovering lead and zinc from smelter waste products at Kabwe that have been accumulating from the Imperial smelting furnace.

TECHNOLOGY

A paper by researchers at EZ Industries and New Jersey Zinc described a process tested on a pilot scale at Risdon, Australia, in which willemite ore was leached and neutralized in a manner that avoided the formation of a gelatinous material. The results of the program demonstrated that deposits of oxidized ore, which have been used to only a limited extent or not at all, can become commercial sources of zinc. The electrolytic plant to be constructed at Tak, Thailand, will be based on this process to use hemimorphite-smithsonite ore.[6] The Kivcet CS shaft furnace pilot plant for simultaneous smelting of lead and zinc has demonstrated that the process is ready for industrial-scale application in the U.S.S.R. The zinc can be recovered as zinc oxide or as zinc metal that would require subsequent refining. Some of the advantages given for the process include reduced volumes of waste gas, improved environmental control, and allowances of the concentrator at the mine to achieve higher lead and zinc recovery.[7]

With the growth in the electrolytic process for the production of zinc in the last 20 years, there has been increased emphasis on methods for the economical treatment of residues to recover more zinc. Methods currently in use include the jarosite, goethite, hematite, and ferric oxide processes. For concentrates with 8% to 10% iron, zinc recoveries could be as high as 95% to 97% using one of these processes, compared with about 87% previously.[8]

A laboratory study has shown the chemical and economic feasibility of recovering zinc from mine water by an ion exchange-precipitation technique. Total operating and capital costs were estimated to be 0.316 cent per pound of zinc recovered, which was considered to be about the break-even point.[9]

The Energy Research and Development Administration (ERDA) sponsored work on the production of clean liquid and gaseous fuels from coal extracts and subbituminous coals using a zinc halide as the cracking catalyst. A bench-scale hydrocracker using zinc chloride as the catalyst successfully converted about 40% of the coal to distillates boiling in the gasoline range.[10]

At the Rolla Metallurgy Research Center of the Federal Bureau of Mines, a process was developed for the high recovery of zinc from pelletized electric furnace flue dust (PEFD). The PEFD would be compatible with the mixture of sintered zinc oxide and coke fed to commercial vertical retort furnaces.[11]

Comprehensive coverage of zinc-related investigations and an extensive review of current world literature on the uses of zinc and its products are contained in bimonthly issues of the 1977 Zinc Abstracts published by the Zinc Institute Inc.

Progress reports of the projects supported by the International Lead and Zinc Research Organization, Inc. (ILZRO) are released annually in the ILZRO Research Digest.

---

[1]Physical scientists, Division of Nonferrous Metals.

[2]World Bureau of Metal Statistics (London). World Metal Statistics. V. 29, No. 5, August 1977, pp. 91, 93.

[3]International Lead and Zinc Study Group. Lead and Zinc Statistics. Monthly Bull., v. 17, No. 6, June 1977, pp. 6-7, 23.

[4]Canadian Mining Journal. Canadian Mineral Survey 1977. V. 99, No. 2, February 1978, pp. 70-75.

[5]Where necessary, 1977 values have been converted from Canadian dollars (Can$) to U.S. dollars at the rate of CAN$1.06=US$1.00.

[6]Wood, J. T., P. L. Kern, and N. C. Ashdown. Electrolytic Recovery of Zinc From Oxidized Ores. J. Metals, v. 29, No. 11, November 1977, pp. 7-11.

[7]Mueller, E. How KIVCET CS Shaft Furnace Simultaneous Smelts Pb-Zn. World Min., v. 30, No. 4, April 1977, pp. 46-49, 99.

[8]Gordon, A. R. Improved Use of Raw Materials, Human and Energy Resources in the Extraction of Zinc. Ch. in Advances in Extractive Metallurgy 1977, ed. by J. J. Jones. Internat. Symp. Inst. of Min. and Met., London, Apr. 18-10, 1977, pp. 153-160.

[9]Gilmore, A. J. The Recovery of Zinc From a Mine Water Containing Small Amounts of Alkali and Heavy Metals. CIM Bull., v. 70, No. 780, April 1977, pp. 142-146.

[10]Zielke, C. W., W. A. Parker, M. Pell, and R. T. Struck. Zinc Halide Hydrocracking Process for Distillate Fuels From Coal. Conoco Coal Development Co. Rept. FE-1743-33, Feb. 20, 1977, 61 pp; Available from National Technical Information Service, Springfield, Va.

[11]Higley, L. W., Jr., and M. M. Fine. Electric Furnace Steelmaking Dust-A Zinc Raw Material. BuMines RI 8209, 1977, 15 pp.

Table 3.—Mine production of recoverable zinc in the United States, by State

(Short tons)

State	1973	1974	1975	1976	1977
Arizona	8,427	9,699	8,655	9,501	4,380
California	20	8	206	170	2
Colorado	58,339	49,489	48,460	50,621	40,267
Idaho	46,107	39,469	40,926	46,586	30,998
Illinois	5,250	4,104	W	W	W
Kentucky	273	--	41	59	--
Maine	19,640	10,425	8,318	7,810	7,269
Missouri	82,350	91,987	74,867	83,530	81,689
Montana	73	136	110	64	79
Nevada	--	3,405	5,496	1,438	1,672
New Jersey	33,027	32,848	31,105	33,767	33,464
New Mexico	12,327	13,784	11,015	W	W
New York	81,455	93,077	76,612	73,671	70,839
Pennsylvania	18,857	20,288	21,090	22,280	22,825
Tennessee	64,172	85,671	83,293	82,512	90,438
Utah	16,800	12,619	19,640	22,481	17,759
Virginia	16,683	17,195	15,151	11,241	13,272
Washington	6,378	6,909	W	W	5,572
Wisconsin	8,672	8,737	W	W	W
Other States	--	23	24,370	38,782	29,095
Total	478,850	[1]499,872	469,355	484,513	449,620

W Withheld to avoid disclosing company proprietary data, included with "Other States."
[1]Data do not add to total shown because of independent rounding.

Table 4.—Mine production of recoverable zinc in the United States, by month

(Short tons)

Month	1976	1977
January	40,404	38,642
February	41,632	40,070
March	42,862	40,390
April	41,199	39,693
May	41,733	38,714
June	41,112	38,284
July	39,033	32,365
August	37,165	37,151
September	40,499	36,262
October	40,507	37,285
November	39,573	35,447
December	38,794	35,317
Total	484,513	449,620

Table 5.—Production of zinc and lead in the United States in 1977, by State and class of ore, from old tailings, etc., in terms of recoverable metals

(Short tons)

State	Zinc ore: Gross weight (dry basis)	Zinc ore: Zinc content	Zinc ore: Lead content	Lead ore: Gross weight (dry basis)	Lead ore: Zinc content	Lead ore: Lead content	Zinc-lead ore: Gross weight (dry basis)	Zinc-lead ore: Zinc content	Zinc-lead ore: Lead content
Arizona	--	--	--	--	--	--	--	--	--
California	--	--	--	--	--	--	--	--	--
Colorado	159,861	11,767	1,758	1,229	--	23	482,937	17,042	12,979
Idaho	9,680	496	12	185,872	2,186	18,609	764,033	27,966	27,879
Maine	--	--	--	--	--	--	--	--	--
Missouri	--	--	--	8,925,602	81,689	500,178	--	--	--
Montana	--	--	--	2,012	2	15	--	--	--
Nevada	300	2	6	100	1	4	104,679	1,668	719
New Jersey	207,052	33,464	--	--	--	--	--	--	--
New York	1,194,510	70,839	2,778	--	--	--	--	--	--
Pennsylvania	584,274	22,825	--	--	--	--	--	--	--
Tennessee	3,744,422	88,669	--	--	--	--	--	--	--
Utah	--	--	--	--	--	--	339,638	17,759	10,746
Virginia	541,875	13,272	2,203	--	--	--	--	--	--
Washington	--	--	--	--	--	--	153,595	5,570	1,200
Other States[1]	655,729	24,810	3,421	150	--	7	--	--	--
Total	7,097,703	266,144	10,178	9,114,965	83,878	518,836	1,844,882	70,005	53,523
Percent of total zinc-lead	--	59	2	--	19	87	--	16	9

State	Copper-zinc, copper-lead, and copper-zinc-lead ores: Gross weight (dry basis)	Copper-zinc, copper-lead, and copper-zinc-lead ores: Zinc content	Copper-zinc, copper-lead, and copper-zinc-lead ores: Lead content	All other sources[2]: Gross weight (dry basis)	All other sources[2]: Zinc content	All other sources[2]: Lead content	Total: Gross weight (dry basis)	Total: Zinc content	Total: Lead content
Arizona	40,710	4,364	--	46,360,681	16	318	46,401,391	4,380	318
California	--	--	--	4,240	2	3	4,240	2	3
Colorado	300,750	10,286	5,648	217,206	1,172	2,586	1,161,983	40,267	22,994
Idaho	--	--	--	571,995	350	758	1,531,580	30,998	47,258
Maine	143,177	7,269	178	--	--	--	143,177	7,269	178
Missouri	--	--	--	--	--	77	8,925,602	81,689	500,255
Montana	--	--	--	10,238	77	91	12,250	79	106
Nevada	--	--	--	1,278,032	1	14	1,383,111	1,672	743
New Jersey	--	--	--	--	--	--	207,052	33,464	--
New York	--	--	--	--	--	--	1,194,510	70,839	2,778
Pennsylvania	--	--	--	--	--	--	584,274	22,825	--
Tennessee	1,250,130	1,769	--	--	--	--	4,994,552	90,438	--
Utah	--	--	--	--	--	--	339,638	17,759	10,746
Virginia	--	--	--	--	--	--	541,875	13,272	2,203
Washington	--	--	--	39,805	2	1	193,400	5,572	1,201
Other States[1]	--	--	--	2,356,034	4,285	280	3,011,913	29,095	3,708
Total	1,734,767	23,688	5,826	50,838,231	5,905	4,128	70,630,548	449,620	592,491
Percent of total zinc-lead	--	5	1	--	1	1	--	100	100

[1]Other States includes Illinois, New Mexico, Oklahoma, and Wisconsin.

[2]Lead and zinc recovered from copper, gold, silver, and fluorspar ores, and from mill tailings and miscellaneous cleanups.

Table 6.—Twenty-five leading zinc-producing mines in the United States in 1977, in order of output

Rank	Mine	County and State	Operator	Source of zinc
1	Balmat	St. Lawrence, N.Y	St. Joe Zinc Co	Zinc ore.
2	Buick	Iron, Mo	AMAX Lead Co. of Missouri.	Lead ore.
3	Sterling	Sussex, N.J	The New Jersey Zinc Co	Zinc ore.
4	Friedensville	Lehigh, Pa	do	Do.
5	Elmwood	Smith, Tenn	do	Do.
6	Star Unit	Shoshone, Idaho	The Bunker Hill Co. and Hecla Mining Co.	Lead, lead-zinc ore.
7	Young	Jefferson, Tenn	ASARCO Incorporated	Zinc ore.
8	Ground Hog	Grant, N. Mex	do	Do.
9	New Market	Jefferson, Tenn	do	Do.
10	Austinville and Ivanhoe.	Wythe, Va	The New Jersey Zinc Co	Do.
11	Immel	Knox, Tenn	ASARCO Incorporated	Do.
12	Bunker Hill	Shoshone, Idaho	The Bunker Hill Co	Lead-zinc ore.
13	Eagle	Eagle, Colo	The New Jersey Zinc Co	Zinc ore.
14	Leadville	Lake, Colo	ASARCO Incorporated	Lead-zinc ore.
15	Magmont	Iron, Mo	Cominco American Inc	Lead ore.
16	Idarado	Ouray, and San Miguel, Colo.	Idarado Mining Co	Copper-lead-zinc ore.
17	Jefferson City	Jefferson, Tenn	The New Jersey Zinc Co	Zinc ore.
18	Ontario	Summit, Utah	Park City Ventures	Lead-zinc ore.
19	Burgin	Utah, Utah	Kennecott Copper Corp	Do.
20	Edwards	St. Lawrence, N.Y	St. Joe Zinc Co	Zinc ore.
21	Blue Hill	Hancock, Maine	Kerramerican Inc	Copper-zinc ore.
22	Ozark	Reynolds, Mo	Ozark Lead Co	Lead ore.
23	Brushy Creek	do	St. Joe Zinc Co	Do.
24	Shullsburg	LaFayette, Wisc	Eagle-Picher Industries, Inc.	Zinc ore.
25	Pend Oreille	Pend Oreille, Wash	The Bunker Hill Co	Lead-zinc ore.

Table 7.—Primary and redistilled secondary slab zinc produced in the United States[1]

(Short tons)

	1973	1974	1975	1976	1977
Primary:					
From domestic ores	399,119	346,993	307,959	381,872	355,174
From foreign ores	184,360	208,195	130,092	116,983	94,971
Total	583,479	555,188	438,051	498,855	450,145
Redistilled secondary	83,187	78,535	57,886	r68,555	50,611
Total (excludes zinc recovered by remelting)	666,666	633,723	495,937	r567,410	500,756

rRevised.
[1]Excludes processed zinc from the General Services Administration (GSA).

Table 8.—Distilled and electrolytic zinc, primary and secondary, produced in the United States, by method of reduction

(Short tons)

Method of reduction	1973	1974	1975	1976	1977
Electrolytic primary	211,921	227,430	232,059	257,624	235,640
Distilled	371,558	327,758	205,992	241,231	214,505
Redistilled secondary:					
At primary smelters	67,758	56,342	34,931	37,624	29,154
At secondary smelters	15,429	22,193	22,955	r30,931	21,457
Total	666,666	633,723	495,937	r567,410	500,756

rRevised.

Table 9.—Distilled and electrolytic zinc, primary and secondary, produced in the United States, by grade

(Short tons)

Grade	1973	1974	1975	1976	1977
Special High	275,665	277,024	242,128	234,171	166,685
High	25,900	16,912	18,913	31,378	42,433
Intermediate	r6,468	r8,868	r8,590	r10,489	9,184
Brass Special	r1	r482	(1)	(1)	(1)
Prime Western	r358,632	r330,437	r226,306	r291,372	282,454
Total	666,666	633,723	495,937	r567,410	500,756

rRevised.
1Revised to zero.

Table 10.—Primary slab zinc produced in the United States, by State where smelted

(Short tons)

State	1973	1974	1975	1976	1977
Idaho	98,321	92,321	92,300	100,694	60,577
Illinois	26,616	55,527	55,337	68,206	64,374
Oklahoma	77,819	43,187	35,071	22,402	44,198
Pennsylvania	250,752	240,891	152,280	218,829	214,505
Texas	129,971	123,262	103,063	88,724	66,491
Total	583,479	555,188	438,051	498,855	450,145

Table 11.—Annual slab zinc capacity of primary zinc plants in the United States in 1977

Type of plant	Plant location	Slab zinc capacity (short tons)
Electrolytic plants:		
Amax Zinc Co., Inc	Sauget, Ill	84,000
ASARCO Incorporated	Corpus Christi, Tex	108,000
The Bunker Hill Co	Kellogg, Idaho	109,000
National Zinc Co	Bartlesville, Okla	56,000
Vertical-retort plants:		
The New Jersey Zinc Co	Palmerton, Pa	120,000
St. Joe Zinc Co	Monaca, Pa	222,000

Table 12.—Secondary slab zinc plants, by group capacity, in the United States in 1977

Company	Plant location	Slab zinc capacity[e] (short tons)
Arco Alloys Corp	Detroit, Mich	
ASARCO Incorporated	Trenton, N.J	
Belmont Smelting & Refining Works	Brooklyn, N.Y	
W. J. Bullock, Inc	Fairfield, Ala	
T. L. Diamond & Co., Inc	Spelter, W. Va	
Gulf Reduction Co	Houston, Tex	
Hugo Neu-Proler Co	Terminal Island, Calif	
Illinois Smelting & Refining Co	Chicago, Ill	1 50,000
H. Kramer & Co	do	
New England Smelting Works, Inc	West Springfield, Mass	
Pacific Smelting Co	Torrance, Calif	
Peerless Alloy Inc	Denver, Colo	
Prolerized Schiabo Neu Co	Jersey City, N.J	
S-G Metals Industries Inc	Kansas City, Kans	

eEstimate.
1Includes capacity at Proler International Corp., Houston, Tex., which did not produce slab zinc in 1977.

Table 13.—Stocks and consumption of new and old zinc scrap in the United States in 1977

(Short tons, zinc content)

Class of consumer and type of scrap	Stocks Jan. 1	Receipts	Consumption: New scrap	Consumption: Old scrap	Consumption: Total	Stocks Dec. 31
Smelters and distillers:						
New clippings	322	1,306	1,377	--	1,377	251
Old zinc	457	10,418	--	9,856	9,856	1,019
Remelt zinc	678	2,452	2,730	--	2,730	400
Engravers' plates	93	926	--	872	872	147
Rod and die scrap	1,382	8,658	--	9,600	9,600	440
Diecastings	[r]1,576	18,520	--	18,838	18,838	1,258
Fragmentized diecastings	886	9,739	--	10,326	10,326	299
Remelt die-cast slab	487	14,584	--	14,640	14,640	431
Skimmings and ashes	[r]10,690	41,722	40,008	--	40,008	12,404
Sal skimmings	44	881	879	--	879	46
Die-cast skimmings	1,491	7,705	6,505	--	6,505	2,691
Galvanizers' dross	19,689	54,527	48,446	--	48,446	25,770
Flue dust	425	8,694	8,545	--	8,545	574
Chemical residues	--	3,009	3,009	--	3,009	--
Other	4	551	555	--	555	--
Total	[r]38,224	183,692	112,054	64,132	176,186	45,730
Chemical plant, foundries, and other manufacturers:						
New clippings	--	--	--	--	--	--
Old zinc	9	28	--	26	26	11
Rod and die scrap	8	93	--	81	81	20
Diecastings	39	2,086	--	2,099	2,099	26
Skimmings and ashes	3,052	5,041	4,523	--	4,523	3,570
Sal skimmings	1,002	4,694	3,838	--	3,838	1,858
Die-cast skimmings	--	469	--	--	--	469
Flue dust	[r]413	6,108	6,108	--	6,108	413
Chemical residues	2,966	12,557	9,805	--	9,805	5,718
Other	[r]500	6,161	6,161	--	6,161	500
Total	[r]7,989	37,237	30,435	2,206	32,641	12,585
All classes of consumers:						
New clippings	322	1,306	1,377	--	1,377	251
Old zinc	466	10,446	--	9,882	9,882	1,030
Remelt zinc	678	2,452	2,730	--	2,730	400
Engravers' plates	93	926	--	872	872	147
Rod and die scrap	1,390	8,751	--	9,681	9,681	460
Diecastings	[r]1,615	20,606	--	20,937	20,937	1,284
Fragmentized diecastings	886	9,739	--	10,326	10,326	299
Remelt die-cast slab	487	14,584	--	14,640	14,640	431
Skimmings and ashes	[r]13,742	46,763	44,531	--	44,531	15,974
Sal skimmings	1,046	5,575	4,717	--	4,717	1,904
Die-cast skimmings	1,491	8,174	6,505	--	6,505	3,160
Galvanizers' dross	19,689	54,527	48,446	--	48,446	25,770
Flue dust	[r]838	14,802	14,653	--	14,653	987
Chemical residues	2,966	15,566	12,814	--	12,814	5,718
Other	[r]504	6,712	6,716	--	6,716	500
Total	[r]46,213	220,929	142,489	66,338	208,827	58,315

[r]Revised.

Table 14.—Production of zinc products from zinc-base scrap in the United States

(Short tons)

Products	1973	1974	1975	1976	1977
Redistilled slab zinc	83,187	78,535	57,886	[r]68,555	50,611
Zinc dust	36,531	29,339	35,479	40,471	39,674
Remelt zinc	1,096	893	127	342	295
Remelt die-cast slab	12,595	12,358	4,829	4,639	3,897
Zinc-die and diecasting alloys	4,786	4,393	4,740	7,049	8,333
Galvanizing stocks	670	872	1,435	2,486	2,302
Secondary zinc in chemical products	56,591	56,275	32,966	48,981	60,971

[r]Revised.

Table 15.—Zinc recovered from scrap processed in the United States, by kind of scrap and form of recovery

(Short tons)

	1976	1977
KIND OF SCRAP		
New scrap:		
Zinc-base	147,833	142,196
Copper-base	129,562	130,459
Magnesium-base	104	187
Total	277,499	272,842
Old scrap:		
Zinc-base	71,117	64,957
Copper-base	23,764	25,413
Aluminum-base	282	288
Magnesium-base	229	239
Total	95,392	90,897
Grand total	372,891	363,739
FORM OF RECOVERY		
As metal:		
By distillation:		
Slab zinc[1]	r68,555	50,611
Zinc dust	40,471	39,674
By remelting	2,828	2,597
Total	r111,854	92,882
In zinc-base alloys	11,688	12,230
In brass and bronze	r199,530	196,942
In aluminum-base alloys	314	288
In magnesium-base alloys	340	426
In chemical products:		
Zinc oxide (lead free)	26,069	32,981
Zinc sulfate	8,724	10,047
Zinc chloride	13,862	13,364
Miscellaneous	510	4,579
Total	r261,037	270,857
Grand total	372,891	363,739

rRevised.
[1]Includes zinc content of redistilled slab made from remelt die-cast slab.

Table 16.—Zinc dust produced in the United States

Year	Quantity (short tons)	Value: Total (thousands)	Value: Average per pound
1973	56,154	$29,279	$0.261
1974	50,775	46,398	.457
1975	42,149	40,294	.478
1976	46,358	45,282	.488
1977	47,594	45,414	.477

Table 17.—Consumption of zinc in the United States

(Short tons)

	1973	1974	1975	1976	1977
Slab zinc	1,503,938	1,287,696	925,330	1,134,141	1,101,765
Ores (zinc content)[1]	129,651	127,113	82,732	101,241	95,339
Secondary (zinc content)[2]	298,336	258,204	223,753	r301,508	310,531
Total	1,931,925	1,673,013	1,231,815	r1,536,890	1,507,635

rRevised.
[1]Includes ore used directly in galvanizing.
[2]Excludes redistilled slab and remelt zinc.

Table 18.—Slab zinc consumption in the United States, by industry use

(Short tons)

Industry and product	1973	1974	1975	1976	1977
Galvanizing:					
Sheet and strip	321,927	291,008	185,795	[r]244,711	260,173
Wire and wire rope	34,315	27,579	24,945	26,801	23,654
Tubes and pipe	68,048	59,995	47,180	48,968	47,021
Fittings (for tube and pipe)	11,969	9,294	6,359	6,450	6,416
Tanks and containers	2,941	3,203	1,917	3,326	3,370
Structural shapes	21,714	36,784	41,235	[r]36,601	29,347
Fasteners	4,782	5,703	4,426	4,028	4,289
Pole-line hardware	8,193	6,783	4,934	4,728	4,933
Fencing, wire cloth, netting	25,418	26,284	20,051	22,006	22,455
Other and unspecified uses	64,530	56,636	40,045	35,464	35,340
Total	563,837	523,269	376,887	433,083	436,998
Brass products:					
Sheet, strip, plate	109,582	99,971	64,958	91,157	77,347
Rod and wire	63,164	57,725	33,415	54,552	43,569
Tube	10,858	9,930	6,451	7,388	6,109
Castings and billets	6,000	4,431	3,079	4,240	4,493
Copper-base ingots	6,895	8,244	6,623	7,681	8,316
Other copper-base products	1,151	1,262	800	1,226	1,604
Total	197,650	181,563	115,326	166,244	141,438
Zinc-base alloy:					
Diecasting alloy	598,725	436,377	330,190	419,708	396,550
Dies and rod alloy	111	384	149	1,028	614
Slush and sand casting alloy	11,770	3,498	3,852	6,295	7,527
Total	610,606	440,259	334,191	427,031	404,691
Rolled zinc	40,763	39,393	27,308	29,859	30,210
Zinc oxide	61,734	65,376	39,020	39,027	42,454
Other uses:					
Light-metal alloys	7,466	9,690	5,832	5,767	6,156
Other[1]	21,882	28,146	26,766	33,130	39,818
Total	29,348	37,836	32,598	38,897	45,974
Grand total	1,503,938	1,287,696	925,330	1,134,141	1,101,765

[r]Revised.
[1]Includes zinc used in making zinc dust, wet batteries, desilverizing lead, powder, alloys, chemicals, castings, and miscellaneous uses not elsewhere mentioned.

Table 19.—Slab zinc consumption in the United States in 1977, by grade and industry use

(Short tons)

Industry	Special High Grade	High Grade	Inter-mediate	Brass Special	Prime[1] Western	Remelt	Total
Galvanizing	31,104	25,980	10,593	108,509	259,737	1,075	436,998
Brass and bronze	51,131	71,761	30	2,973	15,353	190	141,438
Zinc-base alloys	404,092	441	--	--	74	84	404,691
Rolled zinc	18,925	34	11,251	--	--	--	30,210
Zinc oxide	18,591	--	--	--	23,863	--	42,454
Other	19,204	2,086	--	1	24,683	--	45,974
Total	543,047	100,302	21,874	111,483	323,710	1,349	1,101,765

[1]Includes select grade.

Table 20.—Rolled zinc produced and quantity available for consumption in the United States

	1976			1977		
		Value			Value	
	Short tons	Total (thousands)	Average per pound	Short tons	Total (thousands)	Average per pound
Production:[1]						
Photoengraving plate	W	W	W	W	W	W
Strip and foil	22,259	$24,498	$0.550	21,583	$23,707	$0.549
Total rolled zinc[2]	29,874	33,482	.560	27,932	30,903	.553
Exports	2,271	2,817	.620	2,681	3,144	.586
Imports	209	392	.938	205	211	.515
Available for consumption	29,058	XX	XX	24,527	XX	XX

XX Not applicable. W Withheld to avoid disclosing company proprietary data, included in "Total rolled zinc."

[1]Figures represent net production. In addition, 24,630 tons in 1976 and 24,268 tons in 1977 were rerolled from scrap originating in fabricating plants operating in connection with zinc-rolling mills.

[2]Includes other plate over 0.375 inch thick, sheet zinc less than 0.375 inch thick, and rod and wire. Bureau of Mines not at liberty to publish separately.

Table 21.—Slab zinc consumption in the United States in 1977, by industry and State

(Short tons)

State	Galvanizers	Brass mills[1]	Die casters[2]	Other[3]	Total
Alabama	28,467	W	--	W	30,859
Arizona	--	--	--	W	W
Arkansas	--	--	W	W	W
California	32,072	2,652	W	W	44,633
Colorado	W	W	W	W	W
Connecticut	2,745	25,950	W	W	34,876
Delaware	W	W	--	W	W
Florida	4,018	--	--	--	4,018
Georgia	W	--	W	--	W
Hawaii	W	--	--	--	W
Idaho	--	--	W	W	W
Illinois	54,912	24,099	79,087	7,372	165,470
Indiana	59,420	W	17,028	W	98,930
Iowa	395	--	W	W	2,808
Kansas	--	W	W	W	W
Kentucky	16,634	W	--	W	17,357
Louisiana	3,009	--	W	W	4,917
Maine	W	--	--	--	W
Maryland	W	--	--	W	19,201
Massachusetts	2,952	778	W	W	5,416
Michigan	1,898	17,993	88,486	1,024	109,401
Minnesota	885	--	--	--	885
Mississippi	1,951	--	--	--	1,951
Missouri	6,996	W	W	W	10,684
Nebraska	5,415	W	W	W	6,052
New Jersey	2,389	5,120	W	W	14,601
New York	14,517	18,027	82,954	1,696	117,194
North Carolina	W	--	W	--	W
Ohio	67,107	W	61,816	W	139,945
Oklahoma	W	--	--	W	4,982
Oregon	974	W	W	W	1,866
Pennsylvania	57,357	7,438	W	W	131,019
Rhode Island	W	W	--	W	W
South Carolina	W	--	--	--	W
Tennessee	W	--	W	W	W
Texas	16,537	W	W	976	39,794
Utah	W	W	--	--	W
Virginia	W	W	W	W	771
Washington	W	--	--	W	2,125
West Virginia	W	--	--	W	25,317
Wisconsin	1,177	W	7,646	W	12,055
Undistributed	54,096	39,191	67,590	107,570	53,289
Total[4]	435,923	141,248	404,607	118,638	1,100,416

W Withheld to avoid disclosing company proprietary 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 22.—Production and shipments of zinc pigments and compounds[1] in the United States

Pigment or compound	1976 Production (short tons)	1976 Shipments Quantity (short tons)	1976 Shipments Value[2] Total (thousands)	1976 Shipments Value[2] Average per ton	1977 Production (short tons)	1977 Shipments Quantity (short tons)	1977 Shipments Value[2] Total (thousands)	1977 Shipments Value[2] Average per ton
Zinc oxide[3]	194,481	198,078	$136,447	$689	207,725	209,551	$138,134	$659
Zinc sulfate	34,681	34,344	10,096	294	38,818	37,530	10,229	273
Zinc chloride, 50°Baumé[4]	32,626	25,184	W	W	30,885	21,371	W	W

W Withheld to avoid disclosing company proprietary data.
[1]Excludes leaded zinc oxide and lithopone.
[2]Value at plant, exclusive of container.
[3]Zinc oxide containing 5% or more lead is classed as leaded zinc oxide.
[4]Includes zinc content of zinc ammonium chloride and chromated zinc chloride.

Table 23.—Zinc content of zinc pigments[1] and compounds produced by domestic manufacturers, by source

(Short tons)

Pigment or compound	1976 Zinc in pigments and compounds produced from— Ore	1976 Slab zinc	1976 Secondary material	1976 Total zinc in pigments and compounds	1977 Zinc in pigments and compounds produced from— Ore	1977 Slab zinc	1977 Secondary material	1977 Total zinc in pigments and compounds
Zinc oxide	91,399	38,166	26,069	155,634	88,565	43,809	32,981	165,355
Zinc sulfate	1,736	--	11,861	13,597	1,974	--	10,047	12,021
Zinc chloride[2]	--	--	10,634	10,634	--	--	10,118	10,118

[1]Excludes leaded zinc oxide, zinc sulfide, and lithopone.
[2]Includes zinc content of zinc ammonium chloride and chromated zinc chloride.

Table 24.—Distribution of zinc oxide shipments, by industry

(Short tons)

Industry	1973	1974	1975	1976	1977
Rubber	129,462	108,976	96,209	104,669	112,137
Paints	26,115	17,029	11,016	15,699	13,800
Ceramics	11,678	12,177	6,300	8,433	8,106
Chemicals	26,187	35,167	17,544	33,186	29,020
Agriculture	2,044	6,066	1,847	3,481	6,061
Photocopying	38,724	34,577	24,647	24,149	23,537
Other	18,623	18,550	11,922	8,461	16,890
Total	252,833	232,542	169,485	198,078	209,551

Table 25.—Distribution of zinc sulfate shipments, by industry

(Short tons)

Year	Agriculture Gross weight	Agriculture Dry basis	Other[1] Gross weight	Other[1] Dry basis	Total Gross weight	Total Dry basis
1973	13,909	8,353	31,288	24,902	45,197	33,255
1974	14,508	8,677	29,627	18,245	44,135	26,922
1975	8,470	3,579	15,022	5,852	23,492	9,431
1976	12,797	5,326	21,547	10,283	34,344	15,609
1977	15,526	6,121	22,004	9,745	37,530	15,866

[1]Includes rayon; Bureau of Mines not at liberty to publish separately.

Table 26.—Stocks of slab zinc at zinc-reduction plants in the United States, December 31

(Short tons)

	1973	1974	1975	1976	1977
At primary reduction plants	25,229	38,293	73,431	92,553	84,478
At secondary distilling plants	718	1,427	1,245	[r]4,397	7,909
Total	25,947	39,720	74,676	[r]96,950	92,387

[r]Revised.

Table 27.—Consumer stocks of slab zinc at plants, December 31, by grade

(Short tons)

Year	Special High Grade	High Grade	Inter-mediate	Brass Special	Prime Western	Remelt	Total
1976	44,479	10,870	3,467	8,419	53,739	180	121,154
1977	29,602	7,650	3,481	10,234	29,931	43	80,941

Table 28.—Average monthly U.S., LME,[1] and European Producers' prices for Prime Western zinc and equivalent

(Metallic zinc, cents per pound)

Month	1976			1977		
	United States	LME cash	European producer	United States	LME cash	European producer
January	37.12	31.34	36.05	37.00	31.32	36.05
February	37.00	31.27	36.05	37.00	31.86	36.05
March	37.00	32.92	36.05	37.00	32.56	36.05
April	37.00	35.78	36.05	37.00	29.66	36.05
May	37.00	35.03	36.05	35.57	27.71	33.80
June	37.00	35.93	36.05	34.00	24.55	31.75
July	37.00	35.12	36.05	34.00	24.53	31.75
August	37.00	33.53	36.05	34.00	23.54	31.75
September	37.00	32.27	36.05	34.00	23.43	31.75
October	37.00	28.94	36.05	31.90	23.20	29.26
November	37.00	27.34	36.05	30.73	23.79	27.22
December	37.00	29.07	36.05	30.50	24.35	27.22
Average for year	37.01	32.38	36.05	34.39	26.71	32.39

[1]London Metal Exchange.

Source: Metals Week.

Table 29.—U.S. exports of zinc and zinc alloys, by country

Destination	1975 Quantity (short tons)	1975 Value (thousands)	1976 Quantity (short tons)	1976 Value (thousands)	1977 Quantity (short tons)	1977 Value (thousands)
Unwrought zinc and zinc alloys:						
Argentina	10	$8	--	--	20	$34
Bahrain	1	(1)	--	--	44	82
Brazil	1,714	1,628	--	--	--	--
Canada	619	528	972	$640	458	458
Chile	10	22	36	42	14	18
Colombia	142	127	12	22	1	1
Dominican Republic	55	37	1	2	5	13
Egypt	17	34	3	5	115	99
France	397	339	216	105	(1)	1
Germany, Federal Republic of	64	31	36	29	4	12
Guatemala	26	21	(1)	1	138	121
Israel	--	--	6	12	9	17
Italy	--	--	17	13	4	3
Japan	479	391	5	15	27	20
Korea, Republic of	118	50	59	29	--	--
Mexico	181	108	163	85	102	50
Netherlands	4,107	3,781	2,873	1,918	2	6
Nicaragua	2	2	71	57	1	2
Philippines	5	8	6	9	12	11
Saudi Arabia	--	--	351	435	1	2
Singapore	38	57	19	30	--	--
South Africa, Republic of	--	--	23	28	--	--
Spain	58	47	--	--	--	--
Taiwan	4	10	1	4	53	52
United Arab Emirates	21	39	34	44	(1)	1
United Kingdom	202	194	(1)	4	5	8
Venezuela	1,319	1,094	164	143	32	40
Other	r38	r86	r38	r57	181	228
Total	9,627	8,642	5,106	3,729	1,228	1,279
Wrought zinc and zinc alloys:						
Algeria	24	53	31	56	--	--
Australia	53	91	98	182	94	170
Belgium-Luxembourg	8,159	4,113	4,825	2,541	2,267	1,191
Brazil	133	103	--	--	1	1
Canada	3,137	1,975	3,344	2,369	3,679	2,780
Chile	49	65	17	23	38	56
Colombia	58	73	69	88	52	70
Denmark	9	11	23	36	27	83
Dominican Republic	112	121	13	27	1	1
Ecuador	26	38	29	52	58	105
Egypt	56	79	23	28	46	61
Germany, Federal Republic of	63	57	10	73	--	--
Hong Kong	81	93	115	130	37	50
Indonesia	1	5	--	--	10	12
Israel	48	56	60	78	63	77
Italy	2	3	27	39	38	56
Japan	2	4	5	24	19	72
Lebanon	33	43	--	--	26	38
Mexico	81	84	59	112	113	134
Netherlands	10	76	14	37	4	23
New Zealand	41	47	107	122	69	84
Panama	17	5	58	115	24	47
Peru	124	312	28	45	35	54
Philippines	40	53	57	76	48	89
Saudi Arabia	20	4	35	36	8	12
Singapore	5	12	14	16	8	17
South Africa, Republic of	131	191	78	115	106	164
Sweden	3	9	--	--	28	33
Switzerland	56	40	48	27	29	41
Syria	8	10	199	76	41	61
Taiwan	13	15	46	52	58	76
Thailand	11	26	31	45	--	--
Turkey	5	6	38	44	35	30
United Arab Emirates	11	19	5	7	5	8
United Kingdom	180	255	189	317	330	311
Venezuela	76	105	69	100	173	235
Other	r217	r441	r234	r382	267	451
Total	13,095	8,693	9,998	7,470	7,837	6,693

rRevised.
1Less than 1/2 unit.

Table 30.—U.S. exports of zinc, by class

Year	Blocks, pigs, anodes, etc.				Wrought zinc and zinc alloys				Waste and scrap (zinc content)		Dust (blue powder)	
	Unwrought		Unwrought alloys		Sheets, plates, and strip		Angles, bars, pipes, rods, etc.					
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
1975	6,897	$5,870	2,730	$2,772	1,629	$2,086	11,466	$6,607	4,448	$1,610	603	$838
1976	3,513	2,306	1,593	1,423	2,271	2,817	7,727	4,653	8,171	2,820	774	715
1977	237	210	991	1,069	2,681	3,144	5,156	3,549	8,207	2,972	1,023	726

Table 31.—U.S. exports of zinc pigments

Kind	1976 Quantity (short tons)	1976 Value (thousands)	1977 Quantity (short tons)	1977 Value (thousands)
Zinc oxide	4,838	$3,112	6,771	$3,634
Lithopone	779	937	435	698
Total	5,617	4,049	7,206	4,332

Table 32.—U.S. exports of lead and zinc ores and concentrates

(Gross weight)

Year	Quantity (short tons)	Value (thousands)
1965	434	$152
1966	49	9
1967	39	16
1968	11,831	2,931
1969	115	47
1970	15,575	1,458
1971	29,145	3,286
1972	43,845	5,802
1973	104,180	18,884
1974	111,176	27,281
1975	150,830	31,502
1976	148,787	28,892
1977	128,056	28,753

Table 33.—U.S. exports of lead and zinc ores and concentrates, by country

(Gross weight)

Destination	1975 Quantity (short tons)	1975 Value (thousands)	1976 Quantity (short tons	1976 Value (thousands)	1977 Quantity (short tons)	1977 Value (thousands)
Argentina	5,276	$727	--	--	--	--
Belgium-Luxembourg	50,666	10,086	62,111	$13,660	32,704	$8,067
Brazil	5,690	1,008	16,919	3,487	49,807	11,979
Bulgaria	--	--	10,067	1,764	--	--
Canada	5,522	1,559	942	195	3,751	1,067
Finland	--	--	5,430	1,500	--	--
France	12	8	12	7	3,194	439
Germany, Federal Republic of	6,879	1,646	25,154	3,563	71	96
Italy	--	--	--	--	5,904	1,143
Japan	6,271	1,261	15,600	2,526	10,751	1,848
Mexico	8,219	802	11	6	6,482	1,170
Netherlands	8,196	2,045	5,907	838	--	--
Poland	19,930	4,614	--	--	--	--
Spain	16,282	3,750	5,543	1,070	10,274	1,781
U.S.S.R	6,017	1,336	--	--	--	--
United Kingdom	1,461	370	1,082	260	5,112	1,150
Yugoslavia	10,406	2,286	--	--	--	--
Other	r3	r4	r9	r16	6	13
Total	150,830	31,502	148,787	28,892	128,056	28,753

[r]Revised.

Table 34.—U.S. general imports of zinc, by country

Country	1975 Quantity (short tons)	1975 Value (thousands)	1976 Quantity (short tons)	1976 Value (thousands)	1977 Quantity (short tons)	1977 Value (thousands)
ORES AND CONCENTRATES (zinc content)						
Australia	4,044	$485	2,291	$275	4,343	$968
Bolivia	1,217	218	785	87	4,991	673
Canada	98,700	37,084	69,901	27,339	58,578	21,064
Chile	--	--	--	--	11,784	3,750
Colombia	8	1	14	2	18	2
Costa Rica	--	--	--	--	851	553
Germany, Federal Republic of	20	7	231	103	812	302
Greenland	304	46	530	80	--	--
Honduras	13,362	4,936	16,307	7,289	17,369	8,275
Mexico	9,334	3,789	2,625	763	4,289	615
Nicaragua	7,299	2,577	3,637	1,982	3,051	1,907
Peru	4,902	2,011	794	166	1,034	141
Thailand	5,797	882	--	--	15,688	1,303
Total	144,987	52,036	97,115	38,086	122,808	39,553
BLOCKS, PIGS, OR SLABS						
Algeria	--	--	999	621	1,278	557
Angola	5,512	4,354	--	--	--	--
Australia	22,875	17,295	32,586	23,549	29,262	19,612
Belgium-Luxembourg	19,084	16,456	35,473	23,420	42,971	24,686
Canada	181,692	134,010	313,006	223,125	239,555	160,224
China, People's Republic of	298	194	2,532	1,597	1,109	615
Finland	19,157	14,264	31,526	23,006	32,669	21,245
France	1,837	1,232	10,397	7,438	17,427	11,021
Germany, Federal Republic of	17,827	12,507	48,665	32,989	41,552	25,886
Italy	7,299	5,137	30,739	18,867	21,602	13,844
Japan	7,202	5,724	9,483	6,789	14,353	9,769
Korea, Republic of	--	--	57	35	--	--
Liberia	3,601	2,502	--	--	--	--
Malaysia	45	660	--	--	--	--
Mexico	17,605	12,818	62,638	42,762	29,981	18,826
Netherlands	15,123	10,208	9,642	6,586	6,424	3,737
Norway	--	--	1,102	827	--	--
Peru	19,128	12,917	19,911	13,111	18,885	11,740
Poland	440	292	1,018	619	3,941	1,991
South Africa, Republic of	2,077	1,698	3,650	2,453	5,885	3,811
Spain	26,268	16,143	29,687	19,892	28,339	16,821
Switzerland	--	--	118	89	--	--
United Kingdom	2,200	1,528	1,820	1,190	1,643	981
Yugoslavia	7,009	4,557	29,869	19,699	3,574	2,101
Zaire	4,158	2,841	36,922	26,839	35,707	23,910
Zambia	--	--	2,649	1,627	579	359
Total	380,437	277,337	714,489	497,130	576,736	371,736

Table 35.—U.S. imports for consumption of zinc, by country

Country	1975 Quantity (short tons)	1975 Value (thousands)	1976 Quantity (short tons)	1976 Value (thousands)	1977 Quantity (short tons)	1977 Value (thousands)
ORES AND CONCENTRATES (zinc content)						
Australia	22,954	$1,949	2,467	$295	3,657	$896
Bolivia	1,217	218	785	87	4,991	673
Canada	209,150	57,888	124,320	40,148	60,411	21,621
Chile	--	--	--	--	11,784	3,751
Colombia	8	1	14	2	18	2
Germany, Federal Republic of	20	7	231	103	812	302
Greenland	--	--	721	108	--	--
Honduras	43,224	13,040	13,069	6,171	17,369	8,275
Ireland	4,820	750	--	--	--	--
Mexico	61,656	16,037	9,689	1,795	3,748	526
Nicaragua	36,749	8,858	3,019	1,376	945	407
Peru	20,633	3,991	1,488	468	1,034	141
Thailand	25,143	5,172	--	--	15,688	1,303
Turkey	2,970	911	--	--	--	--
Total	428,544	108,822	155,803	50,553	120,457	37,897
BLOCKS, PIGS, OR SLABS						
Algeria	--	--	999	621	971	407
Australia	22,875	17,295	32,586	23,549	29,262	19,612
Belgium-Luxembourg	17,430	14,417	35,197	23,211	41,317	23,986
Canada	181,725	134,015	313,006	223,125	239,555	160,224
China, People's Republic of	298	194	2,532	1,597	914	536
Finland	19,157	14,264	31,526	23,006	32,559	21,115
France	1,837	1,232	8,552	6,099	18,718	11,999
Germany, Federal Republic of	17,853	12,538	47,397	32,119	41,552	25,886
Italy	5,792	4,202	28,636	19,069	18,295	11,909
Japan	8,403	6,832	--	--	--	--
Korea, Republic of	--	--	57	35	--	--
Liberia	3,601	2,502	--	--	--	--
Malaysia	45	660	--	--	--	--
Mexico	14,187	10,083	58,001	39,421	31,991	20,418
Netherlands	15,123	10,208	7,768	5,361	4,906	2,808
Norway	--	--	1,102	827	--	--
Peru	19,128	12,917	19,911	13,111	20,868	13,020
Poland	661	496	1,018	619	3,941	1,991
Portugal	104	87	--	--	--	--
Romania	--	--	6,748	1,957	--	--
South Africa, Republic of	2,077	1,698	3,650	2,453	5,885	3,811
Spain	28,509	18,895	29,687	19,892	23,489	14,416
Switzerland	--	--	118	89	--	--
United Kingdom	2,200	1,528	1,820	1,190	1,643	981
Yugoslavia	7,390	4,861	29,869	19,699	3,216	1,923
Zaire	6,527	4,712	32,302	23,588	35,486	23,733
Zambia	--	--	2,649	1,627	579	359
Total	374,922	273,636	695,131	482,265	555,147	359,134

Table 36.—U.S. imports for consumption of zinc, by class

	Ore (zinc content)		Blocks, pigs, slabs[1]		Sheets, plates, strips other forms		Waste and scrap	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
1975	428,544	$108,822	374,922	$273,636	236	$507	1,418	$468
1976	155,803	50,553	695,131	482,265	209	329	1,803	516
1977	120,457	37,897	555,147	359,134	205	211	10,128	2,175

	Dross and skimmings (zinc content)		Zinc fume (zinc content)		Dust, powder, flakes		Total value[2] (thousands)
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	
1975	3,158	$1,238	33,327	$9,442	5,739	$5,744	$399,857
1976	12,445	4,884	6,927	2,558	6,009	5,134	546,239
1977	12,940	5,204	257	516	7,388	6,277	411,414

[1]Unwrought alloys of zinc were imported as follows: 1975, 101 short tons ($87,395); 1976, 27 short tons ($14,141); and 1977, 354 short tons ($211,624).
[2]In addition, manufactures of zinc were imported as follows: 1975, $78,837; 1976, $96,945; and 1977, $261,554.

Table 37.—U.S. imports for consumption of zinc pigments and compounds

Kind	1976		1977	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Zinc oxide	19,913	$12,391	20,789	$13,108
Zinc sulfide	539	358	686	481
Lithopone	69	25	65	27
Zinc chloride	1,372	701	1,878	1,031
Zinc sulfate	5,435	1,602	5,689	1,757
Zinc cyanide	57	84	71	104
Zinc hydrosulfite	--	--	85	52
Zinc compounds, n.s.p.f	584	575	891	772
Total	27,969	15,736	30,154	17,332

Table 38.—Zinc: World mine production (content of ore), by country

(Short tons)

Country	1975	1976	1977[p]
North America:			
Canada[1]	r1,355,269	1,262,594	1,433,223
Guatemala		1,624	1,129
Honduras	33,398	27,392	29,257
Mexico	318,403	285,700	292,629
Nicaragua	12,321	15,749	11,180
United States (recoverable)	469,355	484,513	449,620
South America:			
Argentina	41,172	44,644	44,974
Bolivia	[2]51,934	53,513	66,983
Brazil	55,120	53,634	e55,000
Chile	3,499	5,573	4,122
Colombia	8	66	--
Ecuador	91	150	2,202
Peru	424,169	436,240	446,859
Europe:			
Austria[3]	r19,175	19,426	21,718
Bulgaria	91,492	r e94,200	e92,600
Czechoslovakia	9,838	10,217	e11,000
Finland	59,917	67,399	67,584
France	r15,322	38,250	47,852
Germany, Federal Republic of	127,947	127,145	125,831
Greece	r17,637	33,510	26,455
Greenland	100,156	89,287	84,437
Hungary[e]	2,400	r2,400	e2,800
Ireland	73,500	69,200	128,200
Italy	83,792	88,610	87,367
Norway	26,460	32,027	33,425
Poland[e]	230,000	r200,000	200,000
Romania (recoverable)[e]	66,000	66,000	66,000
Spain	94,024	93,233	102,498
Sweden	122,715	141,455	149,914
U.S.S.R.[e]	760,000	790,000	810,000
United Kingdom	r4,409	5,291	e5,500
Yugoslavia	114,023	117,551	118,057
Africa:			
Algeria	r12,456	8,708	6,393
Congo	r5,622	5,732	5,732
Morocco	23,100	15,983	12,346
Nigeria	821	e500	--
South Africa, Republic of	73,014	86,596	80,439
South-West Africa, Territory of[e 4]	r41,600	r29,400	42,200
Tunisia	r6,614	8,047	7,826
Zaire	r88,626	74,736	80,469
Zambia	r73,083	53,793	56,328
Asia:			
Burma	2,918	2,437	2,022
China, People's Republic of[e]	110,000	110,000	110,000
Cyprus	--	956	197
India	25,175	29,366	35,825
Iran[5]	r88,000	79,000	67,792
Japan	280,453	286,549	303,941
Korea, North[e]	176,000	r165,000	165,000
Korea, Republic of	50,617	65,186	75,348
Philippines	11,522	14,770	14,640
Thailand[6]	3,549	18	302
Turkey	r28,237	37,811	44,667
Vietnam[e]	11,000	11,000	11,000
Oceania: Australia	552,088	515,445	542,068
Total	r6,448,041	6,357,626	6,682,951

[e]Estimate. [p]Preliminary. [r]Revised.
[1]Content of concentrates.
[2]Production by COMIBOL plus exports by medium, small, and other unspecified sources.
[3]Series revised to show output on a recoverable basis; figures appearing in previous editions were on the basis of content by analysis.
[4]Series revised to reflect estimated mine output of all producers on a calendar year basis.
[5]Series revised to reflect estimated output on a calendar year basis.
[6]Content of zinc concentrates; additional quantities of zinc may be contained in lead concentrates produced, but information is inadequate to make reliable estimates of such production.

Table 39.—World smelter production of zinc, by country[1]

(Short tons)

Country	1975	1976	1977[p]
North America:			
Canada	470,622	520,639	545,521
Mexico[2]	169,711	188,871	188,523
United States	438,051	498,855	450,145
South America:			
Argentina	[r]43,500	38,800	32,000
Brazil	34,643	47,569	[e]50,000
Peru	69,709	71,297	73,799
Europe:			
Austria[2]	17,938	18,240	18,490
Belgium[e 3]	[r]235,000	[r]254,400	265,200
Bulgaria[2]	101,000	102,000	99,200
Finland	121,127	121,952	152,097
France[3]	[r]164,944	195,109	[e]199,500
German Democratic Republic[2]	16,800	16,500	17,100
Germany, Federal Republic of	[r]302,400	[r]312,349	355,968
Italy	198,120	208,804	194,660
Netherlands	136,623	155,213	120,591
Norway	67,121	70,936	76,483
Poland[2]	[r]267,900	261,200	251,500
Romania[2]	[r]77,200	77,200	71,700
Spain	[r]147,013	174,566	172,653
U.S.S.R.[e]	760,000	790,000	810,000
United Kingdom[2]	[r]58,910	45,837	89,817
Yugoslavia[2]	[r]107,591	116,288	108,954
Africa:			
Algeria	22,000	19,800	10,500
South Africa, Republic of[4]	70,243	73,082	83,800
Zaire	72,298	67,994	56,272
Zambia	51,600	41,146	44,218
Asia:			
China, People's Republic of[e 2]	110,000	110,000	110,000
India	28,359	29,525	39,689
Japan	[r]769,716	817,990	858,045
Korea, North[2 e]	[r]155,000	150,000	150,000
Korea, Republic of	[r]23,079	30,366	36,107
Thailand	73	78	--
Turkey[e]	--	2,500	23,000
Vietnam	5,000	11,000	11,000
Oceania: Australia	213,088	267,460	274,302
Total	[r]5,526,379	5,907,566	6,040,834

[e]Estimate. [p]Preliminary. [r]Revised.

[1]An attempt has been made to restrict the contents of this table to primary production only. Where secondary metal is inseparably included, this fact has been so noted.

[2]Known to include secondary production (recovered from reclaimed scrap).

[3]Series revised to exclude secondary production.

[4]May include secondary production from reclaimed scrap.

Table 40.—Zinc: World secondary smelter production, by country[1]

(Short tons)

Country	1975	1976	1977
North America: United States	57,886	68,555	50,611
Europe:			
Belgium[e]	5,200	5,800	8,800
France	34,722	62,009	[e]62,800
Germany, Federal Republic of	22,478	23,584	20,561
Spain	14	--	--
U.S.S.R.[e]	85,000	90,000	90,000
Asia: Japan	26,052	37,452	29,135
Oceania: Australia[e]	7,700	8,800	8,800
Total	239,052	296,200	270,707

[e]Estimate.

[1]Figures presented are incomplete; for the following countries not listed in this table, secondary production is included with primary production because there is no reliable source or basis for estimating the proportion of total output reclaimed from scrap: Bulgaria, the People's Republic of China, the German Democratic Republic, North Korea, Poland, Romania, the Republic of South Africa, the United Kingdom, and Yugoslavia.

Zirconium and Hafnium

By Langtry E. Lynd[1]

Zircon production by domestic mining companies increased 16% in tonnage and decreased 18% in value in 1977 from 1976 levels. Zircon exports increased 52%, while imports increased slightly. Exports of zirconium metal and zirconium alloys decreased in 1977, as did those of zirconium oxide. Production of zirconium-bearing compounds for chemicals and refractories increased slightly. Zircon consumption by foundries, the principal use, increased 3%. Estimates of U.S. production of zirconium sponge metal ranged from 5 million to 10 million pounds. Some hafnium metal was also produced.

In 1977, zircon remained in a condition of oversupply and prices continued to weaken. Published prices for Australian zircon dropped almost 50% during the year. The list price of domestic standard-grade zircon was unchanged.

Zircon use was largely in foundry sands, refractories, abrasives, ceramics, and as a source of zirconium metal. The metal was used mostly in nuclear reactors, in corrosion-resistant equipment for industrial plants, and in refractory alloys. Hafnium was used in nuclear reactors, in flashbulbs, and in refractory alloys.

Legislation and Government Programs.—There were no stockpile goals for zirconium and hafnium materials. The U.S. Department of Energy (DOE) had an inventory as of December 30, 1977, of approximately 948 tons of zirconium sponge, 197 tons of zirconium ingots and shapes, 3 tons of zirconium scrap, 39 tons of hafnium crystal bar, 4 tons of hafnium oxide, and 1 ton of hafnium scrap.

The Food and Drug Administration issued a final order on August 16 banning the use of zirconium in aerosol antiperspirants because of its possible toxic effects to the lungs, skin, and other organs. The action does not affect zirconium-containing nonaerosol antiperspirants.[2]

The Oregon State Health Division announced in May that mineral wastes on the property of Teledyne Wah Chang Albany (TWCA), the sole U.S. producer of zirconium metal, near Albany, Oreg., were radioactive and contained much more radium 226 than could be legally discharged into the environment under State law. The Health Division ordered a halt to shipments of radioactive materials off Wah Chang's plant site, and required the company to apply for licenses to handle such materials, as well as to

Table 1.—Salient zirconium statistics in the United States

(Short tons)

Product	1973	1974	1975	1976	1977
Zircon:					
Production	W	W	W	W	W
Exports	28,921	21,487	18,766	9,428	14,364
Imports	98,023	62,504	40,205	64,643	65,204
Consumption[e 1]	175,000	167,000	122,000	155,000	162,000
Stocks, yearend, dealers' and consumers'[2]	51,500	41,900	37,033	[r]38,625	25,835
Zirconium oxide:					
Production[3]	14,300	11,630	11,760	8,000	7,414
Producers' stocks, yearend[3]	648	1,480	1,745	[r]667	671

[e]Estimate. [r]Revised. W Withheld to avoid disclosing company proprietary data.
[1]Includes baddeleyite: 1973-1,019 tons; 1974-[e]2,950 tons; 1975-[e]1,000 tons; 1976-[e]2,000 tons; 1977-[e]3,000 tons.
[2]Excludes foundries.
[3]Excludes oxide produced by zirconium metal producers.

immediately find a way to stabilize the wastes on the plant site or ship them out of the State to an authorized disposal site. The Oregon Department of Environmental Quality agreed to relax the Wah Chang plant's ammonia disposal limit to allow the company to dump an average of 400 pounds per day. The company asked to be allowed to dump 2,000 pounds of ammonia per day, and was paying a $50 per day fine since July 1 for each day it failed to meet the standards that went into effect on that date.[3]

DOMESTIC PRODUCTION

E. I. du Pont de Nemours & Co., Humphreys Mining Co., and Titanium Enterprises, Inc., were the only producers of zircon mineral concentrate in the United States. Zircon was recovered as a coproduct of titanium mineral concentrates from mineral sands at the dredging and milling facilities owned and operated by Du Pont at Starke and Highland, Fla.; operated by Humphreys Mining Co. for Du Pont, at Boulougne, Fla., and Folkston, Ga.; and owned and operated by Titanium Enterprises at Green Cove Springs, Fla. Production data were withheld from publication to avoid disclosing company proprietary data. The combined zircon capacity of these three plants was estimated to be 135,000 tons per year.

Table 2.—Producers of zirconium and hafnium materials in 1977

Company	Location	Materials
ZIRCONIUM MATERIALS		
AMAX Specialty Metals Corp	Akron, N.Y	Ingot, mill products.
Do	Cleveland, Ohio	Foil, cold-rolled sheet.
Associated Minerals Consolidated Ltd	Bow, N.H	Oxide.
Babcock & Wilcox Co., Nuclear Materials Div	Parks Township, Pa	Powder.
The Carborundum Co	Falconer, N.Y	Refractories.
C-E Cast Industrial Products	Carson, Calif	Milled zircon.
C-E Refractories, Div. of Combustion Engineering, Inc	St. Louis, Mo	Do.
Do	King of Prussia, Pa	Refractories, zircon.
Do	Vandalia, Mo	Do.
Continental Mineral Processing Corp	Sharonville, Ohio	Milled zircon.
Corhart Refractories Co	Buckhannon, W. Va	Refractories.
Do	Corning, N.Y	Do.
Do	Louisville, Ky	Do.
E. I. du Pont de Nemours & Co	Wilmington, Del	Zircon, foundry mixes.
Ferro Corp	Cleveland, Ohio	Ceramics, ceramic colors.
Foote Mineral Co	Cambridge, Ohio	Alloys.
A. P. Green Refractories Co., Remmey Div	Philadelphia, Pa	Refractories.
Harbison-Walker Refractories Co	Mount Union, Pa	Do.
Harshaw Chemical Co., Inc	Cleveland, Ohio	Oxide, ceramics.
Hercules, Inc., Drakenfeld Div	Washington, Pa	Ceramic colors, milled zircon.
Humphreys Mining Co. (now owned by Buttes Gas & Oil Co.)	Folkston, Ga	Zircon.
Lincoln Electric Co., Inc	Cleveland, Ohio	Welding rods.
M & T Chemicals, Inc	Andrews, S.C	Milled zircon.
Magnesium Electron, Inc	Flemington, N.J	Alloys, chemicals.
NL Industries, Inc., Industrial Chemicals Div	Hightstown, N.J	Milled zircon, oxide, alloys, chloride.
Charles Taylor Div	Cincinnati, Ohio	Refractories.
Do	South Shore, Ky	Do.
Norton Co	Huntsville, Ala	Oxide.
Ohio Ferro-Alloys Corp	Brilliant, Ohio	Alloys.
Ronson Metals Corp	Newark, N.J	Baddeleyite (oxide).
Sherwood Refractories Co	Cleveland, Ohio	Zircon cores.
Shieldalloy Corp	Newfield, N.J	Welding rods, alloys.
Teledyne Wah Chang Albany	Albany, Oreg	Oxide, chloride, sponge, ingot, powder, crystal bar.
Titanium Enterprises, Inc	Green Cove Springs, Fla	Zircon.
Transelco, Inc	Dresden, N.Y	Chemicals, ceramics.
Union Carbide Corp	Niagara Falls, N.Y	Alloys.
Ventron Corp	Beverly, Mass	Alloys, oxide, sponge.
Zedmark, Inc	Butler, Pa	Refractories.
Zirconium Corp. of America	Cleveland, Ohio	Oxide, refractories, ceramics.
HAFNIUM MATERIALS		
AMAX Specialty Metals Corp	Akron, N.Y	Ingot, mill products.
Teledyne Wah Chang Albany	Albany, Oreg	Oxide, sponge, crystal bar, ingot.

Statistical data on production of zirconium sponge, ingot, and scrap, and on hafnium sponge and oxide are also withheld to avoid disclosing company proprietary data. Estimates of 1977 zirconium sponge production ranged from 5 million to 10 million pounds.

Approximately 2,460 tons of alloys containing from 3% to 70% zirconium was produced in 1977.

Four firms produced 41,820 tons of milled (ground) zircon from domestic and imported concentrates, an increase of 55% from the reported 1976 production. Seven companies, excluding those that produce metal, produced 7,400 tons of zirconium oxide, 7% less than reported in 1976.

Hafnium crystal bar production was estimated at 30 tons in 1977, the same as for 1976.

Buttes Gas & Oil Co. acquired all the stock of Humphreys Engineering Co., parent company of Humphreys Mining Co., for $3.6 million.

The Parkersburg, W. Va., zirconium plant of AMAX Specialty Metals Corp. remained closed but supplied zirconium and hafnium from stock to AMAX's Akron, N.Y., plant. The Parkersburg site was sold and the plant was being dismantled.

Teledyne, Inc. announced plans to build a second zirconium plant at a new site to augment production of zirconium products at its TWCA plant in Albany, Oreg. The proposed plant was to be devoted initially to the chemical extraction of zirconium from zircon to produce zirconium oxide. Because of environmental requirements, TWCA's zirconium oxide production rate at Albany was said to be limited to 50,000 pounds per day.[4]

Early in 1977, Pechiney Ugine Kuhlmann Corp. withdrew from a plan to build a 3-million-pound-per-year zirconium plant as a joint venture with Western Zirconium Co., Salem, Oreg., in Dallesport, Wash. At yearend, Western Zirconium reportedly was still planning to build a facility in Dallesport, and was seeking a new partner for the project.[5]

CONSUMPTION AND USES

Estimated zircon consumption in the United States in 1977, based on incomplete reported data, was 162,000 tons. Consumption of zircon concentrate and milled zircon was estimated to be 69,000 tons for foundries, 42,000 tons for refractories, 14,000 tons for zirconium oxide, 3,000 tons for zirconium alloys (excluding zirconium-base alloys), and 34,000 tons for all other uses. Foundries used about 43% of domestic zircon consumption, with the remainder consumed by refractory, abrasive, ceramic, metal, and other industries. Domestic zircon was marketed in proprietary mixtures for use as weighting agents, zircon-TiO_2 blends for welding rod manufacture, and zircon-refractory heavy mineral (kyanite, sillimanite, and staurolite) sand blends for foundry sand and sand-blasting applications. The zircon-bearing foundry sand was reportedly designed to provide consistent high-quality performance at low cost for critical casting applications.

In 1977, imported Republic of South Africa baddeleyite ore was used principally in the manufacture of alumina-zirconia abrasives and also in ceramic colors, refractories, and for other uses.

Preliminary Bureau of the Census figures for 1977 showed that shipments of zircon and zirconia brick and shapes, composed mostly of these materials, totaled 1.6 million brick, expressed in terms of equivalent 9-inch brick, valued at $11.5 million. In 1976, final figures for shipments were 1.8 million brick valued at $13.3 million.[6]

Zirconium metal was used in nuclear reactors, in chemical plants for corrosion-resistant material, in refractory alloys, and in photography for flashbulbs. Commercial nuclear powerplants were estimated to consume 80% of the total used, with the rest of the market being shared by the Navy nuclear submarine program, corrosion-resistant applications in the chemical industry, and other uses. Navy requirements were said to be constant, while those of the chemical industry were increasing and expected to reach 300,000 to 400,000 pounds of commercial-grade ingot in 1978. Growth in overall demand has been slowed because of numerous delays in construction of nuclear powerplants.[7]

Zirconium compounds, natural and manufactured, were used in refractories, abrasives, polishes, glazes, enamels, welding rods, chemicals, and sandblasting. Zirconium chemicals were finding increasing application in the paint, textile, and pharmaceutical industries. Hafnium metal, alloys, and compounds continued to have few uses. The metal was used for nuclear reactor control rods, in special refractory alloys, and in photographic flashbulbs. The nonnuclear hafnium metal uses were reportedly increasing.

Table 3.—Estimated[1] consumption of zircon in the United States in 1977, by end use

(Short tons)

Use	Quantity
Zircon refractories[2]	31,000
AZS refractories[3]	11,000
Zirconia [4] and AZ abrasives[5]	14,000
Alloys[6]	3,000
Foundry aids	69,000
Other[7]	34,000
Total	162,000

[1]Based on incomplete reported data.
[2]Dense and pressed zircon brick and shapes.
[3]Fused cast and bonded alumina-zirconia-silica-based refractories.
[4]Excludes oxide produced by zirconium metal producers.
[5]Alumina-zirconia-based abrasives.
[6]Excludes alloys above 90% zirconium.
[7]Includes ceramics, chemicals, metallurgical-grade zirconium tetrachloride, sandblasting, welding rods, and miscellaneous uses.

Table 4.—Estimated[1] consumption of zirconium oxide[2] in the United States in 1977, by end use

(Short tons)

Use	Quantity
AZ abrasives	4,000
AZS refractories[3]	2,000
Other refractories	1,700
Chemicals	700
Glazes, opacifiers, colors	600
Total	9,000

[1]Based on incomplete reported data.
[2]Excludes oxide produced by zirconium metal producers. Includes baddeleyite.
[3]Fused cast and bonded.

Table 5.—Yearend stocks of zirconium and hafnium materials

(Short tons)

Item	1976	1977
Zircon concentrate held by dealers and consumers, excluding foundries	r33,549	21,742
Milled zircon held by dealers and consumers, excluding foundries	r5,076	4,093
Zirconium:[1]		
Oxide	r667	671
Sponge	r209	36
Ingot	66	68
Scrap	146	113
Alloys	539	244
Refractories	r4,762	4,905
Hafnium:e		
Sponge and crystal bar	40	40

eEstimate. rRevised.
[1]Excludes material held by zirconium sponge metal producers.

PRICES

The published yearend price for standard grade domestic zircon remained at $150 per ton in 1977. Prices of zirconium oxides were either unchanged or unlisted for the entire year. The prices of zirconium chemicals, zirconium powder, and hafnium metal sponge were unchanged. Zirconium sponge prices advanced slightly to a range of $5.50 to $9.00 per pound. The baddeleyite prices furnished by Ronson Metals Corp., were about 10% to 40% higher than in 1976.

In March 1977, the Government of Australia announced withdrawal of the minimum price on exports of zircon, which had been subject to export control since 1971, and to a formal floor price which had been reduced to $A115 per ton in November 1976. A more flexible control policy was to be used in which each export contract was to be viewed on its own merit. Published prices for Australian zircon dropped from $A115 to $A125 per metric ton in January to $A65 to $A70 per metric ton in December, f.o.b. Australian ports.

Table 6.—Published prices of zirconium and hafnium materials in 1977

Specification of material	Price
Zircon:	
Domestic, standard grade, f.o.b. Starke, Fla., bulk, per short ton[1]	$150.00
Domestic, 75% minimum quantity zircon and aluminum silicates, Starke, Fla., bulk, per short ton[1]	90.00
Imported sand, containing 65% ZrO_2, f.o.b., bulk, per metric ton[2]	$74.00— 79.00
Domestic, granular, 30-ton lots, from works, bags, per short ton[3]	435.00—440.00
Domestic, milled, 220-mesh, 18-ton lots, from works, bags, per short ton[3]	490.00—495.00
Baddeleyite imported concentrate:[4]	
96% to 98% ZrO_2, minus 100-mesh, c.i.f. Atlantic ports, per pound	.25— .35
99+% ZrO_2, minus 325-mesh, c.i.f. Atlantic ports per pound	.60— .80
Zirconium oxide:[3]	
Powder, commercial-reactor grade, drums, from works, bags, per pound	NA
Chemically pure white ground, barrels or bags, works, per pound	2.22
Lump electric fused, bags, 500- to 1,999-pound lots, from works, per pound	NA
Lump electric fused, bags, smaller lots, from works, per pound	NA
Milled, bags, carlots, from works, per pound	NA
Glass-polishing grade, ton lots, bags, 94% to 97% ZrO_2, from works, per pound	1.11
Opacifier grade, 3,300-pound lots, 85% to 90% ZrO_2, bags, per pound	.81
Stabilized oxide, 100-pound bags, 91% ZrO_2, milled, per pound	1.57
Zirconium oxychloride: Crystal, cartons, 5-ton lots, from works, per pound	.515
Zirconium acetate solution:	
13% ZrO_2, drums, carlots, 15-tons minimum, from works, per pound	.22
22% ZrO_2, same basis, per pound	.38
Zirconium hydride: Electronic grade, powder, drums, 100- to 990-pound lots, from works, per pound	14.50— 16.00
Zirconium:	
Powder, per pound	70.00—100.00
Sponge, per pound[5]	5.50— 9.00
Sheets, strip, bars, per pound[5]	10.00— 15.00
Hafnium:[5] Sponge, per pound	75.00

NA Not available.
[1]E. I. du Pont de Nemours & Co. Price List (effective Jan. 1, 1978). December 1977.
[2]Industrial Minerals (London). No. 123, December 1977, p. 81.
[3]Chemical Marketing Reporter. V. 213, No. 26, Dec. 26, 1977, p. 37.
[4]Ronson Metals Corp. Baddeleyite Price List. Jan. 1, 1978.
[5]American Metal Market. V. 85, No. 252, Dec. 30, 1977, p. 8.

FOREIGN TRADE

Exports of zirconium oxide decreased in 1977, while exports of zirconium ore and concentrate increased above those of 1976. Exports of wrought zirconium metal and alloys decreased in 1977 compared with 1976, while exports of unwrought zirconium and scrap increased. Hafnium was not exported.

Exports of zirconium ore and concentrate were shipped to 18 countries in 1977, and increased from 9,428 tons with a value of $2,783,994 in 1976 to 14,364 tons valued at $2,242,155. The quantity exported increased 52%, while the value of these exports decreased 19% in 1977. The average value of the zirconium ore and concentrate exported in 1977 was $156 per ton, 47% less than the 1976 value of $295 per ton. The major recipients of the exported zirconium ore and concentrate were the United Kingdom 42%, Mexico 27%, Brazil 11%, Canada 8%, and the Federal Republic of Germany 6%.

Total exports of zirconium metal decreased 15% in 1977 to 1,964,551 pounds valued at $36,827,521, 16% less than in 1976. Exports of wrought zirconium and zirconium alloys, and zirconium and zirconium alloy foil and leaf decreased 15% and 75%, respectively, in 1977. Exports of unwrought and waste and scrap zirconium increased 11% in 1977.

Exports of zirconium oxide in 1977 were 3,703,999 pounds, 30% lower than in 1976. The value of these exports was $3,845,996, 37% lower than in 1976. These zirconium oxide shipments were made to 26 countries, the five major recipients in 1977 being Japan, France, the Federal Republic of Germany, Canada, and the United Kingdom, each receiving 16% to 19%.

Imports for consumption of zirconium ores in 1977 rose about 1% to 65,204 short tons. In addition to the data in table 10, it was estimated that approximately 3,000 short tons of South African baddeleyite was imported in 1977.

The average declared value of imported zircon at foreign ports decreased 17% in 1977 to $175 per short ton, compared with $212 in 1976.

Imports for consumption of zirconium and hafnium in 1977 increased both in quantity and value in the following categories: Zirconium, wrought; zirconium, unwrought and waste and scrap; zirconium alloys unwrought; zirconium oxide; and hafnium, wrought. Imports for consumption of zirconium chemicals and unwrought zirconium alloys decreased in both quantity and value. Imports of hafnium in the unwrought and waste category increased in quantity but decreased in value in 1977.

Table 7.—U.S. exports of zirconium ore and concentrate, by country

Destination	1976		1977	
	Pounds	Value	Pounds	Value
Argentina	393,919	$104,979	94,414	$9,158
Australia	--	--	809,200	71,808
Belgium-Luxembourg	100,429	4,218	7,052	5,147
Brazil	2,827,203	1,002,444	3,170,660	214,820
Canada	2,347,886	353,507	2,224,054	231,592
Colombia	8,000	2,235	--	--
Dominican Republic	--	--	37,791	1,560
Germany, Federal Republic of	862,304	74,253	1,584,295	106,940
Israel	--	--	5,350	1,472
Italy	--	--	25,991	7,920
Japan	--	--	257,457	241,162
Korea, Republic of	135,600	43,419	49,200	14,510
Mexico	8,136,643	915,708	7,760,881	651,928
Netherlands	3,210,689	200,821	--	--
New Zealand	4,000	660	--	--
Peru	26,422	9,350	55,100	6,300
South Africa, Republic of	--	--	23,021	30,200
Surinam	--	--	438,800	9,521
Switzerland	--	--	6,156	3,078
Thailand	2,000	592	--	--
United Kingdom	800,500	71,808	12,165,300	629,747
Yugoslavia	--	--	12,384	5,292
Total	18,855,595	2,783,994	28,727,106	2,242,155

Table 8.—U.S. exports of zirconium, by class and country

Country	1976		1977	
	Pounds	Value	Pounds	Value
Zirconium and zirconium alloys, wrought:				
Argentina	9,427	$100,585	166	$1,100
Australia	382	4,474	306	6,093
Belgium-Luxembourg	117,251	4,571,126	100,965	4,544,827
Brazil	90	2,647	169	4,250
Canada	449,341	8,560,395	557,201	10,251,980
Chile	--	--	13	1,950
France	2,883	13,502	1,371	31,947
Germany, Federal Republic of	599,480	8,388,128	521,188	8,599,667
Israel	--	--	692	8,369
Italy	2,756	102,078	6,918	464,891
Japan	536,634	13,077,686	303,219	7,000,793
Korea, Republic of	298	5,228	2,079	92,700
Netherlands	21,174	272,081	49,420	736,883
Norway	--	--	6,847	32,597
Portugal	--	--	490	11,506
South Africa, Republic of	102	846	--	--
Spain	2,561	35,684	20,955	564,918
Sweden	108,820	1,629,181	126,924	1,653,035
Switzerland	--	--	68	3,726
Taiwan	103,625	3,444,617	130	4,440
Thailand	--	--	900	6,197
U.S.S.R	--	--	7,336	603,396
United Kingdom	85,859	1,191,755	37,392	453,838
Total	2,040,683	41,400,013	1,744,749	35,079,103

Table 8.—U.S. exports of zirconium, by class and country —Continued

Country	1976		1977	
	Pounds	Value	Pounds	Value
Zirconium and zirconium alloys, unwrought and waste and scrap:				
Australia	--	--	17	$2,101
Belgium-Luxembourg	9,177	$62,404	11,725	47,232
Brazil	--	--	85	2,217
Canada	1,333	24,615	8,136	54,273
France	5,951	69,299	22,083	156,314
Germany, Federal Republic of	36,682	373,525	1,165	14,723
Japan	8,190	76,001	60,819	282,320
Korea, Republic of	--	--	6,835	28,206
Netherlands	35,991	419,012	4,386	18,142
Norway	--	--	6,614	29,233
Peru	956	12,926	--	--
South Africa, Republic of	--	--	23	2,868
Sweden	4,937	83,158	--	--
Switzerland	1,132	10,188	--	--
United Kingdom	74,142	703,554	76,951	771,034
Total	178,491	1,834,682	198,839	1,408,663
Zirconium and zirconium alloy foil and leaf:				
Belgium-Luxembourg	5,393	97,119	10,544	184,710
Canada	12,317	256,782	5,005	117,679
France	315	5,580	28	1,410
Germany, Federal Republic of	488	16,155	242	6,906
Japan	61,299	61,299	34	1,220
Netherlands	--	--	100	2,582
Switzerland	--	--	427	5,405
United Kingdom	5,216	136,895	4,583	19,843
Total	85,028	573,830	20,963	339,755

Table 9.—U.S. exports of zirconium oxide, by country

Country	1976		1977	
	Pounds	Value	Pounds	Value
Argentina	146,431	$166,392	32,488	$42,641
Australia	5,227	5,048	1,957	3,850
Austria	100	806	--	--
Belgium-Luxembourg	5,396	6,927	12,498	19,258
Brazil	215,022	238,700	78,529	88,913
Canada	671,495	449,904	627,106	428,186
France	1,562,642	3,097,169	654,452	1,604,309
Germany, Federal Republic of	1,184,289	533,140	652,785	330,208
Greece	1,000	1,553	1,000	1,812
Hong Kong	3,170	6,249	6,478	6,850
India	1,000	3,005	1,248	1,898
Ireland	408	2,752	8,966	10,294
Israel	1,350	2,442	122	1,830
Italy	4,843	8,591	19,982	35,930
Japan	796,994	822,740	688,658	661,436
Korea, Republic of	--	--	2,372	7,350
Kuwait	300	552	--	--
Mexico	145,202	148,415	201,279	225,100
Netherlands	523,278	501,700	35,286	52,745
Norway	6,615	27,965	--	--
Portugal	100	2,374	2,232	2,682
South Africa, Republic of	1,462	6,142	440	826
Spain	13,331	22,409	7,000	11,928
Sweden	779	522	52,691	54,420
Switzerland	5,178	4,315	1,015	680
Taiwan	200	3,108	17,938	29,935
Trinidad and Tobago	180	2,432	--	--
Turkey	--	--	400	5,448
United Kingdom	27,244	33,372	596,637	216,647
Venezuela	2,000	2,976	--	--
Yugoslavia	2	2,500	440	820
Total	5,325,238	6,104,200	3,703,999	3,845,996

Table 10.—U.S. imports for consumption of zirconium ores, by country

Country	1975		1976		1977	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Australia	36,114	$7,602	62,604	$13,230	64,638	$11,174
Canada[1]	377	61	2,014	492	504	198
Christmas Island[1]	--	--	25	10	--	--
India	2,756	894	(2)	1	--	--
Malaysia	440	82	--	--	--	--
Mozambique	22	10	--	--	--	--
South Africa, Republic of	496	225	--	--	62	29
Total	40,205	8,874	64,643	13,733	65,204	11,401

[1]Believed to be country of shipment rather than country of origin.
[2]Less than 1/2 unit.

Table 11.—U.S. imports for consumption of zirconium and hafnium, 1977

Country	Pounds	Value
Zirconium, wrought:		
France	412,271	$5,293,548
Germany, Federal Republic of	959	30,737
Netherlands	3	670
Total	413,233	5,324,955
Zirconium, unwrought and waste and scrap:		
Canada	97,773	124,487
France	13,664	20,649
Germany, Federal Republic of	135,079	264,174
Japan	521,645	3,168,925
Sweden	19,581	22,005
United Kingdom	37,231	51,826
Total	824,973	3,652,066
Zirconium alloys, unwrought:		
France	34,241	337,060
Germany, Federal Republic of	220	5,079
United Kingdom	5,004	12,947
Total	39,465	355,086
Zirconium oxide:		
France	1,356	3,638
Germany, Federal Republic of	1,521	33,510
Japan	44	836
South Africa, Republic of	2,205	600
Switzerland	150	5,524
United Kingdom	116,844	116,214
U.S.S.R	76,015	70,003
Total	198,135	230,325
Zirconium compounds:		
Australia	88	316
France	33,069	22,744
Germany, Federal Republic of	33,926	34,055
India	15,432	27,539
Madagascar	41,802	14,028
South Africa, Republic of	766,212	213,589
United Kingdom	393,850	394,681
Total	1,284,379	706,952
Hafnium, unwrought and waste and scrap: France	72	2,088
Hafnium, wrought:		
Mexico	2,880	35,251
Spain	370	3,980
Total	3,250	39,231

WORLD REVIEW

Australia leads the world in production of zircon, which is recovered from sand mining operations along its eastern coast (53%) and in Western Australia (47%). Production of zircon, as a coproduct of rutile on the east coast, is expected to remain relatively constant due to lower grades and reserves coupled with persistent environmental problems. However, substantial zircon reserves, with coproduct ilmenite as well as rutile, have been developed in Western Australia and will assure Australia's continuing role in world zircon markets.

Zircon sand is also produced in Brazil, the People's Republic of China, India, Malaysia, the Republic of South Africa, Sri Lanka, Thailand, and the U.S.S.R.

Baddeleyite is produced in the Republic of South Africa and in Brazil and also is found in East Africa, Sri Lanka, and the U.S.S.R.

In 1977, production of zirconium ingot in market economy countries was approximately 8.5 million pounds, of which about 7.0 million pounds was used for commercial nuclear powerplants. Assuming no change in current projections for nuclear capacity, the total requirements for nuclear plants are expected to reach about 11.5 million pounds of zirconium ingot by 1985.[8]

Australia.—Zircon and other beach sand minerals continued to be in a condition of oversupply. Depressed prices for zircon and rutile coupled with metallurgical problems led to suspension of Western Mining Corp.'s mineral sands operation at Jurien Bay in Western Australia. Kibuka Mines Pty. Ltd. was reported to have suspended its Naracoopa, King Island, Tasmania, rutile-zircon operation because of the slump in the zircon market.

Following the withdrawal of export licenses for mineral concentrates mined from sands on Fraser Island, Queensland, at the end of 1976, there was continued environmental pressure to further restrict mining of sand minerals. The Queensland State Government was reportedly considering allowing only 6% of Moreton Island, near Brisbane, to be mined with all mining to cease by 1990 when the island would become a national park. Among the companies involved on Moreton Island were Dillingham Minerals, Associated Minerals Consolidated Ltd., and Mineral Deposits Ltd. In New South Wales, the State Government reportedly decided to permit sand mining to continue in national park areas for the next 5 years, after which no mining is to be permitted in national parkland.

Mining applications were reported to have been rejected on environmental grounds for the first time by the Government of Western Australia. The applications involved plans for recovering ilmenite, zircon, and other heavy minerals by dredging in Hardy inlet at Augusta by Northwest Development Corp. Ltd.

Queensland Titanium Mines Pty. Ltd. reportedly accepted the Australian Government's offer of $440,000 compensation for 1977 profits the company was denied as a result of the Government's withdrawal of export licenses for Fraser Island mineral concentrates. However, Dillingham-Murphyores Minerals, whose operations were also halted, late in 1977 rejected a $4.4 million offer and was reportedly demanding a $23.9 million settlement.

Mineral Deposits Ltd. was reported to have deferred development of its planned $15 million Agnes Waters mineral sands project in Queensland, because of the uncertainty concerning future sand mining regulations.

Tioxide Australia Pty. Ltd. and Westralian Sands Ltd. agreed on a plan to merge the two firms, giving Tioxide a 40% share in Westralian Sands.

Du Pont reportedly acquired an additional 25% interest in Allied Eneabba Pty. Ltd. through its subsidiary Du Pont (Australia), increasing its total equity in Allied Eneabba to 40%.

Canada.—Great Canadian Oil Sands Ltd. (GCOS), and Canadian Titanium Pigments Ltd., (a subsidiary of NL Industries, Inc.) were reportedly planning a joint project to recover zircon as a byproduct of GCOS synthetic crude oil production. The zircon recovery plant was to be operated by Canadian Titanium Pigments, which planned to process into zirconium oxide about 1,500 tons per day of zircon concentrate. Consideration was also being given to recovery of titanium minerals associated with the zircon.[9]

France.—Péchiney Ugine Kuhlmann Corp. was reportedly planning to double its

Table 12.—Zirconium concentrate: World production, by country[1]

(Short tons)

Country	1975	1976	1977[p]
Australia	[r]421,322	461,227	438,086
Brazil	3,224	3,371	[e]3,500
India[e]	11,400	11,400	11,400
Korea, Republic of	[e]22	--	--
Malaysia[2]	11,417	3,449	1,300
South Africa, Republic of	12,780	12,403	13,551
Sri Lanka	43	11	[e]10
Thailand	422	61	[e]60
United States	W	W	W
Total	[r]460,630	491,922	467,907

[e]Estimate. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data.
[1]No data are available on production, if any, within the centrally-planned economy nations, nor is there any basis for the formulation of reliable estimates of output levels.
[2]Exports (production not officially reported; exports believed to closely approximate total output).

production of zirconium sponge by 1979. Pechiney reportedly uses TWCA zirconium oxide for metal production, and produced an estimated 1.2 million pounds of sponge in 1977.

Japan.—Sumitomo Metal Industries, Ltd., was expected to treble its Zircaloy tube production from 328,000 feet per year to 984,000 feet per year. Zircaloy tube manufacturers in Japan reportedly were expanding their production facilities in a belief that nuclear powerplants will account for 27.6% of electric power generation in 1985 compared with 7.5% in 1975. Kobe Steel, Ltd. and Mitsubishi Metal Corp. reportedly each has a Zircaloy tube plant of 984,000-feet-per-year capacity, and Kobe was said to be planning to raise its production level to 1,968,000 to 2,953,000 feet by 1980.[10]

Zirconium Industry Co., Ltd., in Hiratsuka, was said to be converting TWCA reactor-grade zirconium oxide to sponge metal, which is returned to TWCA for melting and fabrication. Zirconium Industry was reportedly expanding capacity in 1978.[11]

Sierra Leone.—Sierra Rutile Ltd. (owned 85% by Bethlehem Steel Corp. and 15% by Nord Resources Corp.) was reportedly progressing on schedule with development of the former Sherbro Minerals property. Initial output was expected in late 1978, with a planned annual production rate of 110,000 tons of rutile, 27,000 tons of ilmenite, and 11,000 tons of zircon.

South Africa, Republic of.—Shipments of zircon and rutile were started from the Richards Bay mineral sands operation in Natal. Richards Bay Minerals will manage the combined affairs of Tisand (Pty.) Ltd. and Richards Bay Iron and Titanium (Pty.) Ltd., the companies responsible for operating the new mine facilities and the ilmenite smelting plant, respectively. An 85% TiO_2 slag was to be produced at the smelter beginning in March 1978. Planned annual production rates from Richards Bay Minerals were about 127,000 tons of zircon, 62,000 tons of rutile, 440,000 tons of high-TiO_2 slag, and 239,000 tons of low-manganese pig iron. The Richards Bay production was expected to aggravate the oversupply situation in zircon and rutile, dampening hopes for early price recovery in these commodities. It has been pointed out that under these circumstances there will be a tendency for buyers to become more selective in purchasing zircon. This was demonstrated by a trend in Australia, where the substantial stock increases in 1977 almost all occurred on the west coast where zircon quality is generally lower than on the east coast.[12]

Sri Lanka.—The processing facilities of the Sri Lanka Mineral Sands Corp. at Pulmoddai were expanded and integrated, including the transfer of the rutile-zircon plant from China Bay and the installation of new equipment. Annual installed capacity was reportedly about 100,000 tons of ilmenite, 14,000 tons rutile, and 8,000 tons zircon. Estimated reserves were 2.1 million tons ilmenite, 276,000 tons rutile, and 287,000 tons zircon.

TECHNOLOGY

Published results of Bureau of Mines research on zirconium included papers on the effect of oxygen pressure on the sputtering of zirconium,[13] and on stabilization of silver reflecting films with light undercoatings of Ti, Zr, and Cr.[14] Other Bureau research pertaining to zirconium and hafnium included investigation of physical beneficiation methods for recovering zircon and other heavy minerals from the black sands resulting from dredging and sand and gravel operations on the west coast, development of improved technology for recovering hafnium-free zirconium oxide from zircon sands, and cooperative research on the metallurgy of zirconium, hafnium, and other reactive and refractory metals involving collaboration with Teledyne Wah Chang Albany, the Zirtech division of Kawecki Berylco Industries, Inc., Precision Castparts Corp., and Oregon Metallurgical Corp.

An extensive discussion was published on the use of the Reichert Cone gravity concentrator for recovery of mineral concentrates from low-grade ores.[15] A paper on minerals used in the foundry industry reviewed the properties of the main refractory sand materials, and pointed out the advantages and disadvantages of zircon compared with other materials, such as chromite.[16]

A sensor composed of yttria-stabilized zirconia coated with platinum on the inside and outside surfaces was being marketed to continuously gage the oxygen content of furnace atmospheres. The 200-millimeter-long, test-tube-shaped sensors are mounted in small refractory blocks at selected positions on the furnace wall, where their external surfaces come into contact with furnace gases; the inside surfaces are in contact with external air which serves as a reference.[17] The same principle has been applied to develop zirconia-electrolyte exhaust gas sensors for automobiles.[18]

Product yields in the casting of high-purity uranium-titanium ingots were increased by 30% by lining the graphite crucible with a protective coating of plasma-sprayed, lime-stabilized zirconium oxide. National Lead of Ohio, Ferndale, Ohio, claimed that the coating keeps carbon migration low, and saves $40 in titanium costs for each ingot poured.[19]

Surftech Corp., Hollis, N.H. was to begin marketing hafnium carbide-coated cutting tool inserts that were expected to outperform uncoated types at no extra cost.[20]

Investigation of the use of stabilized zirconia in the magnetohydrodynamic (MHD) process for generating electricity was continued as part of an MHD program being carried out by the Department of Energy in cooperation with the National Bureau of Standards and several private laboratories, and under a joint research agreement with the U.S.S.R.[21] Zirconia may find application in the air preheater section where very large amounts would be required for each plant, and for electrodes in the generator section.[22] Zirconia is well suited for these applications because of its ability to withstand high temperature, and because it has adequate high temperature electrical conductivity. For electrode use, zirconia doped with cerium oxide is used, since the cerium imparts electronic conduction which is preferred in MHD over ionic conduction characteristic of conventional stabilized zirconias. Ionic conduction makes stabilized zirconia useful for fuel cells.

---

[1]Physical scientist, Division of Nonferrous Metals.

[2]Chemical Marketing Reporter. FDA Puts Final Ban on Zirconium Products. V. 212, No. 8, 1977, pp. 3, 64.

[3]Hayes, J. Wah Chang Series of Articles. The Oregon Statesman Capital J., Salem, Oreg., Dec. 25-31, 1977.

[4]Smith, Q. Company Owning Wah Chang Plans Second Zirc Plant. Albany Democrat-Herald, Oct. 13, 1977, p. 1.

[5]Mari, A. Teledyne Wah Chang Will Build Another Zirconium Producing Plant. Am. Metal Market, v. 85, No. 208, Oct. 26, 1977, p. 10.

[6]U.S. Bureau of the Census. Refractories. Series MQ-32C, quarterly, 1977.

[7]DePoix, V. Zirconium: Growth Rate Suffers Further Setbacks. Eng. and Min. J., v. 179, No. 3, March 1978, p. 134.

[8]Work cited in footnote 7.

[9]Cotter, N. P. Canada's First Zircon Plant Planned for Alberta. Northern Miner, v. 62, No. 43, Jan. 6, 1977, p. 24.

[10]Japan Metal Bulletin. Sumitomo to Treble Zircaloy Tube Output. No. 3475, Jan. 18, 1977, p. 1.

[11]Work cited in footnote 7.

[12]Bartle, W. W. Mineral Sands Markets—The Impact of Richards Bay. Presented at 3rd Industrial Minerals Internat. Cong., Paris, France, Mar. 13-15, 1978.

[13]Blickensderfer, R., R. L. Lincoln, and P. A. Romans. Reactive Sputtering of Zirconium With Oxygen. Thin Solid Films, Elsevier Sequoia S.A., Lausanne, Switzerland v. 37, 1976, pp. L73-L75.

[14]Wood, F. W., and R. Blickensderfer. Stabilization of Absorber Stacks Containing Zr or Ti Compounds on Ag. Pres. at Internat. Conf. on Metallurgical Coatings, San Francisco, Calif., Apr. 5-8, 1976; pub. in Thin Solid Films, Elsevier Sequoia S.A., Lausanne, Switzerland, v. 39, No.1, December 1976, pp. 133-142.

[15]Paterson, O. D. How Many Low Grade Ores Are Now Being Recovered by Gravity Concentration. World Min., v. 30, No. 8, July 1977, pp. 44-49.

[16]Ashby, G. Minerals in the Foundry Industry. Industrial Minerals, No. 124, January 1978, pp. 29-45.

[17]Financial Times. Oxygen Test Will Help Save Fuel. No. 27316, July 8, 1977. p. 13.

[18]Wilhelm, R. V., Jr., and D. S. Eddy. $MgO-Y_2O_3$-Stabilized ZrO_2 Ceramics in Exhaust Gas Sensor. Am. Ceram. Soc. Bull., v. 56, No. 5, 1977, pp. 509-512.

[19]American Metal Market. Nat'l Lead Says Spraying Process Hikes Uranium-Titanium Ingot Yield. V. 84, No. 16, Jan. 24, 1977, p. 29.

[20]———. Surftech Preparing to Market Hafnium Carbide-Coated Inserts. V. 84, No. 11, Jan. 17, 1977, p.4.

[21]Levi, E. MHD's Target: Payoff by 2000. Inst. for Electr. & Electr. Eng. Spectrum, May 1978, pp. 46-51.

[22]Frederikse, H. P. R., and W. R. Hosler. Electrodes and Insulators: Design and Materials Considerations. 16th Symp. on Engineering Aspects of Magnetohydrodynamics. The University of Pittsburgh Pa., May 16-18, 1977, pp. IV.4.22-IV.4.28.

Minor Metals

By Staff, Division of Nonferrous Metals

CONTENTS

ARSENIC[1]

Legislation and Government Programs.—On February 4, 1977, the Occupational Safety and Health Administration (OSHA) issued its final environmental impact statement on the occupational use of inorganic arsenic.[2] The statement examined the ramifications of the original proposed standard published in the Draft Environmental Impact Statement (DEIS).[3] The DEIS proposed to limit the exposure of employees to no more than 4 micrograms of arsenic per cubic meter of air as determined on an 8-hour-time-weighted average basis; or a ceiling limit of 10 micrograms of arsenic per cubic meter of air based on a 15-minute sampling period. The purpose of the proposed regulation is to reduce the risk of smelter workers developing lung and skin cancer as a result of exposure. A comprehensive study compiled by the Committee on Medical and Biologic Effects of Environmental Pollutants concluded that "there is strong epidemiologic evidence that inorganic arsenic is a skin and lung carcinogen in man."[4]

In April 1977, the Environmental Protection Agency (EPA) served notice to ASARCO Incorporated that its Tacoma copper smelter and associated arsenic-producing facilities were in violation of State laws which limit sulfur dioxide and particulate matter emissions. This notice followed the Washington State Pollution Control Hearing Board overturning a prior ruling by the Puget Sound Air Pollution Control Agency (PSAPCA) which had permitted a 5-year variance from the State of Washington air quality standards. In December 1977, ASARCO appealed in court the decision of the Hearing Board.

Domestic Production.—Arsenic trioxide (95% As_2O_3), white arsenic, was produced only at the Tacoma, Wash., copper smelter of ASARCO Incorporated. Production data cannot be published. In 1977, production dropped 28%, shipments increased 15%, and stocks declined 90%, relative to 1976.

ASARCO processes arsenic residues and high-arsenic copper concentrates from both imported and domestic sources. In the last 5 years, domestic arsenic trioxide production has declined partly as a result of environmental constraints. Implementation of proposed arsenic emission standards could further curtail output of arsenic at the ASARCO Tacoma plant.

ASARCO began producing arsenic metal in 1974 and has steadily been increasing production since that time.

Consumption and Uses.—The most important commercial arsenic compound is white arsenic. Apparent consumption of white arsenic in the United States increased in 1977. Major uses of arsenic were in the manufacture of agricultural chemicals, glass and glassware, industrial chemicals, copper and lead alloys, and pharmaceuticals.

Agricultural chemicals include arsenical pesticides (insecticides and herbicides) and arsenical crop desiccants. Arsenical pesticides account for a very small percentage of the total pesticide market. Insecticides still in use today but of minor importance include calcium and lead arsenate and Paris green (copper acetoarsenite). The U.S. Department of Agriculture no longer reports domestic production of these chemicals. The growing usage of the major organic arsenical herbicides include monosodium methanearsonate (MSMA), disodium methanearsonate (DSMA), and cacodylic acid (dimethylarsinic acid). In addition, the usage of arsenic acid as a desiccant to prepare cotton for harvesting has increased in the last decade. Estimated consumption of methanearsonates in 1974 was 8,000 to 10,500 tons; and estimated consumption of arsenic acid in 1975 was 6,100 tons.[5]

The chief industrial use of arsenic is in wood preservatives such as chromated copper arsenate (CCA) and fluor chrome arsenate phenol (Wolman salts and osmosalts). Usage of CCA has increased every year since 1967, reaching a level of 8,546 tons in 1976, the latest year for which data are available. Consumption of fluor chrome arsenate phenol steadily dropped between 1969 and 1975, but increased in 1976 to 1,223 tons.

Other uses of arsenic are as a decolorizer in glass manufacture, a feed additive for poultry, a nonferrous alloying agent, and as a component of certain pharmaceuticals, semiconductors, and electronic devices. In the glass industry, cerium oxide and selenium, as well as arsenic, are being used as decolorizers.

Prices.—The price of refined white arsenic, 99.5%, at New York docks, remained stable at 20 to 21 cents per pound throughout 1977. Refined white arsenic, 99%, at Laredo, increased from 17 to 18 cents per pound on January 1, 1977. The price of crude white arsenic, 95%, at Tacoma, remained unchanged at 13 cents per pound throughout 1977. Tacoma's price of arsenic metal rose from $1.75 per pound to $1.90 per pound on September 9, 1977. Arsenic metal was quoted in London at £2,950 per metric ton, unchanged since December 1976.

Table 1.—U.S. imports for consumption of white arsenic (As_2O_3) content, by country

Country	1975		1976		1977	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Belgium-Luxembourg	--	--	1	$1	44	$13
Canada	--	--	--	--	22	10
China, People's Republic of	--	--	2	1	--	--
France	595	$261	462	163	1,352	420
Germany, Federal Republic of	6	5	([1])	4	1	4
Japan	--	--	--	--	140	57
Mexico	3,174	913	3,793	1,354	3,089	1,009
Peru	66	11	--	--	--	--
South-West Africa, Territory of	970	252	--	--	--	--
Sweden	7,172	2,973	3	4	1,323	443
Switzerland	30	11	--	--	--	--
United Kingdom	--	--	1	1	10	6
Total	12,013	4,426	4,262	1,528	5,981	1,962

[1]Less than 1/2 unit.

Table 2.—U.S. imports for consumption of arsenicals, by class

(Thousand pounds and thousand dollars)

Class	1975		1976		1977	
	Quantity	Value	Quantity	Value	Quantity	Value
White arsenic (As_2O_3)	24,027	4,426	8,524	1,528	11,962	1,962
Metallic arsenic	966	2,716	575	1,735	713	1,381
Sulfide	([1])	([1])	550	110	--	--
Sodium arsenate	1	5	39	17	2	1
Arsenic acid	([1])	1	40	67	765	180
Arsenic compounds n.e.c	152	90	81	57	2,218	686

[1]Less than 1/2 unit.

Foreign Trade.—U.S. imports of white arsenic increased from 4,262 tons in 1976 to 5,981 tons in 1977, the first increase since 1974. Mexico supplied 52%, France 23%, and Sweden 22% of total white arsenic imports. Of the 764,842 pounds of arsenic acid imported, 576,128 pounds was received from Mexico and 188,714 pounds was received from the United Kingdom. All of the lead arsenate (220,460 pounds) came from the Republic of Korea and all of the sheep dip (2,646 pounds) was received from New Zealand. Of the 2,376 pounds of sodium arsenate imported, 1,102 pounds was from the United Kingdom, 1,054 pounds was from Hong Kong, and the remaining 220 pounds was from the Federal Republic of Germany. Imports of other arsenic compounds totaled 2,217,669 pounds, with the United Kingdom supplying 2,216,746 pounds; the Federal Republic of Germany, 893 pounds; Japan, 20 pounds; and Belgium-Luxembourg, 10 pounds.

Arsenic metal imports increased from 288 tons in 1976 to 356 tons in 1977. Sweden shipped 329 tons; Canada, 25 tons; and Japan, 2 tons. Smaller quantities were received from the Federal Republic of Germany, the Netherlands, and the United Kingdom.

Tariff.—Arsenic oxide (white arsenic) and arsenic sulfide enter the United States duty free. A duty of 2 cents per pound was applicable to arsenic metal, and 5% ad valorem to other arsenic compounds.

Table 3.—White arsenic (arsenic trioxide):[1] World production by country

(Short tons)

Country[2]	1975	1976	1977[p]
Brazil	14	(3)	--
France[e]	[r]7,300	[r]7,600	7,600
Germany, Federal Republic of[e]	[r]350	[r]400	400
Japan	66	66	--
Korea, Republic of	[e]110	778	541
Mexico	6,747	4,591	[e]4,400
Peru	1,461	870	[e]880
Portugal	282	306	265
South-West Africa, Territory of[4]	7,345	[e]7,700	[e]8,000
Sweden	12,884	7,994	7,412
U.S.S.R.[e]	8,100	[r]8,200	8,300
United States	W	W	W
Total	[r]44,659	38,505	37,798

[e]Estimate. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data.

[1]Including calculated arsenic trioxide equivalent of output of elemental arsenic and arsenic compounds other than white arsenic, where inclusion of such materials would not duplicate reported white arsenic production.

[2]In addition to the countries listed, Austria, Belgium, the People's Republic of China, Czechoslovakia, the German Democratic Republic, Finland, Hungary, Southern Rhodesia, the United Kingdom, and Yugoslavia have produced arsenic and/or arsenic compounds in previous years, but information is inadequate to make reliable estimates of output levels.

[3]Revised to zero.

[4]Output of Tsumeb Corp. Ltd. only.

CESIUM AND RUBIDIUM[6]

Domestic Production.—There was no domestic production of cesium- or rubidium-bearing minerals during 1977. Cesium and its compounds were produced from imported cesium ore (pollucite). ALKARB, a residue from the processing of lithium ore in previous years, and lepidolite were the sources of domestically produced rubidium and its compounds. Compared with 1976 levels, total cesium compound production about doubled while rubidium compound production more than doubled.

The following companies were sources of cesium and rubidium metal and chemicals: Callery Chemical Co., Callery, Pa.; Kawecki Berylco Industries, Inc., Revere, Pa.; Kerr-McGee Corp., Trona, Calif.; and Research Organic-Inorganic Chemical Co., Sun Valley, Calif.

Consumption and Uses.—Data pertaining to consumption and end use distribution of cesium and rubidium metals and compounds were not available. These materials found commercial application in the manufacture of pharmaceuticals, ultracentrifuge separation of organic compounds, and in electronic apparatus such as scintillation counters, photomultiplier tubes, and photoelectric cells. Cesium, rubidium, and their compounds can be substituted for each other in some end uses.

While there were no large-scale commercial uses for cesium, cesium metal and compounds have been used in experimental magnetohydrodynamic (MHD) power generators. If MHD electrical generation is successfully developed, demand for cesium may increase in the future.

Prices.—The yearend American Metal Market quotation for cesium metal, 99+% purity, was $275 to $325 per pound. At yearend the Metal Bulletin quoted the nominal price for pollucite concentrates containing a minimum of 24% Cs_2O, f.o.b. source, at $12.40 to $13 per metric ton unit (22.046 pounds of Cs_2O). Rubidium metal, 99.5% purity, according to industry sources, was priced at $250 to $300 per pound.

Table 4.—Prices of selected cesium and rubidium compounds in 1977

Item	Base price per pound[1]	
	Technical grade	High-purity grade
Cesium bromide	$28	$65
Cesium carbonate	29	67
Cesium chloride	30	68
Cesium fluoride	35	75
Cesium hydroxide	35	75
Rubidium carbonate	45	75
Rubidium chloride	46	76
Rubidium fluoride	51	83
Rubidium hydroxide	51	83

[1]Excludes packaging cost, 50- to 100-pound quantities, f.o.b. Revere, Pa.

Source: Kawecki Berylco Industries, Inc.

Foreign Trade.—Pollucite import data were not available. Imports of cesium compounds increased from 4,506 pounds valued at $197,553 in 1976, to 11,486 pounds valued at $476,011 in 1977. No cesium or rubidium metal was imported during the year.

Table 5.—U.S. imports for consumption of cesium compounds in 1977, by country

Country	Cesium chloride		Cesium compounds, n.s.p.f.	
	Pounds	Value	Pounds	Value
Canada	60	$2,079	--	--
Germany, Federal Republic of	3,148	131,561	7,832	$328,648
United Kingdom	413	12,926	33	797
Total	3,621	146,566	7,865	329,445

Technology.—The Department of Energy and the Environmental Protection Agency funded research to investigate the potential of using gamma radiation to reduce pathogen levels in sewage sludge.[7] Cesium-137 extracted from reactor waste would be the radiation source. Reportedly, sludge disposal cost could be lowered from $200 to $300 per dry ton for landfill disposal to near zero if the radiation processing plus composting procedure could be used.

GERMANIUM[8]

Consumption of germanium in infrared optical systems registered a substantial gain in 1977, but the declining use of germanium in transistors and light-emitting diodes restricted overall demand to the same level as the past 7 years. Demand for germanium in other traditional or experimental applications continued at about the same level as the previous years.

Domestic Production.—Eagle-Picher Industries, Inc. at Quapaw, Okla., was the sole domestic producer of primary germanium. Most of the output was extracted from stockpiled smelter residues produced in past years from concentrates derived from zinc mining operations in the Kansas-Missouri-Oklahoma district. Domestic production was supplemented by secondary material or new scrap generated during the manufacture of electronic devices and electro-optical components.

Kawecki Berylco Industries, Inc., Revere, Pa., and Atomergic Chemetals Co., Plainview, N.Y., produced germanium from domestic secondary materials as well as imported metal, oxide, and scrap.

An estimated 35,000 pounds of germanium was produced from domestic sources during 1977. Based on the U.S. producer price for refined germanium the value of production was $5 million.

Consumption and Uses.—Germanium usage in infrared optical systems increased substantially during 1977. Forward-looking infrared (FLIR) detection devices which usually employ several large germanium lenses are finding increasing application in various military guidance systems. The demand for germanium as a substrate upon which gallium arsenide phosphide is deposited to form an essential part of light-emitting diodes declined slightly from the 1976 level. The production of germanium semiconductors for use in transistors and signal diodes continued to decline as less expensive, more versatile silicon devices were developed. However, several manufacturers of heavy-current power devices anticipated a growing demand for germanium power devices which can operate with higher power efficiencies at lower voltage than similar mechanisms employing silicon. Germanium was also used in single-crystal gamma-radiation detectors, glass microscope lenses, petroleum catalysts, fluorescent lamp phosphors, and special purpose alloys. Germanium dioxide has been used in Europe as a catalyst in polyester fiber manufacturing. The development of glass fiber light guides for long-distance telecommunications was advanced by the use of high-index germania-core fibers which were found to achieve the lowest practical attenuation or optical resistance of any materials tested thus far. The fiber optic system which replaces conventional wire conductors could provide a compact, inexpensive, short-circuit-free transmission medium which is not susceptible to distortion by an electromagnetic field, and which cannot be tapped using currently available devices. Research continued on energy-saving superconductors utilizing thin films of germanium and columbium, and photovoltaic solar cells which employ germanium as a substrate upon which photoconductive materials may be deposited.

The estimated consumption pattern for various end uses of germanium was about 60% in electronics, 36% in instruments and optics, and about 4% for other uses including research.

Prices.—In February 1977 the price of domestically produced germanium was increased for the first time since 1970. Zone-refined germanium metal was raised from $293 to $316 per kilogram; electronic-grade germanium dioxide was increased from $167.50 to $177.50 per kilogram. New York dealer prices for imported germanium, unchanged since 1975, were $174.50 and $330 per kilogram for dioxide and metal, respectively.

Foreign Trade.—During 1977, 5,884 pounds of unwrought germanium having a value of $1.05 million was imported for domestic consumption. Of the major source countries, the U.S.S.R. accounted for 31% of the total followed by Switzerland, 27%; the Federal Republic of Germany, 20%; and Belgium-Luxembourg, 17%. Seventy-three percent of the total import value was attributed to imports from Belgium-Luxembourg; this higher unit value represented expensive high-purity monocrystalline material whereas other imnorts were largely industrial scrap and waste. Only 20 pounds of wrought material were imported during the year.

Table 6.—U.S. imports for consumption of germanium in 1977, by country

Country	Quantity (pounds)	Value
Unwrought, and waste and scrap:		
Belgium-Luxembourg	994	$766,654
Denmark	134	15,919
Germany, Federal Republic of	1,206	102,808
Switzerland	1,567	20,531
United Kingdom	165	9,895
U.S.S.R	1,818	138,239
Total	5,884	1,054,046
Wrought:		
Belgium-Luxembourg	19	4,080
Germany, Federal Republic of	1	1,005
Total	20	5,085

World Review.—As a byproduct of base metal mining, mainly zinc, primary germanium supplies are dependent upon the rate of production and recovery of the host metal. Zaire, the U.S.S.R., the Federal Republic of Germany, France, Italy, and the United States are the major sources of germanium-bearing raw materials. The largest reserves of germanium are located in the Shaba (formerly Katanga) Province of Zaire, and germanium-bearing concentrates from that country have traditionally been refined in Belgium by Métallurgie Hoboken-Overpelt, S.A./N.V. However, due to recent political difficulties in Zaire, no germanium-bearing material has been reported to have moved from Zaire to Belgium during the past 2 years. The Belgium refiner also relied upon material derived from mines in Italy as well as stockpiled material from Zaire. Other germanium refineries are located in the Federal Republic of Germany, the Netherlands, France, Italy, and Japan.

The mines of the Tsumeb Corp. in the Territory of South-West Africa contain some of the richest deposits of germanium in the world. Production of germanium metal ceased in the Territory in 1970, and since then most of the germanium has been recovered from South-West African blister copper exported to the Federal Republic of Germany.

World production of germanium during 1977 was estimated at 198,000 pounds. Of this production, the United States accounted for approximately 35,000 pounds. Japan was reported to have refined 28,827 pounds of metal and 35,527 pounds of oxide, all of which was probably refined from domestic coal ash and imported raw materials, waste, and scrap. Austria reported that 8,774 pounds of germanium were contained in zinc ores produced during the year.

Technology.—The second International Conference on Organometallic and Coordination Chemistry of Germanium, Tin, and Lead was held in England on July 12-15, 1977. A paper was presented on organosilicon and organogermanium compounds.[9]

INDIUM[10]

Domestic Production.—Indium was produced by ASARCO Incorporated at its Denver, Colo. plant and by Indium Corp. of America in Utica, N.Y. NJZ Alloys, Inc., a partnership formed by The New Jersey Zinc Co. and Indium Corp. in 1977, commenced production at the Palmerton, Pa. plant of New Jersey Zinc. Further refining and marketing was provided by Indium Corp. Total domestic production, the data for which were withheld to avoid disclosing company proprietary information, remained about the same as that of 1976.

Consumption and Uses.—Indium consumption slackened somewhat in 1977. The metal however, continued to find application in numerous uses. Estimated consumption patterns for indium were instruments, 30%; solders, alloys, and coatings, 40%; electronic components, 10%; and research and other uses, 20%.

Stocks.—Producer stocks remained relatively constant throughout the year.

Prices.—The price in January was $10 to $10.25 per troy ounce, and declined in several steps to $8.50 to $10 per troy ounce by yearend.

Foreign Trade.—Imports of indium in 1977 were nearly the same as those of 1976, and still well below the high levels of the 1970-74 period. The value of indium imports, at $2.2 million, was the highest in recent years and reflected higher indium prices. Peru remained the dominant supplier, with the United Kingdom moving into second place, followed by Canada and Japan.

The duty on unwrought, waste and scrap indium has been 5% ad valorem since January 1, 1972 for the most favored nations. Duties on waste and scrap have been suspended until June 30, 1978. The duty on wrought indium was 9%. Statutory duties for the U.S.S.R. and the German Democratic Republic were 25% ad valorem on unwrought and 45% ad valorem on wrought metal.

Table 7.—U.S. imports for consumption of indium, by country

(Thousand troy ounces and thousand dollars)

Country	1975		1976		1977	
	Quantity	Value	Quantity	Value	Quantity	Value
Unwrought, and waste and scrap:						
Belgium-Luxembourg	2	9	(1)	1	4	22
Canada	12	64	76	472	60	524
France	--	--	12	18	--	--
German Democratic Republic	--	--	27	174	--	--
Germany, Federal Republic of	37	201	--	--	19	186
India	--	--	3	18	--	--
Japan	22	130	50	398	24	175
Netherlands	--	--	16	76	20	137
Peru	21	116	70	476	89	865
Switzerland	(1)	3	--	--	--	--
U.S.S.R	1	2	--	--	--	--
United Kingdom	19	102	20	168	70	294
Total	114	627	274	1,801	286	2,203
Wrought:						
Canada	--	--	(1)	4	(1)	2
France	--	--	--	--	(1)	1
Japan	(1)	(1)	--	--	--	--
Peru	--	--	--	--	5	43
South Africa, Republic of	--	--	16	3	--	--
United Kingdom	(1)	2	--	--	(1)	5
Total	(1)	2	16	7	5	51

[1]Less than 1/2 unit.

World Review.—Sporadic production patterns again characterized the key indium producers. Cominco Ltd., normally a dominant factor among world producers and Canada's only indium producer, reduced indium output sharply to 36,000 troy ounces in 1977, mainly due to lower indium content in their ore supplies. Belgium's only indium producer, Métallurgie Hoboken-Overpelt S.A./N.V., experienced a significant increase in indium output in 1977. The U.S.S.R. is known to be a major indium producer; however, little information on specific plant locations and quantities produced is available. A new indium production unit at Tashkent, in the Republic of Uzbek, recently started operations.

RADIUM[11]

The major use for radium was in therapeutic treatment of cancer. Replacement of radium by other radioisotopes continued.

Domestic Production.—There was no reported radium production in the United States during 1977. Imports, withdrawals from company stocks, and reprocessing, supplied sufficient radium to meet the small domestic demand. Radium Chemical Co., Inc., New York, was the main domestic dealer.

Consumption and Uses.—Radium was mostly used in the therapeutic treatment of cancer. A few tens of millicuries of radium were consumed in the production of home alarm smoke detectors. Other uses of radium were as a source of gamma radiation, used in soil moisture density gages, and in static eliminators, although polonium-210 was replacing radium. One traditional use of radium, as an illuminator on alarm clocks, was almost completely replaced by tritium. Radium is also used in calibration sources and laboratory standards.

About 900 grams of radium were used in the United States, and around 100 grams were stored in a Government-owned depository in Alabama during 1977. About 74 requests for deposits containing a total of 11,143 milligrams of radium were received by the Environmental Protection Agency.

Prices.—Radium prices, per milligram unencapsulated, were quoted by Radium Chemical Co., as follows: Less than 100 milligrams $26.50; 100 to 199 milligrams, $25; 200 to 499 milligrams, $22; 500 milligrams to 5 grams, $18. There was no increase from the 1976 prices.

Foreign Trade.—Official trade statistics did not report trade in radium, as such, but included radium with other radioactive commodities. Belgium was believed to be the principal source of imported radium.

World Review.—Information on radium in world markets was not readily available. The largest radium producer and supplier was thought to be the Belgian company Union Minière S.A. Small quantities of radium were also apparently produced in Canada, the United Kingdom, the Federal Republic of Germany, and in some centrally controlled economy countries. The industrial nations consumed most of the radium in use patterns similar to the United States.

Technology.—During uranium extraction nearly all the radium remains in the mill tailings, causing storage and possible environmental problems. The Environmental Protection Agency, the Nuclear Regulatory Commission, U.S. Department of Energy, and the Federal Bureau of Mines continued studying potential health hazards, and possible seepage and erosional problems of radioactive uranium tailings. The effects of phosphate mineralization and the phosphate industry on radium in ground water of central Florida were also studied.[12] Methods of removal of radium from water supplies were discussed.[13]

Radium content of spring water was measured in an effort to locate uranium deposits.[14] Radium-226 was recommended for use as a calibration standard for lithium-drifted germanium spectrometers.[15]

SCANDIUM[16]

Production of scandium metal nearly doubled in 1977 compared with the 1976 level. There was no domestic mine production during the year; producers' inventories and imports were adequate to meet demand. Shipments during the year increased from the 1976 level.

Domestic Production.—There was no domestic mine production of scandium. Research Chemicals, Div. of Nucor Corp., Phoenix, Ariz., and Atomergic Chemetals Corp., Plainview, N.Y., produced scandium metal and compounds. During 1977, production of scandium metal nearly doubled and shipments tripled from the 1976 level.

Consumption and Uses.—Research and development continued to be the major application of scandium. A system for filtering the neutron beams at the High Flux Beam Reactor at Brookhaven National Laboratory at Upton, N.Y. was described.[17] The system used filters primarily composed of scandium and iron, which reduced the gamma-ray and thermal neutron contamination of the external beams. Scandium metal was used in high-intensity mercury vapor lamps, to strengthen magnesium alloys, and as a tracer in petroleum production.

Prices.—During 1977, prices of scandium metal were quoted by Research Chemicals as follows:

Metal	Per gram, 1 to 99 grams	Per gram, 100 to 453 grams
Ingots	$10.50	$8.00
Powder	11.50	10.35
Chips	11.50	10.35
Distilled	19.00	15.00
Oxide:		
99.99%	5.00	4.00
99.9%	3.50	2.80
Salts [1]	2.50	2.00

[1]Salts include acetates, carbonates, chlorides, nitrates, and oxalates in most stable, hydrous form produced from oxides of 99.9% minimum purity.

Scandium was also available in sheet foil of 0.001 to 0.05 inch thick at $22.00 to $60.25 per square inch, in lots of 1 to 10 square inches.

Foreign Trade.—There are no official U.S. foreign trade statistics for scandium. Data on scandium were included in data for other minerals and metals, n.e.c.; however, scandium trade was believed to be minor. Based on available information, Australia and the centrally controlled economy countries were the principal suppliers of scandium-bearing raw materials.

World Review.—Investigations of samples of rauhaugite and rodberg from the Fen area of southern Norway indicated the presence of larger than normal amounts of scandium.[18] The study concluded that carbonatites could become a future source of scandium if demand were to increase.

Technology.—Synthesis of a new olivine, $LiScSiO_4$, and the presence of a solid-solution series between $MgSiO_4$ and $LiScSiO_4$ proved the direct Sc^{3+} substitution for Mg^{2+} in silicates.[19] Charge balance was maintained by the simultaneous entry of Li^+ into the Mg^{2+} octahedra.

A zirconia-scandia system was studied using X-ray diffraction, differential thermal, and melting point analyses.[20] Addition of scandia decreased the temperature of the monoclinic-tetragonal transformation in zirconia. The temperature range over which the transformation occurred increased with heating and cooling when the scandia content was increased.

A patent was issued for a three-layer silicon carbide light-emitting semiconductor in which the intermediate layer was doped with luminescence activators of the donor type (oxygen or nitrogen) and the acceptor type (scandium, boron, beryllium, aluminum, or gallium).[21] The three-layer structure increased the brightness, lowered the device rejection rate, and extended the operating temperature range.

The elastic properties of scandium sesquioxide were discussed.[22]

SELENIUM[23]

Despite an industry-wide copper strike in 1977, domestic production of selenium increased 25% to 499,475 pounds while shipments to consumers decreased 4% to 353,098 pounds compared with 1976. This led to the highest level of yearend producer stocks since 1968. Producer stocks were 323,119 pounds in 1977, an increase of 83% over those of 1976. Net imports of 518,063 pounds and apparent consumption of 871,161 pounds represented declines for the second and third consecutive years. Japan was the largest single producer of refined selenium and contributed 33% of the world's total output of 3.02 million pounds.

Table 8.—Salient selenium statistics

(Pounds of contained selenium)

	1973	1974	1975	1976	1977
United States:					
Production, primary	795,731	644,055	357,722	400,609	499,475
Shipments to consumers	851,200	670,875	284,479	369,588	353,098
Imports for consumption	553,000	837,191	889,320	811,257	585,673
Exports	[e]264,000	166,206	117,596	193,484	67,610
Shipments from Government stocks	228,689	223,606	6,169	2,470	--
Apparent consumption	1,368,889	1,565,466	1,062,372	989,831	871,161
Stocks, yearend, producer	105,950	79,130	152,373	176,742	323,119
Producers' price, average per pound, commercial and high-purity grades	$9.25-$12.36	$16.53-$19.19	$18-$22	$18-$22	$17.12-$20.86
World: Refinery production	2,682,000	2,667,679	[r]2,608,356	[r]2,501,100	3,018,569

[e]Estimate. [r]Revised.

Domestic Production.—In the United States in 1977 primary selenium was recovered at three copper refineries; AMAX Copper, Inc., Carteret, N.J.; ASARCO Incorporated, Amarillo, Tex.; and Kennecott Copper Corp., Magma, Utah.

In addition, anode slimes recovered from the electrolytic tanks of copper refineries and residues of pollution abatement plants at nonferrous smelters and refineries owned by other foreign and domestic mining companies were shipped to these plants for recovery of gold, silver, selenium, and tellurium. High-purity selenium and various selenium compounds were produced by primary and other processors from commercial-grade metal.

The 1977 copper strike forced the shutdown of one selenium refining plant for the entire third quarter and the other two selenium plants for 3 weeks and 2 months, respectively.

Most of the U.S. selenium scrap supply is sent to Canada for reprocessing and returned to U.S. markets for consumption. Selenium scrap is recovered from xerographic, rectifier, and chemical processes.

The Wittenzellner Refining Co. of Providence, R.I., a wholly owned subsidiary of A. J. Oster Co., was purchased by Selenium Inc., a subsidiary of RefineMet International Co. The Wittenzellner Refining Co. was involved in the reprocessing of selenium from scrap wastes.

Consumption and Uses.—Apparent consumption of selenium in 1977, consisting of shipments from primary producers, net imports, and stockpile releases decreased 12% to 871,161 pounds from 1976 and 18% from 1975. Trends in 1977 suggested the following estimate of selenium purchases and consumption by end use categories: Electronic and photocopier components, 35%; glass manufacturing, 30%; chemicals and pigments, 25%; and other, 10%.

In electronic and photocopier applications selenium is used in semiconductors, rectifiers, photoelectric cells, calculators, and as the photoreceptor coating on drums used in xerography. Silicon and germanium compete with selenium as one of the materials used in manufacturing electronic rectifiers. High-purity grades of selenium are preferred for these applications.

The glass industry continued to be the single largest industrial consumer of selenium. The iron impurity which occurs naturally in "flint" glass, produces a green tint which may be neutralized by adding selenium in amounts of 0.02 to 0.03 pound per ton of glass. Selenium is added to environmental glass used in office buildings to reduce glare and heat transfer.

In the industrial chemical field, selenium in the form of cadmium sulfoselenate is used to impart pigmentation to plastics, paints, inks, and enamels. Colors range from yellow to deep maroon, becoming darker as the ratio of selenium to sulfur increases. These pigments are known for their resistance to deterioration caused by heat, sunlight, and chemical action. Pharmaceutical compounds such as selenium sulfide are used in making antidandruff shampoos.

Demand for selenium in other end uses included the addition of small amounts of ferroselenium to improve the casting, forging, and machining characteristics of stainless steel. Iron selenide is added to casting steels to prevent pinhole porosity. The addition of copper selenide to copper alloys improves machinability and working properties. In the rubber industry, selenium diethyldithiocarbamate is used as a curing-accelerator for a number of rubbers. Selenium, in the form of sodium selenite, has been administered to chickens, sheep, cattle, and hogs to control animal deficiency diseases.

Stocks.—U.S. producer stocks continued to rise, increasing 83% over the 1976 level to 323,100 pounds. This was the highest level attained since 1968 when yearend stocks were 428,000 pounds. Stock levels represent about 4 months supply at the 1977 rate of apparent consumption.

Prices.—Selenium is usually sold as minus 200-mesh commercial-grade powder containing 97% to 99.94% selenium or as high-purity grade in pellets, sticks, and powder containing 99.95% to 99.99+% selenium. Pellets containing 99.999+% selenium are also available.

The producer price of selenium, which began the year at $18 per pound for commercial grade and $21 to $22 per pound for high-purity grade, dropped by mid-September to $15 per pound and $18 per pound, respectively. The price cut nearly coincided with a strike against 13 glass manufacturers by the American Flint Glass Workers Union.[24] The New York dealer price of commercial-grade selenium began in January at $13.50 per pound, rose to a high in March, April, and May of $17.50 per pound, and then gradually declined to a low of $10 to $11 per pound by yearend.

Foreign Trade.—Selenium exports decreased 65% from 1976 to 67,610 pounds valued at $1,144,763, with an average value of $16.93 per pound. As shown in table 9, the Netherlands (32%), the Federal Republic of Germany (21%), the United Kingdom (20%), and Poland (10%) took delivery of the major share of exports.

Selenium imports for consumption dropped to 585,673 pounds, a decrease of 28% from 1976, while the value of imports decreased 23% to $9,322,012. The average value of unwrought selenium metal imported during the year was $16.89 per pound and for selenium dioxide $13.90 per pound. Canada supplied 41% by quantity and 56% by value, and Japan 18% and 16%, respectively, of all selenium imported.

U.S. import tariff schedule items 632.40, selenium metal, unwrought, other than alloys, and waste and scrap; 420.50, selenium dioxide; and 420.52, selenium salts, were duty-free at yearend. The duty on Tariff Schedule of the United States (TSUS) item 420.54, other selenium compounds, was 5% ad valorem.

Table 9.—U.S. exports of selenium metal, waste, and scrap in 1977, by country

Country	Quantity (pounds)	Value
Canada	3,857	$45,258
Colombia	1,540	26,334
France	562	7,038
Germany, Federal Republic of	13,866	242,781
Israel	79	1,927
Japan	2,384	35,766
Mexico	310	2,790
Netherlands	21,681	371,091
Nicaragua	56	506
Poland	6,709	110,032
Spain	2,773	45,732
United Kingdom	13,793	255,508
Total	67,610	1,144,763

Table 10.—U.S. imports for consumption of selenium in 1977, by country

(Pounds of contained selenium)

Country	Quantity	Value
Unwrought, and waste and scrap:		
Belgium-Luxembourg	46,942	$390,362
Canada	241,416	5,184,236
Chile	26,014	390,903
Germany, Federal Republic of	2,440	41,095
Italy	1,113	25,798
Japan	107,074	1,482,928
Mexico	15,653	183,169
Norway	1,605	27,086
Peru	4,752	81,611
Sweden	165	4,377
United Kingdom	3,488	40,823
Yugoslavia	60,626	782,526
Total	511,288	8,634,914
Selenium dioxide:		
Germany, Federal Republic of	12,404	149,171
Sweden	20,945	314,438
Total	33,349	463,609
Selenium salts:		
Germany, Federal Republic of	264	9,600
United Kingdom	2,208	2,683
Total	2,472	12,283
Other selenium compounds:		
Germany, Federal Republic of	34,100	165,172
Japan	607	11,931
United Kingdom	3,857	34,103
Total	38,564	211,206
Total, all forms	585,673	9,322,012

World Review.—Japan was the world's leading selenium producer with an output of 1,006,158 pounds in 1977. Canada produced 905,111 pounds followed by the United States' production of 499,475 pounds. The U.S.S.R. is known to be a major producer, but available data are insufficient to estimate annual production.

Canada.—Refinery output from all sources, including imported material and secondary sources, declined sharply in 1976 to 499,168 pounds from 754,842 pounds in 1975, and then spurted ahead in 1977 to 905,111 pounds. Selenium production from primary sources increased in 1977 to 456,000 pounds valued at $7.8 million compared with 1976 when 241,734 pounds of selenium were produced valued at $4.4 million. The major selenium producers in Canada were Canadian Copper Refiners Ltd. (CCR) owned by Noranda Mines Ltd. and Inco Ltd. Canada exported 435,400 pounds of selenium metal in 1977, a decrease of 18% from that of 1976. The bulk of exported metal in 1976 was shipped to the United States (54%), and the United Kingdom (38%).

Japan.—Total output of refined selenium by the six Japanese producers decreased less than 1% in 1977 to 1,006,158 pounds. Exports of metal in 1977 totaled 652,219 pounds, a drop of 16% from 1976, with the bulk being shipped to the Netherlands (46%), the United Kingdom (18%), and the United States (14%).

Table 11.—Selenium: World refinery production, by country[1]

(Pounds)

Country[2]	1975	1976	1977[p]
Belgium[e]	145,000	[r]130,000	130,000
Canada[3]	[r]754,842	499,168	905,111
Chile	26,056	33,160	[e]35,000
Finland	18,689	21,894	25,693
Japan	920,089	1,014,586	1,006,158
Mexico	[r]128,000	128,000	[e]128,000
Peru	14,744	19,299	35,132
Sweden	147,710	[r e]155,000	[e]155,000
United States	357,722	400,609	499,475
Yugoslavia	95,504	99,384	[e]99,000
Total	[r]2,608,356	2,501,100	3,018,569

[e]Estimate. [p]Preliminary. [r]Revised.

[1]Insofar as possible, data relate to refinery output only; thus countries that produce selenium contained in copper ores, copper concentrates, blister copper, and/or refinery residues, but do not recover refined selenium from these materials indigenously are excluded to avoid double counting.

[2]In addition to the countries listed, Australia, the Federal Republic of Germany, the U.S.S.R., and Zambia produce refined selenium, but output is not reported, and available information is inadequate for formulation of reliable estimates of output levels.

[3]Refinery output from all sources, including imported materials and secondary sources.

Technology.—Maintenance-free automobile batteries are beginning to have a major impact on consumer markets. Their advantage is that they require no additional water during normal service life, suffer less from terminal corrosion, and have a longer shelf life. Metals which can be substituted or combined with lead and antimony in such batteries include selenium, calcium, strontium, tin, and cadmium. The calcium-lead, maintenance-free battery contains no antimony whatsoever. VARTA Batteries Ltd., headquartered in the Federal Republic of Germany, produces a selenium-antimony-lead battery that contains approximately 2% antimony, versus the 4.5% antimony commonly used in conventional lead-antimony batteries.[25] A trace amount of selenium added to the lead-antimony produces a particularly fine and uniform grid structure comparable to a pure antimony-lead mixture. Much experimentation and refinement is continuing in this field.

TELLURIUM[26]

Domestic Production.—Tellurium was recovered domestically as a byproduct of electrolytic copper refining by AMAX Copper, Inc., at Carteret, N.J., and ASARCO Incorporated at Amarillo, Tex. Commercial-grade tellurium and tellurium dioxide were also produced from the precious-metal-rich anode slimes shipped from domestic copper refinery tankhouses. High-purity tellurium, tellurium master alloys, and tellurium compounds were produced by primary and intermediate processors from commercial-grade metal and tellurium dioxide. In 1977, refined tellurium production, shipments to consumers, and yearend producer stocks all increased. Figures have been withheld to avoid disclosing company proprietary data.

Table 12.—Salient tellurium statistics

(Pounds of contained tellurium)

	1973	1974	1975	1976	1977
United States:					
Refinery production	240,879	191,324	130,844	W	W
Shipments to consumers	286,721	160,162	163,089	W	W
Imports for consumption	79,159	164,344	97,350	203,534	171,291
Apparent consumption	365,880	324,506	260,439	W	W
Stocks, yearend, producer	56,279	87,441	55,196	W	W
Producers' price: Average per pound, commercial grade	$6.05	$8.34	$9.28	$10.33	$17.15
World: Refinery production	446,000	466,866	[r]342,402	NA	NA

[r]Revised. NA Not available. W Withheld to avoid disclosing company proprietary data.

Consumption and Uses.—Apparent consumption of tellurium remained at essentially the same level as 1976. Tellurium consumption by end use in 1977 was estimated as follows: Iron and steel production, 77%; nonferrous metal production, 14%; chemical uses, 5%; and other uses including rubber manufacturing, 4%.

In the iron and steel industry, the addition of approximately 0.04% by weight of elemental tellurium to leaded, resulfurized, low-carbon steel produces a marked improvement in machinability. Small amounts of tellurium added to gray cast iron and malleable cast iron produce a hard, wear-resistant surface, an effect know as "chilling."

In nonferrous metal production, tellurium is added to copper, lead, and tin-base alloys as a means to improve machinability, fatigue strengths, and electrical conductivity.

Other applications include the use of bismuth and lead telluride alloys in making semiconductors and thermoelectric devices. In the rubber industry, elemental tellurium and tellurium diethyldithiocarbamate as well as sulfur are used as curing agents and accelerators. Tellurium oxide and chloride compounds are used in the chemical industry as catalysts for oxidation, hydrogenation, and halogenation reactions.

Prices.—Reduced imports and midyear work stoppages resulting from labor-management disagreements contributed to the increase in the U.S. producer price of commercial-grade tellurium from $12 per pound on January 1 to $20 per pound by mid-September. The price increased $3 per pound in January, an additional $3 per pound in June, and another $2 per pound in September. The price remained at $20 per pound from mid-September until yearend.

Tellurium metal is usually marketed in the form of minus 200-mesh powder or as slabs, tablets, or sticks. Normal commercial grades contain a minimum of 99% or 99.5% tellurium. Further refining through distillation and sublimation processes produces high-purity grades chiefly for use in semiconductors containing 99.95%, 99.999%, and 99.9999% tellurium.

Foreign Trade.—Tellurium metal imports totaled 118,373 pounds or about two-thirds the amount imported in 1976. The average value of imported metal increased substantially from $8.68 per pound in 1976 to $20.27 per pound in 1977. In addition, 52,918 pounds of tellurium in compounds was also imported. Canada supplied 42%, Peru 21%, and Fiji 16% of all imports. The first year that Fiji began shipping tellurium to the United States was 1977. There are no data on tellurium exports.

The U.S. tariff for 1977 on TSUS Item 632.48, tellurium metal, unwrought, other than alloys, and waste and scrap, was 4% ad valorem; and TSUS Items 421.90, tellurium compounds, and 427.12, tellurium salts, were 5% ad valorem.

Table 13.—U.S. imports for consumption of tellurium in 1977, by country

Country	Pounds	Value
Unwrought, and waste and scrap:		
Australia	2,233	$49,581
Belgium-Luxembourg	318	7,071
Canada	41,108	654,689
Fiji	13,237	283,059
Japan	18,824	408,911
Peru	36,467	861,586
United Kingdom	6,186	135,051
Total	118,373	2,399,948
Compounds:		
Australia	2,210	38,242
Canada	30,087	404,568
Fiji	13,616	236,284
Germany, Federal Republic of	129	8,794
Netherlands	6,376	57,840
United Kingdom	500	12,500
Total	52,918	758,228
Grand total	171,291	3,158,176

World Review.—World production of tellurium, excluding the United States, increased from 220,000 pounds in 1976 to 279,000 pounds in 1977.

The United States was the world's largest producer and consumer of tellurium. The last publishable figure on U.S. production was 130,844 pounds produced in 1975. In that year, the United States produced 38% and consumed 76% of total world production. Other major producing nations were Japan, Canada, and Peru.

Fiji.—Tellurium was produced for the first time in 1976. The Emperor Gold Mining Co., Ltd. at Vatukoula extracted tellurium as a byproduct of gold. Severe financial and labor problems plus declining gold ore grades have threatened to close the gold mine in the past few years. The Fijian Government authorized a loan of up to $F2 million to the mine over a 28-month period, beginning March 1, 1977.[27] Despite the loan, the mine continued deficit operations throughout the remaining year. In December, the Government decided against loaning more funds and began negotiations to purchase the gold mine.[28] The future viability of the mine will depend to a large extent on the future price of gold.

Japan.—Japan more than doubled its production of tellurium in 1977. The increase was a result of Mitsubishi Metal Corp.'s decision to increase its productive capacity for refined tellurium based on imported slag.[29] In addition, Sumitomo Metal Mining Co. Ltd., which began production in November 1976, produced on full scale in 1977.

Table 14.—Tellurium: World refinery production, by country[1]

(Pounds)

Country[2]	1975	1976	1977[p]
Canada[3]	[r]93,150	117,156	81,617
Fiji	--	2,446	[e]2,500
Japan	71,650	73,634	[e]154,000
Peru	46,758	27,185	40,498
United States	130,844	W	W
Total	[r]342,402	[4]NA	[4]NA

[e]Estimate. [p]Preliminary. [r]Revised. NA Not available. W Witheld to avoid disclosing company proprietary data.

[1]Insofar as possible, data relate to refinery output only; thus countries that produce tellurium contained in copper ores, copper concentrates, blister copper, and/or refinery residues, but do not recover refined tellurium, are excluded to avoid double counting.

[2]In addition to the countries listed, Australia, Belgium, the Federal Republic of Germany, and the U.S.S.R. are known to produce refined tellerium, but output is not reported, and available information is inadequate for formulation of reliable estimates of output levels. Moreover, other major copper refining nations such as Chile, Zaire, and Zambia may produce refined tellurium, but output in these nations is conjectural.

[3]Refinery output from all sources, including imports and secondary sources.

[4]Not totaled because of the exclusion of United States' data owing to company confidentiality.

THALLIUM[30]

Thallium is a highly toxic metallic element limited in production and size of market.

Domestic Production.—Thallium was produced domestically by ASARCO Incorporated at its' Globe refinery in Denver, Colo. The company recovered thallium metal and compounds as a byproduct from the treatment of dusts, slags, and residues generated from smelting and refining of zinc, lead, and copper ores. No metal was produced in 1977 but production of compounds was slightly higher than that of 1976. Shipments of both metal and compounds increased in 1977.

Consumption and Uses.—Apparent consumption in 1977 was approximately 3,900 pounds on a metal basis. Thallium was used in photography and xerography where its incorporation in certain chemical emulsions improved the developing process and aided in the transmission of infrared light. General laboratory use continued to be an important part of the consumption total.

Prices.—The price of thallium in 25-pound lots was $7.50 per pound, a price in effect since December 1957.

Table 15.—U.S. imports for consumption of thallium in 1977, by country

Country of origin	Compounds (gross weight)		Unwrought, and waste and scrap	
	Pounds	Value	Pounds	Value
Belgium-Luxembourg	7	$256	20	$459
Canada	--	--	5	1,376
Germany, Federal Republic of	185	4,530	--	--
United Kingdom	11	556	--	--
Total	203	5,342	25	1,835

Foreign Trade.—U.S. imports for consumption in 1977 were 25 pounds of unwrought metal, waste, and scrap valued at $1,835, and 203 pounds of compounds valued at $5,342.

World Review.—In addition to the United States, Belgium, the Federal Republic of Germany, and the U.S.S.R. produced refined thallium metal.

---

[1]Prepared by J. Roger Loebenstein, physical scientist.

[2]U.S. Department of Labor, Occupational Safety and Health Administration. Inorganic Arsenic. Final Environmental Impact Statement, February 1977, 217 pp.

[3]———.Proposed Regulation, Inorganic Arsenic. Draft Environmental Impact Statement, Mar. 21, 1975, 63 pp.

[4]National Research Council, National Academy of Sciences. Arsenic. 1977, p. 223.

[5]Page 56 of work cited in footnote 2.

[6]Prepared by Keith L. Harris, physical scientist.

[7]Morris, M., et al. Report on Technical and Economic Factors in the Beneficial Use of Radiation in Municipal Sludge Management. Sandia Laboratory, SAND77-7029, November 1977, 107 pp. Available from the National Technical Information Service, Springfield, Va.

Remini, W. C., E. J. Wahlquist, and H. D. Sivinski. Beneficial Use of Waste Nuclear Isotopes. 137 Cesium Irradiation Treatment of Municipal Sludge and Compost. Energy Research and Development Administration. ERDA 77-17, Jan. 5, 1977, 18 pp. Available from National Technical Information Service, Springfield, Va.

[8]Prepared by John M. Lucas, physical scientist.

[9]Mazerolles, P. Comparative Study of Cyclic Organosilicon and Organogermanium Derivatives. Pres. at 2d Internat. Conf. on the Organometallic and Coordination Chemistry of Germanium, Tin and Lead, Nottingham, England, July 12-15, 1977.

[10]Prepared by James F. Carlin, Jr., physical scientist.

[11]Prepared by Martha L. Kahn, physical scientist.

[12]Kaufmann, R. D., and J. F. Bliss. Effects of Phosphate Mineralization and the Phosphate Industry on Radium-226 in Ground Water of Central Florida. Office of Radiation Programs, Environmental Protection Agency, Las Vegas, Nev. October 1977, 127 pp.

[13]Sinsley, J. E., B. A. Beaudet, W. E. Bolch, and J. F. Palmer. Costs of Radium Removal from Potable Water Supplies. Florida University, Gainesville, Department of Environmental Engineering Sciences, April 1977, 153 pp.

[14]Skilling's Mining Review. Radium in Utah Spring is Clue to Uranium. V. 66, No. 23, June 4, 1977, p. 29.

[15]Zobel, V., J. Eberth, V. Eberth, and E. Eube. (Inst. Kernphys.; Univ. Koeln, Cologne, Germany). Nucl. Instr. Methods (England), v. 141, No. 2, 1977, pp. 329-369.

[16]Prepared by Christine M. Moore, mineral specialist.

[17]Greenwood, R. C., and R. E. Chrien. Filtered Reactor Beams for Fast Neutron Capture Gamma-Ray Experiments. Nucl. Instr. Methods., v.12, No. 1, 1976, pp. 125-143.

[18]Amli, R. Carbonatites, a Possible Source of Scandium as Indicated by Sc Mineralization in the Fen Peralkaline Complex, Southern Norway. Econ. Geol., v. 72, No. 5, August 1977, pp. 855-859.

[19] Ito, J. Crystal Synthesis of a New Olivine, $LiScSiO_4$. Am. Mineralogist, v. 62, No. 3-4, March-April 1977, pp. 356-361.

[20]Rush, R., H. J. Garret, R. F. Domagala, and F. A. Patel. The System Zirconia-Scandia. J. Am. Ceram. Soc., v. 60, No. 9-10, September-October 1977, pp. 399-403.

[21]Vodakov, Y. A., G. A. Lomakina, E. N. Mokhov, I. I. Kruglov, I. V. Ryzhikov, V. I. Pavlichenko, T. G. Kmita, G. F. Kholuyanov, and E. E. Violin. Semiconductor Silicon Carbide Light Source. U.S. Pat. 3,986,196, Oct. 12, 1976.

[22]Dole, S. L., O. Hunter, Jr., and F. W. Calderwood. Elastic Properties of Polycrystalline Scandium and Thulium Sesquioxides. J. Am. Ceram. Soc., v. 60, No. 3-4, March-April 1977, pp. 167-168.

[23]Prepared by J. Roger Loebenstein, physical scientist.

[24]Metals Week. Selenium Hit by Glassworkers' Strike. V. 48, No. 39, Sept. 26, 1977, p. 7.

[25]Peters, U. W. (assigned to VARTA Batteries Ltd.). Maintenance Free Batteries, VARTA's Fine Grain Alloy Concept. Pres. at IBMA 40th Convention, Chicago, Ill., Oct. 13, 1977.

[26]Prepared by J. Roger Loebenstein, physical scientist.

[27]Mining Journal. Fijian Gold, Emperor Bows Out. V. 289, No. 7426, Dec. 16, 1977, p. 494.

[28]Mining Journal. Fiji to Buy Emperor. V. 290, No. 7432, Jan. 27, 1978, p. 65.

[29]Japan Metal Journal. Sharp Increase in Production of Tellurium Planned. V. 7, No. 25, June 20, 1977, p. 8

[30]Prepared by John A. Rathjen, mineral specialist.

Minor Nonmetals

By Staff, Division of Nonmetallic Minerals

CONTENTS

ASPHALT (NATIVE)[1]

Native asphalt was produced in 1977 by six companies in four States. Leading States were Texas and Utah. Output declined 39% to 1,237,000 tons valued at $13,874,000.

Bituminous limestone was produced by Whites Uvalde Mines and by Uvalde Rock Asphalt Co. in Uvalde County, Tex.; by Southern Stone Co. in Colbert, Ala.; and by Barton County Rock Asphalt Co. in Barton County, Mo.

Gilsonite was produced by American Gilsonite Co. in Uinta County, Utah, and by Ziegler Chemical and Mineral Corp. in Weber County, Utah.

The asphalt was used for streets and roads, and for other purposes.

GREENSAND[2]

Greensand, which is widely distributed in the Eastern United States, was produced in 1977 only by the Inversand Co., a subsidiary of Hungerford and Terry Inc., near Clayton, N.J, Production and sales information is withheld to avoid disclosing company proprietary data.

Raw greensand produced by the company was sold for agricultural use as a soil conditioner. Processed greensand was sold for use as a filter media for the removal of manganese, iron, sulfide, and other elements from water.

IODINE[3]

World markets for crude iodine continued to recover in 1977. The increase in U.S. demand was satisfied by a significant increase in domestic production and withdrawals from the surplus world supply accumulated in prior years. Of the three major market economy countries producing crude iodine, the United States and Chile increased output over the 1976 level while the output of Japan, by far the largest world supplier, declined. Strong U.S. demand for crude iodine was reflected in greater consumption reported by the major chemical companies, up 11% from that of 1976, and an increase in imports of 7%; furthermore, company inventories decreased considerably during the year. The quoted market price of crude iodine was reduced from $2.59 to $2.31 per pound; however, discounted sales prices were beginning to rise toward yearend.

Although the small output of The Dow Chemical Co., formerly the sole U.S. producer, continued to decline, the initial production in 1977 of Woodward Iodine Operations increased the ratio of domestic supply to demand. The new facility near Woodward, Okla., owned jointly by PPG Industries, Inc. and Amoco Production Co., has capacity to produce 2 million pounds per year from brines averaging 330 parts per million iodine. Compared with the operations in Michigan, Japan, and Chile, Woodward is unique because crude iodine is the primary product.

Japan further delayed plans to expand iodine production. Japanese plants were operating at about 80% of capacity, with total production 12% below that of 1976. Exports remained near the 1976 level despite the smaller output as world demand was met from excess inventories. The Japanese were assessing the effect of the new U.S. producer on the market, as well as the effect of possible release of iodine that is excess to the U.S. Government stockpile goals. Chile's output of crude iodine increased 16% in 1977, and U. S. imports of Chilean iodine were more than double those of 1976.

Legislation and Government Programs.— On December 31, 1977, the U.S. Government strategic stockpile contained 8,011,814 pounds of crude iodine, the same quantity reported at yearend 1976. The stockpile goal for iodine remained at 3,333,000 pounds. No iodine disposals were authorized.

The depletion allowance for iodine remained at 14% of gross income, and may not exceed 50% of net income without the depletion deduction.

Domestic Production.—In its first year of production, Woodward Iodine Operations, which began producing in February 1977, nearly doubled the ratio of domestic supply to demand. Amoco Production Co., (with a 49% interest in the joint venture with PPG Industries, Inc.) operated nine production wells and five reinjection wells. Amoco pumped brines and natural gas from 7,500 feet below the surface to the PPG plant where the natural gas constituents were separated from the iodine-rich brines. The iodine was recovered by the conventional blow-out process with incorporated proprietary refinements. Most of the natural gas was used for space and water heating for the facility. Designed to minimize environmental degradation, the entire operation made use of modern recycling techniques. The effluent stream was adjusted chemically to approximate its original state (less the gas and iodine) and reinjected into the subterranean formation, thereby reducing the potential for the type of subsidence that has damaged the Japanese iodine industry.

The Dow Chemical Co. supplied a small part of the total U.S. requirement for 1977. Dow recovered iodine as a coproduct of bromine, calcium and magnesium compounds, and potash from subterranean brines at Midland, Mich. The company's iodine production declined from the 1976 level.

Consumption and Uses.—According to the Bureau of Mines canvass for 1977, approximately 5.9 million pounds of iodine was consumed by 31 plants in 14 States, representing an 11% increase over reported iodine consumption in 1976. Seventeen of these plants, which were located in the leading consumer States of Missouri, New Jersey, New York, and Pennsylvania (in decreasing magnitude of consumption), accounted for 67% of total iodine consumption.

While the canvass information indicates a general consumption pattern, establishing an accurate pattern of demand by end use is difficult because iodine is frequently converted into intermediate compounds and marketed as such before reaching its ultimate end use. Moreover, iodine and iodides used in catalytic and other dissipative processes are not well covered. This situation has been revealed consistently in recent years by import figures that exceeded reported consumption figures; in 1977 crude iodine imports exceeded reported consumption by 1.04 million pounds. Combining imports with domestic production and inventory withdrawals, apparent consumption in 1977 was about 8.6 million pounds.

Comparison of the results of the 1977 canvass with 1976 figures showed an increase of 15% in consumption of crude iodine for making organic iodine chemicals and an increase of 9% for inorganic iodine compounds (including resublimed iodine). The most significant rise in inorganic compounds was attributed to a 70% increase in iodine consumed in making calcium iodate. Other important inorganics decreased: Potassium iodide, down 2%; ammonium iodide, down 77%; sodium iodide, down 26%;

Table 1.—Crude iodine consumed in the United States

Products	1976			1977		
	Number of plants	Consumption		Number of plants	Consumption	
		Thousand pounds	Percent of total		Thousand pounds	Percent of total
Reported consumption:						
Resublimed iodine	6	697	13	6	506	9
Potassium iodide	9	1,259	24	7	1,237	21
Other inorganic compounds	r12	r1,273	r24	14	1,782	30
Organic compounds	r21	r2,070	r39	20	2,376	40
Total[1]	[2]31	5,298	100	[2]31	5,900	100
Apparent consumption	XX	7,200	XX	XX	8,600	XX

rRevised. XX Not applicable.
[1]Data may not add to totals shown because of independent rounding.
[2]Nonadditive total because some plants produce more than one product.

and resublimed iodine, down 27%. With respect to iodine consumed in making organic chemicals, ethylene diamine dihydroiodide, a cattle feed additive, increased 20%.

The major downstream uses for iodine in 1977 continued to be catalysts (for synthetic rubber, stabilized rosin, tall oil), estimated at 22%; animal feed supplements (mainly for cattle), 18%; stabilizers (as in nylon precursors), 15%; inks and colorants, 14%; pharmaceuticals, 13%; sanitary and industrial disinfectants, 9%; photographic film, 3%; and other uses, 6%. Other uses includes the making of high-purity metals, motor fuels, iodized salt, smog inhibitors, and lubricants. Iodine also has application in cloud seeding and radio-opaque diagnosis in medicine.

Prices.—The quoted price for crude iodine was reduced temporarily during the latter half of 1977 from $2.59 to $2.31 per pound. Although U.S. demand for iodine and its compounds was greater than in 1976, and surplus stocks were reduced in the United States and Japan, the continued existence of these inventories plus the new source of U.S. supply combined to exert downward pressure on prices. Higher production costs and the declining value of the dollar versus the yen counterbalanced this pressure to some extent and discounted sales prices began rising toward yearend. As the leading vendor of crude iodine in the world market, Japan exemplified this upward trend in discount prices. Exports of Japanese iodine for the year had an average value of $2.27 per pound, 1.7% below the temporary base price and 6% above the average value of $2.14 per pound for Japanese exports in 1976.

The quoted U.S. prices for the element and its primary compounds at yearend 1977 were as follows:

	Per pound
Iodine, crude, drums	$2.31
Resublimed iodine, U.S.P., granular, 100-pound drums, works	$4.00-5.25
Calcium iodate, drums, delivered	3.32
Calcium iodide, 35-pound drums, works	5.98
Potassium iodide, U.S.P., granular, crystals, drums, 1,000-pound lots, delivered	3.76
Sodium iodide, U.S.P., crystals, 300- to 500-pound lots, drums, freight equalized	5.16
Iodoform, N.F., 300-pound drums, f.o.b. works	7.75-14.30

Source: Chemical Marketing Reporter, v. 213, No. 27, Jan. 2, 1978.

Foreign Trade.—The quantity of crude iodine imported by the United States increased 7% over that of 1976, but remained below the peak levels of 1974, while the value remained about the same as that of 1976. The average U.S. Customs declared value of imported crude iodine dropped from $2.13 per pound in 1976 to $1.99 per pound in 1977. Of the 6.9 million pounds imported, 78% was from Japan and 22% was from Chile. Although the proportion of imports from Chile remained below the sizable share of the U.S. market that Chile enjoyed prior to 1972 (in 1971 U.S. imports from Chile amounted to 41% of total imports), imports did increase by 133% over those of 1976.

Imports of resublimed iodine, mostly from Japan, amounted to 44,822 pounds, compared with 23,231 pounds in 1976.

Tariff rates were 8 cents per pound on resublimed iodine and 12 cents per pound on potassium iodide. Crude iodine enters the United States duty free.

Table 2.—U.S. imports for consumption of crude iodine, by country

(Thousand pounds and thousand dollars)

Country	1975 Quantity	1975 Value	1976 Quantity	1976 Value	1977 Quantity	1977 Value
Canada	--	--	--	--	7	4
Chile	365	856	661	1,253	1,543	2,860
Japan	4,944	10,865	5,821	12,571	5,390	10,967
Total	5,309	11,721	6,482	13,824	6,940	13,831

World Review.—*Chile.*— Production of crude iodine increased in 1977 to 3.6 million pounds.[4] This figure was 16% greater than 1976 output, but also 16% less than the 4.3-million-pound output of 1975. Iodine, a by-product of potassium and sodium nitrates extracted from Chile's caliche deposits, is dependent on nitrate production; however, in 1977 nitrate production declined by 9% while iodine production gained. The Government-owned mining concern, Sociedad Quimica y Minera de Chile S.A. (SOQUIMICH), produced nitrates and iodine from three mines and plants: Pedro de Valdivia, Maria Elena, and Victoria.

It was reported that a joint venture between Garret Research and Development Co., Inc. and the Chilean Corporation of Development was organized to improve nitrate production methods.[5] Part of the program is the design of an efficient plant to recover nitrates, sodium sulfate, sodium borate, and iodine from caliche. The efficiencies of the existing plants will also be improved, with the possible effect of drastically reducing the labor force of 9,200 workers in caliche processing plants and complementary port operations.

U.S. imports of Chilean iodine increased 133% in 1977 to 1.5 million pounds, or about two-fifths of Chilean production. Most of the balance went to Western Europe and Latin America.

China, People's Republic of.—The No. 115 geological prospecting team discovered an extensive phosphate deposit embedded with high-grade iodine in Kweichow Province.[6] It was reported that exploitation of the deposit was underway. Although data are not available, it is believed that Chinese consumption of iodine is equivalent to about one-fourth the quantity consumed in the United States. No exports of iodine from Japan to China were reported in 1977, and figures on Chilean exports for the year were not available.

Indonesia.—The iodine plant of P.T. Kimia Farma, at Mojokerto, East Java, remained the only crude iodine producer in Indonesia.[7] Production in 1977 decreased 25% to 45,000 pounds.[8] Indonesia has traditionally exported about half of its iodine output and used the balance for manufacture of pharmaceuticals.

Japan.—Production of crude iodine in Japan, the foremost producer for the world market, declined 12% from that of 1976.[9] The total of 13.4 million pounds was 19% below the 1972 record of 16.5 million pounds; however, reviving demand brought about withdrawals that were expected to return inventories to basic reserve levels by 1978.

Japanese exports of crude iodine in 1977 were about 1% less than in 1976. Export values averaged $2.27 per pound, or 1.7% below the reduced base price of $2.31 per pound. Exports to the United States amounted to 47% of the total of 12.1 million pounds of iodine shipped to 38 countries. The countries of the European Community represented another 38%, and other significant markets were India (4%), Canada (3%), and Poland (2%).

Ise Chemical Industries, Ltd., which produces about 60% of Japan's iodine, and the other five producers operated on the Chiba peninsula, the original site of the industry. However, irreversible subsidence caused by removal of the subterranean natural gas brines have forced the closing of approximately 150 wells at Chiba, and only Ise has developed additional resources in other parts of the country. The need to reduce excess inventories to more acceptable levels in 1977 further delayed Ise's expansion plans at Miyazaki and Niigata.

U.S.S.R.—It is believed that the Soviet iodine industry is operating near capacity (estimated at 3.8 million pounds per year), and a 1977 article indicated that this capacity may soon be enlarged. Some of the largest chemical centers in the republics of Transcaucus (Azerbaidzhan, Georgia, and Armenia) are under expansion. Azerbaidzhan, representing about 46% of the chemical and petrochemical production in the region, possesses a variety of natural resources including iodine, bromine, oil, natural gas, and rock salt. The republic's leading chemicals industries are plastics, resins, synthetic rubber, and phosphate fertilizers.[10]

Technology.—Research progressed in 1977 to develop hydrogen generation processes, the need for which is related to the long-term requirement for a replacement for natural gas and synthetic natural gas. It is possible that a nonfossil source of hydrogen, that is water, may eventually become a necessity. Among the various promising techniques proposed for splitting water molecules is the Westinghouse sulfur-iodine cycle, which employs electrolysis and high-temperature chemistry.[11] Westinghouse's objective is large-scale production after 1985, although it is generally believed that commercial thermochemical generation of hydrogen will not be available until after the year 2000. The Westinghouse hybrid cycle, unlike other proposed cycles, is being developed for integration into heat sources such as coal-fired powerplants as well as nuclear powerplants.

The Department of Energy is providing funds to another company, General Atomic Co., to develop a pure thermochemical sulfur-iodine water splitting cycle. Research has progressed to the bench-scale test phase. Japanese research is also advancing in this area. Hitachi is planning to design a pilot plant for its process of thermochemical hydrogen generation in an iodine-sodium carbonate system.[12] The process consists of four stages beginning with ammonia decomposition in the presence of a nickel catalyst. Total thermal efficiency of the system is expected to exceed 30%.

Two U.S. Government chemists have developed a laser fluorescent technique for monitoring airborne concentrations of iodine-129 at nuclear fuel reprocessing plants.[13] This radioactive isotope occurs as a fission product of uranium, but in the past has been impractical as a tracer because its low specific activity, long half-life, and the low energy decay of its radiations have inhibited its detection by radio-counting techniques.

MEERSCHAUM[14]

Imports of crude meerschaum in 1977 totaled only 485 pounds compared with 1,200 pounds in 1976. Spain (331 pounds) and the Federal Republic of Germany (154 pounds) were the import sources. Customs value of the imported meerschaum was declared at $2.62 per pound. Imported meerschaum is primarily used to manufacture smoking articles such as pipes.

QUARTZ CRYSTAL[15]

Cultured quartz crystal production decreased 31% from 849,000 pounds in 1976 to 583,000 pounds in 1977. Consumption of both cultured and natural quartz decreased 20% from 349,000 pounds in 1976 to 280,000 pounds. Consumption of cultured quartz increased from 190,000 pounds in 1976 to 224,000 pounds or 18%, and the consumption of natural quartz decreased from 159,000 pounds in 1976 to 56,000 pounds or 65%. Exports of natural and cultured quartz decreased from 645,000 pounds in 1976 to 502,000 pounds or 22%. Production of finished piezoelectric units decreased 40% from 83 million in 1976 to 50 million.

Legislation and Government Programs.— At yearend, the total Defense Materials Inventory was 2.6 million pounds of electronic-grade quartz crystal valued at $15.7 million, or $6.00 per pound, average market value. The stockpile objective for electronic-grade crystal remained at zero throughout 1977, so the entire stock of quartz crystals was excess. Sales from the stockpile during 1977 totaled 74,000 pounds and shipments amounted to 120,000 pounds. Some of the stockpile material was sold for consumption in fused quartz operations for which statistics are unavailable. The stockpiled electronic-grade quartz was natural quartz crystal.

Table 3.—Salient electronic- and optical-grade quartz crystal statistics

(Thousand pounds and thousand dollars unless otherwise noted)

	1973	1974	1975	1976	1977
Production of cultured quartz	307	529	724	849	583
Imports of electronic- and optical-grade natural quartz crystal:					
Quantity	104	389	NA	NA	NA
Value	$92	$368	NA	NA	NA
Exports of electronic- and optical-grade quartz crystal:					
Quantity	287	299	486	645	502
Value	$3,283	$4,398	$5,713	$10,908	$4,005
Natural:					
Quantity	205	166	313	188	370
Value	$1,933	$1,634	$1,656	$1,626	$1,371
Cultured:					
Quantity	82	133	173	457	133
Value	$1,350	$2,764	$4,057	$9,282	$2,634
Consumption of raw electronic-grade quartz crystal	249	285	240	349	280
Natural	99	122	90	159	56
Cultured	150	163	149	190	224
Production piezoelectric units, number .... thousands	27,006	35,541	39,545	82,730	49,927

NA Not available.

Domestic Production.—Three companies produced 606,000 pounds of various grades of natural quartz in Arkansas in 1977. These companies were: The Quartz Processing Co., Hot Springs, Ark., 594,000 pounds; Ocus Stanley, Mt. Ida, Ark., 11,000 pounds; and Terry Mining Co. of Midwest, Okla., 550 pounds. The production from Terry Mining Corp. was in Garland County, Ark.[16] It was reported that some of the production of the Quartz Processing Co. was used as lasca (lump quartz used as feedstock for growing cultured quartz crystal).

Eight companies in five States reported production of cultured quartz for use by the quartz-crystal cutting industry. These companies were Motorola, Inc., Chicago, Ill.; Electro Dynamics Corp., and Thermodynamics Corp., both in Shawnee Mission, Kans.; Western Electric Co., Inc., North Andover, Mass.; Bliley Electric Co., Cortland, Ohio; Crystal Systems, Inc., Chardon, Ohio; Sawyer Research Products, Inc., Eastlake, Ohio; and P. R. Hoffman Co., Carlisle, Pa. These eight companies reported consumption of 939,000 pounds of lasca in 1977.

Consumption and Uses.— Consumption of raw cultured quartz crystal increased to 224,000 pounds, 18% above the 190,000 pounds consumed in 1976. Natural quartz crystal consumption decreased 65% from 159,000 pounds in 1976 to 56,000 pounds. Total consumption of electronic- and optical-grade natural and cultured quartz crystal was 280,000 pounds in 1977.

Production and consumption data for 1977 were derived from reports of 70 operations in 20 States. There were 40 crystal cutting operations in 16 States. Of the total cutting operations, 26 cut cultured quartz only, and 14 cut both natural and cultured quartz. Kansas was the leading quartz-crystal consuming State followed by Pennsylvania, Illinois, New York, and Massachusetts.

Finished piezoelectric units were manufactured by 58 operations in 19 States. Oscillator plates comprised 76% of the production; filter plates, 21%; and telephone resonator plates and units for other uses, 3%. Of the approximately 50 million units produced, 93% were produced by 23 plants in 14 States.

Stocks.—Total stocks of raw quartz crystal (cultured and natural) increased from 292,000 pounds in 1976 to 462,000 pounds. Of this total 236,000 pounds was cultured quartz and 226,000 pounds was natural quartz crystal.

Prices.—There was a decline in the prices of finished quartz crystals. This was attributed to both the considerable expansion of capacity in the industry and increased imports of quartz crystal components. Wholesale prices for quartz crystal units that had been in the range of $2.35 to $2.85 in 1976, dropped to an average of $1.15 to $1.50 in 1977.[17]

One producer of quartz cystal oscillators reported that as long as crystal units were valued at $2 or more each, it continued to manufacture the units for watches. When the units could be imported for less than $2, the firm discontinued production and purchased imports at 75 cents each to supply its needs.

Finished quartz crystal units in wholesale quantities were reported at low prices: Citizens band (CB) radio crystals, 60 cents to $1.05 each; XY flexure bar watch crystals, 50 cents each; and tuning fork watch crystals, 80 to 90 cents each.[18]

Foreign Trade.—Exports of natural quartz from the United States almost doubled from 188,130 pounds in 1976 to 370,363 pounds in 1977, valued at $1,371,379. The unit value, $3.70 per pound, was a marked decrease from $8.64 in 1976, suggesting the inclusion of lower grade material. The leading countries of destination were: Poland, 174,301 pounds; Japan, 141,266 pounds; and the Federal Republic of Germany, 15,385 pounds.

U.S. exports of cultured quartz decreased from 457,410 pounds in 1976 to 132,761 pounds in 1977, valued at $2,633,810. The unit value for cultured quartz was $19.84 per pound, a 2% decrease from $20.29 per pound in 1976. The countries that received most of the cultured quartz were: Japan, 47,974 pounds; Belgium, 30,177 pounds; the Federal Republic of Germany, 23,481 pounds; and the United Kingdom, 16,640 pounds.

U.S. imports of raw natural quartz, designated as crude Brazilian pebble, were reported in two categories, above and below 50 cents per pound. The Bureau of the Census advised that imports in both categories from Mexico were not correctly classified, and the Mexican import figures were eliminated from the following statistics. Imports of raw natural quartz valued over 50 cents per pound increased 42% from 187,243 pounds in 1976 to 265,389 pounds in 1977. Both electronic-grade quartz and lasca were included in this category. Brazil supplied 99% and Canada, 1%. The average unit price was $1.49 per pound. U.S. imports of raw natural quartz, valued at less than 50 cents per pound, increased 11% from 961,558 pounds in 1976 to 1,068,474 pounds in 1977. Brazil was the source of 63% of this low-grade material; France, 29%; and Canada, 8%.

World Review.—*Brazil.*—The leading world source for electronic-grade and lasca-grade quartz continued to be Brazil.

Canada.—Quartz crystal components were supplied by Croven Ltd., Whittby, Ont.[19]

Hong Kong.—Solider (Hong Kong) Ltd., a subsidiary of Solitron Services, planned to increase production of finished crystal units for watches and citizens band (CB) radios from 150,000 to 500,000 per month.[20] The United States and Japan were the main suppliers of quartz crystals to Hong Kong. According to the Hong Kong Trade Development Council, International Quartz Ltd., was formed to produce cultured quartz crystal for the manufacture of watches for export.[21]

Japan.—The Government reported that 34 million mounted piezoelectric crystals valued at $12 million were exported to the United States during 1977. It was not stated how many of these crystals were quartz. This represented a 47% increase over 1976.[22] It was estimated that Japan would supply 65% of the watch crystals sold in the United States in 1977. Manufacture of tuning fork crystals for watches continued and exports of them to the United States increased.[23]

Korea, Republic of (South).—American Microsystems ended quartz crystal production for watches.[24]

Madagascar.—A small quantity of natural piezoelectric quartz (2.54 pounds) was produced in 1977.[25]

Mexico.—A quartz crystal plant was operated in Juarez by Sentry Manufacturing Co. of Chickasha and Lawton, Okla.[26]

Taiwan.—CTS Knights Inc., Sandwich, Ill., operated a quartz crystal plant in Taiwan.

Technology.—Tuning fork watch crystals were considered to have some advantages over the XY flexure-bar-type watch crystals: Smaller size, lower cost, more resistance to shock, and firm mounting on a base instead of being mounted on two wires.[27]

Investigations of the growth rate of cultured quartz crystals were summarized. It was demonstrated that the growth rate of cultured quartz crystals increased linearly from 24 to 43 mils per day as the hydrogen concentration (H) in the ratio H:10^6 silicon increased from zero to 1,100. Also the mechanical efficiency Q of the oscillating quartz was shown to increase exponentially from 10×10^{-4} to 160×10^{-4} as the growth rate decreased from 100 to about 43 mils per day. Mechanical Q not only depended on growth rate but also on the nature of the solvent used and other variables in the operation.[28]

STAUROLITE[29]

Staurolite is a naturally occurring mineral of uncertain and variable composition, but with the general formula $FeAl_5Si_2O_{12}(OH)$. It occurs as reddish-brown to black opaque crystals with specific gravity of 3.65 to 3.77 and hardness of between 7 and 8 (Moh's scale). Staurolite begins to melt at 2,800° F and has a high rate of thermal conductivity and a low rate of thermal expansion.

Aside from a small rock-shop trade in cruciform-twinned crystals (sometimes called fairy crosses) from some deposits in Georgia, North Carolina, and Virginia that are sold as curios or amulets, all the staurolite in the United States is produced commercially by E. I. du Pont de Nemours & Co., Inc. This staurolite is a byproduct of heavy minerals recovery from beach sand from a glacial age deposit in Clay County, in north-central Florida. After caustic scrubbing and drying, the staurolite is removed by electromagnetic separation. This staurolite concentrate, about 77% of which is mineral staurolite with uniformly sized, clean, and rounded grains, may contain minor proportions of various other minerals; but has a nominal composition of 45% Al_2O_3 (minimum), 18% Fe_2O_3 (maximum), 3% ZrO_2 (maximum), 5% TiO_2 (maximum), and 5% SiO_2. Although originally marketed only for use in portland cement manufacture, it is now being marketed as a specialty foundry sand under the trade name "Biasill," and as a sandblast abrasive under the trade name "Starblast."

Quantitative production data are not released for publication, but the 1977 output of staurolite was 10% over that of 1976. Shipments increased 44% in tonnage but decreased 3% in price per ton from 1976.

STRONTIUM[30]

Domestic consumption of strontium on a carbonate basis was estimated at 29,000 short tons in 1977, representing a 12% increase over that of 1976. Imports of strontium minerals increased 20% to 42,986 short tons. Imports of strontium compounds, primarily from the Federal Republic of Germany, decreased 67% compared with those of 1976.

Legislation and Government Programs.—Government stockpiles contained 14,408 short tons of nonstockpile-grade celestite (strontium sulfate) at yearend, unchanged from that of 1976. This material was available for disposal throughout 1977, but no sales were made.

Domestic Production.—Strontium minerals have not been produced commercially in the United States since 1959. However, a number of firms produced strontium compounds from imported celestite.

Table 4.—Major producers of strontium compounds, 1977

Company	Location	Compounds
Chemical Products Corp	Cartersville, Ga	Carbonate.
FMC Corp	Modesto, Calif	Carbonate, nitrate.
Mallinckrodt Chemical Works	St. Louis, Mo	Various.
Milwhite Co., Inc	Houston, Tex	Carbonate.

Consumption and Uses.—Domestic consumption of strontium in the manufacture of various strontium compounds increased 12% to 29,000 short tons on a strontium carbonate basis. Although quantitative information concerning consumption is incomplete, sales of domestically produced strontium carbonate to manufacturers of glass for color television picture tubes appeared to have declined. Strontium nitrate consumption in the manufacture of pyrotechnics and signals increased slightly from that of 1976.

Miscellaneous applications for strontium compounds included ferrites, greases, ceramics, plastics, toothpaste, pharmaceuticals, paint, electronic components, welding fluxes, and the making of high-purity zinc metals. Small quantities of strontium metal were produced by research companies.

Prices.—At yearend, prices quoted in Chemical Marketing Reporter were as follows: Strontium carbonate-technical, bags, carlots, works, 18 to 20.8 cents per pound; strontium nitrate-bags, carlots, works, $24 per 100 pounds, unchanged from the previous year. Prices for strontium minerals are usually determined by direct negotiations between buyer and seller and are seldom published. The average value of imported strontium minerals at foreign ports was $44.55 per short ton, up $2.94 from 1976.

Foreign Trade.—Imports of strontium minerals totaled 42,986 short tons, a 20% increase over those of 1976. Virtually all the material was imported from Mexico. Imports of strontium compounds decreased 67% from those of 1976, although material coming from the Federal Republic of Germany, the leading exporter of strontium compounds to the United States in 1977, more than quadrupled. Imports of strontium carbonate were down 71%, and imports of strontium nitrate were down 77% from those of 1976. Quantitative data on U.S. exports of strontium compounds were not available.

Table 5.—U.S. imports for consumption of strontium minerals,[1] by country

Country	1976		1977	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Mexico	35,711	$1,486	42,968	$1,913
Sweden	--	--	(2)	1
United Kingdom	--	--	18	1
Total	35,711	1,486	42,986	1,915

[1]Strontianite or mineral strontium carbonate and celestite or mineral strontium sulfate.
[2]Less than 1/2 unit.

Table 6.—U.S. imports for consumption of strontium compounds, by country

Country	1976		1977	
	Pounds	Value	Pounds	Value
Strontium carbonate, not percipitated:				
Germany, Federal Republic of	--	--	39,802	$6,388
Strontium carbonate, precipitated:				
Canada	8,421,573	$1,538,757	131,484	24,850
China, People's Republic of	--	--	62,059	12,481
Germany, Federal Republic of	464,685	61,513	2,292,716	364,387
Japan	200	403	--	--
Mexico	--	--	75,527	13,035
Netherlands	--	--	2,557	663
United Kingdom	4	451	--	--
Total	8,886,462	1,601,124	2,564,343	415,416
Strontium chromate:				
Canada	473,382	357,767	553,800	461,019
Germany, Federal Republic of	--	--	661	1,561
Norway	40,000	19,655	--	--
Total	513,382	377,422	554,461	462,580
Strontium nitrate:				
Canada	1,178,500	276,065	80,000	18,400
Germany, Federal Republic of	22,046	6,738	200,932	61,319
Total	1,200,546	282,803	280,932	79,719
Strontium compounds, n.s.p.f.:				
Canada	81,191	22,622	--	--
France	2,205	6,562	882	2,498
Germany, Federal Republic of	44,862	33,956	46,495	39,663
Japan	21,444	10,283	31,262	13,961
United Kingdom	--	--	1	326
Total	149,702	73,423	78,640	56,448
Grand total	10,750,092	2,334,772	3,518,178	1,020,551

World Review.—Deposits of strontium minerals are numerous throughout the world, but 95% of known world production was produced by four countries in 1977. World production of these minerals increased 10% over that reported for 1976, even though Kaiser Strontium Products, Ltd., closed its Nova Scotia Canadian plant in 1976. Renewed operations in Algeria, which last reported production in 1974, and a 40% increase in Mexican production primarily accounted for this increase.

Table 7.—Strontium minerals: World production, by country

(Short tons)

Country[1]	1975	1976	1977[p]
Algeria	--	--	5,732
Argentina	1,102	2,264	2,435
Canada[e]	28,000	13,200	--
Iran[e 2]	330	220	220
Italy[e]	800	770	770
Mexico	16,228	[e]36,000	50,302
Pakistan	1,121	665	756
Spain	8,818	[e]8,300	[e]8,300
United Kingdom	2,094	5,952	[e]6,000
Total	58,493	67,371	74,219

[e]Estimate. [p]Preliminary.

[1]In addition to the countries listed, the Federal Republic of Germany, Poland, and the U.S.S.R. produce strontium minerals, but output is not reported quantitatively and available information is inadequate for formulation of reliable estimates of output levels.

[2]Year beginning March 21 of that stated.

WOLLASTONITE[31]

Wollastonite is a natural calcium metasilicate, usually white or light-colored, with a specific gravity of 2.87 to 3.09 and a Moh's hardness of 4.5 to 5. It theoretically consists of 48.3% lime combined with 51.7% silica. Wollastonite from selected deposits has found increasing use as an ingredient in ceramic mixes for glazes and enamels and especially for floor and wall tile; in the building industry for the production of mineral wool and cold-setting insulation foams, and as a pigment and extender for paints; as a filling agent for plastics, rubber, and asphalt products; in agriculture as a fertilizer and soil conditioner; and in a wide variety of other applications still being developed.

Wollastonite output in the United States in 1977 was 7% lower in tonnage than in 1976, and the corresponding total value was 3% higher. Output data are withheld to avoid disclosing company proprietary data. Interpace Corp. at Willsboro, Essex County, N.Y., had been the only U.S. producer in recent years. However, R. T. Vanderbilt announced in 1977 that it also would be marketing wollastonite, from its property at Gouverneur, N.Y.

Interpace announced that additional beneficiation, milling, and auxiliary equipment was being installed at its Willsboro facility. This 30% increase in wollastonite production capacity was to be followed by an additional 15% expansion planned by the end of 1977. The two-phase expansion was necessitated by improving market penetration into the plastics and coatings industries.[32]

Chemical Marketing Reporter, December 26, 1977, quoted the price of wollastonite, fine paint grade, bagged, in carload lots, f.o.b. works, as $80 per ton; medium paint grade, $70 per ton. The December 19, 1977, issue of American Paint & Coatings Journal quoted prices ranging from $29 to $50.50 per ton for paint-grade wollastonite.

ZEOLITES[33]

Natural zeolite production in the United States in 1977 rose from several hundred tons in 1976 to more than 5,000 tons. There was still no clear emergence of sustained markets. Roughly 1,800 tons of chabazite was sold from the Bowie, Ariz. deposit, and 1,500 tons of clinoptilolite from the Creede, Colo. area. Another 2,000 tons of clinoptilolite from an undisclosed source was sold. Prices were unavailable, but would not be relevant because of the market development period that zeolites were undergoing during 1977.

A promising market in the insulation industry opened up temporarily and ended abruptly when cellulose insulation demand slackened. One insulation manufacturer resolved an ammonia-emission problem, on heating, by adding clinoptilolite to absorb the liberated ammonia fumes.

The Bureau of Mines survey early in 1977 produced some interesting, if fragmentary, information. The information is incomplete because at least two large holders of zeolite properties felt it inadvisable to list their properties, and it is almost certain there are several smaller owners that could not be contacted. At least 15 companies hold about 500 zeolite claims in approximately 7 Western States.

Several domestic companies continued their applications research to develop markets for natural zeolites with very encouraging but confidential results.

In Japan, 10 or more companies either produce natural zeolites or possess the potential to do so. Pratley Perlite Mining Co. brought onstream a new operation in Zululand, Republic of South Africa, that has a zeolite production capability.

In an article reviewing past and current research in the animal sciences, it was demonstrated that natural zeolites, abundantly available at a nominal $50 to $75 per ton, had great potential in the agriculture and aquaculture areas of animal science.[34]

The current expansion rate of the synthetic zeolite industry is difficult to assess. Legislative and regulatory proposals in several parts of the world are hastening development and production of zeolites for the newest market—substitution for phosphates in detergents. The Dutch Minister of Health and Environmental Protection proposed a full ban on detergent phosphates in the Netherlands, preferably by 1980, but with 1985 as the final target date. Federal Republic of Germany plans call for 50% replacement by 1983. In the United States, a new ruling by Michigan's Natural Resources Commission would ban the use of household laundry detergents containing phosphates in that State. Part of the Federal Clean Water Act of 1977 will restrict the use of phosphate detergents in eight States bordering the Great Lakes and will also require the Environmental Protection Agency (EPA) to investigate the feasibility of introducing a national ban on phosphate detergents.

At the 1977 World Soaps and Detergents Conference in Switzerland, Henkel GmbH of the Federal Republic of Germany described the successful test of zeolite detergents in a community of 11,000 households near Stuttgart. The effects on the associated sewage works were minimal. Another firm from the Federal Republic of Germany, Degussa GmbH, will expand its present zeolite pilot plant capacity of approximately 5,000 tons per year to meet the growing demand for detergent zeolites even prior to completion of its 50,000-ton-per-year plant. The plant, at Wesseling, the Federal Republic of Germany, will be owned and operated by Degussa, but is a joint development with Henkel. Akzo Chemie Nederland is planning a 20,000- to 30,000-ton-per-year plant in Amsterdam to manufacture its own zeolites for detergents, and in the United States, Ethyl Corp. is building a plant, reportedly of 75,000 tons capacity, at Houston, Tex., to produce zeolites for Proctor & Gamble Co.'s detergents.

The following estimation of current world markets and projections for synthetic zeolites in thousand metric tons, was given at the 1977 World Soaps and Detergents Conference by Dr. George C. Sweiker of the PQ Corp., Philadelphia, Pa.:

World region	1975	1977	1979	1981
North America:				
Detergents	--	27	90	225
Catalysts	20	23	28	35
Adsorbents	11	14	16	20
Total	31	64	134	280
South America:				
Detergents	--	--	(1)	(1)
Catalysts	3	3	4	5
Adsorbents	7	9	10	13
Total	10	12	14	18
Europe:				
Detergents	--	27	90	225
Catalysts	3	4	4	5
Adsorbents	5	7	9	11
Total	8	38	103	241
Asia:				
Detergents	--	--	29	90
Catalysts	3	5	6	8
Adsorbents	8	11	14	18
Total	11	16	49	116
World total	60	130	300	655

[1]Unknown.

Source: European Chemical News, v. 31, No. 813, Nov. 25, 1977, p. 35.

Among research reports issued during 1977 was one detailing a practical way of regenerating clinoptilolite for reuse.[35] Another article revealed that the zeolite used by Mobil Corp. to convert methanol and/or syn gas directly to high octane gasoline was its ZSM-5 version.[36] This versatile zeolite can also dewax residual oils, make ethyl benzene by alkalating benzene with ethylene, isomerize xylenes to the para isomer, and catalyze disproportionation of toluene to xylene and benzene. A copper version of ZSM-5 can also selectively absorb carbon monoxide from a water-containing stream of carbon monoxide and carbon dioxide. This makes possible the recovery of carbon monoxide for fuel from the off-gases of a steel mill basic oxygen furnace.

---

[1]Prepared by Avery H. Reed, supervisory physical scientist.

[2]Prepared by Richard H. Singleton, physical scientist.

[3]Prepared by Sandra T. Absalom, physical scientist.

[4]U.S. Embassy, Santiago, Chile. State Department Airgram A-41, July 14, 1978, p. 7.

[5]Industrial Minerals. No. 115, April 1977, p. 49.

[6]New China News Agency, Peking. Mar. 18, 1978.

[7]U.S. Embassy, Jakarta, Indonesia. State Department Airgram A-009, Jan. 27, 1978, p. 1.

[8]U.S. Embassy, Jakarta, Indonesia. State Department Airgram A-49, May 16, 1978, p. 1 of Enclosure A.

[9]U.S. Embassy, Tokyo, Japan. State Department Airgram A-134, May 25, 1978, p. 5.

[10]European Chemical News. Soviet Transcaucus Region Sets Sights on New Complexes. V. 30, No. 782, Apr. 15, 1977, p. 45.

[11]Chemical and Engineering News. Developers Vie for Best Hydrogen Technology. V. 55, No. 47, Nov. 21, 1977, pp. 27-28.

[12]Chemical Economics. New Hydrogen Production Process. V. 9, No. 1 (No. 102), January 1977, p. 25.

[13]Baronavski, A.P., and J.R. McDonald. Radioiodine Detector Based on Laser Induced Fluorescence. Naval Research Laboratory, Washington, D.C., May 1977, 24 pp.

[14]Prepared by A. C. Meisinger, industry economist.

[15]Prepared by Stanley K. Haines and C. Mead Patterson, physical scientists.

[16]Arkansas Geological Commission and U.S. Bureau of Mines. Directory of Arkansas Mineral Producers and Production 1977. Little Rock, Ark., March 1978, p.4.

[17]Electronic News. Quartz Overflow. V. 23, No. 1120, Feb. 28, 1977, p. 23.

[18]———. V. 23, No. 1147, Aug. 29, 1977, pp. 1, 40-42.

[19]Page 42 of work cited in footnote 18.

[20]Work cited in footnote 17.

[21]Jewelers' Circular Keystone. August 1977, p. 140.

[22]Japan Exports & Imports. Commodity by Country. December 1976, p. 872.

———. Commodity by Country. December 1977, p. 906.

[23]Work cited in footnote 18.

[24]U.S. Embassy, Antananarivo, Madagascar. State Department Airgram A-006, May 19, 1978, p. 4.

[25]Work cited in footnote 17.

[26]Work cited in footnote 17.

[27]Work cited in footnote 18.

Electronic News. V. 23, No. 1149, September 1977.

[28]Chakraborty, D. Dependence of Mechanical Q on Growth Rate of Quartz Single Crystals. J. of Crystal Growth, v. 41, 1977, pp. 177-180.

[29]Prepared by W. Thomas Cocke, physical scientist.

[30]Prepared by Travis Q. Lyday, physical scientist.

[31]Prepared by Michael J. Potter, physical scientist.

[32]American Paint & Coatings Journal. Interpace Expanding Wollastonite Potential. V. 61, No. 47, May 2, 1977, p. 56.

[33]Prepared by Robert Clifton, physical scientist.

[34]Mumpton, F.A., and P. H. Fishman. The Application of Natural Zeolites in Animal Science and Aquaculture. J. Animal Sci., v. 45, No. 5, November 1977, pp. 1188-1203.

[35]Semmens, M. J., and R. R. Goodrich. Biological Regeneration of Ammonium-Saturated Clinoptilolite. Environ. Sci. & Technol., v. 11, No. 3, March 1977, pp. 255-265.

[36]Hughes, D. Heart Cut. Chemtech, v. 7, No. 10, October 1977, pp. 588-589, 633.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1980 0-311-330(176)